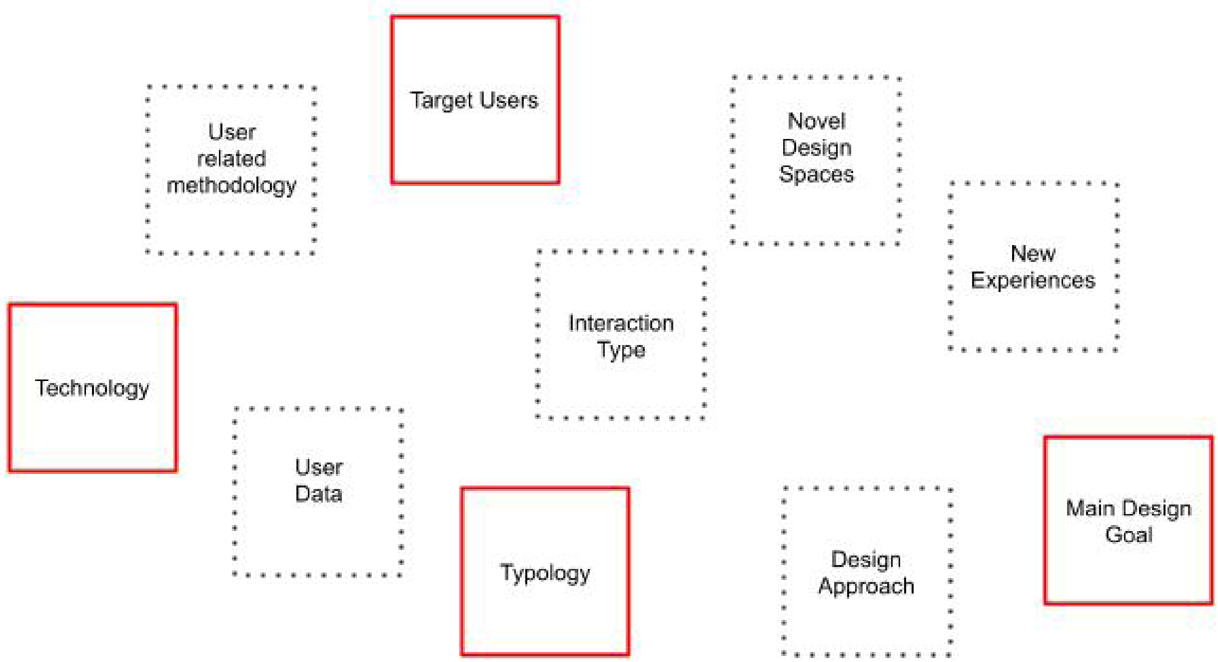
Digital Media Strategies in Architectural Design: the user as an active participant in the era of IoT

Anna Karagianni



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Abstract

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In our data driven society, technology offers a new perspective in dynamic spatial analysis and design. The radically growing IoT opens up new horizons in the understanding of user spatial perception and experience. This study aims to determine how user experience and perception of space are shaped in hybrid spaces and suggest strategies to integrate this new knowledge into the process of architectural design.

First of all, the evolution of interaction between user and system is historically analyzed, identifying a. the era where people imagined interactive structures, being unable to establish a direct user – system – space communication; b. the emergence of the smartphone, which solved interoperability and communication issues and c. the future of user – system interaction, by presenting current possibilities and threats arising from the latest IoT technologies.

The second part redefines users in the light of their social, behavioral, psychological and educational nature, underlining hidden attributes: crowdsourcing agents, intermediary informants, social and technological innovators. By analyzing the difference between a user-centered and a system-based ecosystem, the significance of user empowerment and control over the interactive system is highlighted.

Having investigated how user perception is transformed within the new hybrid spatiality consisting sensors, devices and data, the question arises as to whether this information can be

successfully integrated into the architectural design. The third part of the study intends to answer this question, by presenting case studies of interactive environments embracing novel design spaces. This happens through the analysis of four distinct design approaches of interactive architecture. Specifically, the analysis aims at decoding the ways to translate interaction into spatiality, creating novel user – centric design spaces, either physical or virtual.

To test the hypothesis that interaction between user, system and space is a valuable tool at various stages of the architectural design, a series of studies are conducted, at a theoretical, technological and practical level. Throughout the studies, it becomes evident that a framework describing how to design interactive systems and integrate user feedback should be established, allowing for new technologies to get easily integrated into this scenario and inaugurate innovative streams of knowledge exchange.

As a result, this study orchestrates a two-way innovation process: people participating in the production of knowledge, as significant parts of the hybrid space feedback loop; and architects using emerging material and immaterial tools to analyze, get inspired and experiment at the design process.

This doctoral thesis contributes to the scientific sector of architectural design with new technologies by analyzing, defining and presenting the new design directions that appear as a result of the interaction of user with technology in hyper connected environments. Its dynamic exploration and experimental approach renders it a manual for architects and designers that wish to integrate the technological capabilities of our era into their design process.

Acknowledgements

Almost ten years ago, in March 2010, I was in the UNL (Ubiquitous Networking Laboratory) in Tokyo, Japan with my colleagues from GSAPP, Columbia University and my Professors, Toru Hasegawa and Mark Collins, instructors of the Kaizen Algorithmic Design Studio. In UNL, Ken Sakamura, UNL Director, highlighted the potential of Ubiquitous Computing and presented his research on smart spatial environments and the TRON Prototypes. I remember myself thinking that technology can alter space and experience; and that the architects have an enormous chance to integrate all this scientific knowledge into the way they perceive space, but also enhance the coherence of their design. This is where the journey began; A couple of years later, still fascinated by algorithms and sensors, I attended a Symposium in Chania, where a renowned professor from the States argued that algorithms will totally replace design. At that point, a professor from the Technical University from Crete disagreed and stated that this is not possible: technology should be integrated into architectural design instead of replacing it.

Another couple of years later, I decided to pursue a PhD, trying to answer this exact question: how we are going to integrate technology into our design instead of eliminating the design in the face of all the emerging technological capabilities. This journey would be totally different if I wouldn't teach parallel to the research. For that, I wish to thank the School of Architecture at the Technical University of Crete, for giving me the opportunity to teach Architectural Design and Digital Media during the last six years. Special thanks to the Dean of the School, Constantinos Providakis for trusting me, but also to all my colleagues at the School for discussing, exchanging ideas and methods and for inviting me to give lectures on my research. Presenting new research and discussing it with fresh minds triggers new ideas and opens up new horizons for research. Special thanks also to the Architectural Design and Digital Media Colleagues Dimitra Chatzisavva, Panita Karamanea, Nora Lefa, Konstantinos – Alketas Oungrinis, Alexis Tzompanakis, Dimitri Tsakalakis, Ioannis Tsaras, Alexandros Vazakas and Socrates Yiannoudes.

Moreover, I wish to specially thank the Professor that stood up and talked at that Symposium, my advisor: Prof. Panos (Panagiotis) Parthenios, Director of the Digital Media Lab at the

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I would like to thank my supervisors, Prof. Spiro Pollalis and Prof. Costa Synolakis for their guidance and immense knowledge. Thank you to Spiro Pollalis for reading and correcting my draft texts, for giving me valuable advice and for encouraging me to finish the PhD thesis. Also thank you to Costa Synolakis for offering constructive comments on the thesis during these years and also for being a genuine academic inspiration for me.

Besides my advisor and committee, I would like to thank immensely Prof. Valina Geropanta for her academic, emotional and moral support during the last three years. Prof. Geropanta was my colleague at the School of Architecture, University of Patras and I truly feel lucky for having met her again and collaborate at the Technical University of Crete. I praise the enormous amount of help and guidance, her insightful comments and advice on structure, organization, ideas and writing skills. She has actively contributed to the evolution of this research and findings.

I wish to thank all the people whose assistance was a milestone in the completion of this project – all the undergraduate and graduate students that participated in the experimental studies of the thesis. Their names are individually mentioned at the beginning of each paper that appears in the fourth chapter of the thesis. Moreover, I wish to thank Nikos Bakker and Yiannis Rogan, my partners at the e-nnovation competition, in 2015. Together, we designed the EcoMotivate platform, which was selected among 400 innovative entrepreneurial ideas and is further analyzed in the fourth chapter.

I wish to thank my friends who were by my side during this long journey. Special thanks to Stavrianna Kaisari, who gave her insightful comments during the research and Vasilis Avarkiotis, for always reminding me to work hard and be dedicated to achieve my goals. I also thank my friends (too many to list here but you know who you are!) for providing support and friendship that I needed.

I finish with my precious family who has patiently and steadily supported this effort: my husband Nikos and my kids, Vangelis and Klimentini. Nikos has the magic ability to make things simple and looks at the big picture – which is always very helpful when you feel trapped at the micro-scale of the PhD. Also, my kids: when I started the PhD, back in 2014, they were only 3 and 2 years old. Despite all odds, this journey has been not only manageable, but also joyful; and they have been the best part of the PhD (Mum, what are you up to? Ah, I know…PhD!). I also thank my brother, Georgios – Marios Karagiannis, who read and corrected part of the thesis; and my sister-in-law Katerina Argyriou: thank you for being the 'crazy scientists' of the family, always enriching my interest into research.

I thank my mother for always being an inspiration on how to make things 'perfect' and never give up; and finally, my father, to whom I dedicate this thesis, for teaching me the real power of knowledge and education.

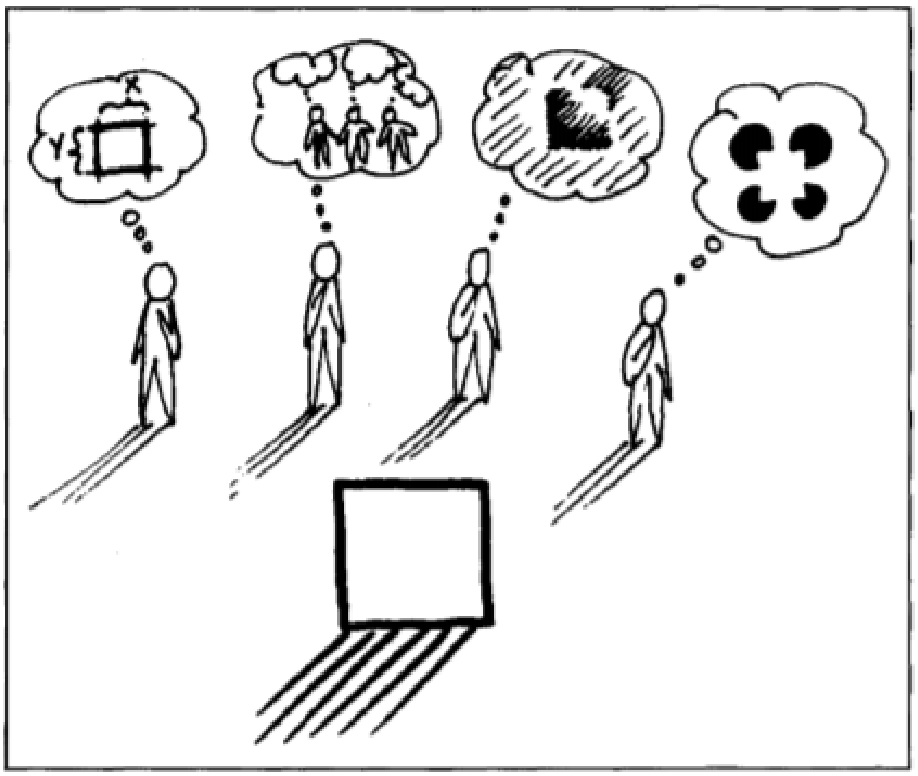

Figure i
'What one person values as important others may not even see'
(Kim, cited in Preece et al., 2002)

To my father

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TERMINOLOGY

smart system is a device or set of devices that can sense, actuate, control or self-detect, self-diagnose, self-correct or self-control.

smart ecosystem includes all the entities, material and immaterial, human and non-human, static and dynamic within a ubiquitously connected space.

user will be used to refer to the person that satisfies two requirements: firstly, by interacting physically with the built space; secondly, by being familiar with technology.

interaction: a mutual or reciprocal action or influence between two or more objects, people, agents, etc. (Merriam-Webster cited in Barbas et al.).

INTRODUCTION

Theoretical Background

In the Information Age, the application of new technologies has played a crucial role in the evolution of smart built spaces. “New media techniques are being incorporated into [how we envision] … spaces and all these different technologies become how we ‘write’ spaces in different ways” (Thrift, 2009, p. 86). As a new kind of spatiality has emerged, the way that users experience space has also evolved.

Smart systems in the built space and IoT (Internet of Things) applications have become a broad area of inquiry. The IoT is a continually expanding network of internet-connected sensors and tools that transmit data from the environment to a central storehouse or processor for rapid analysis and returns it to a sensor of a user; it helps users “maximize energy efficiency, optimize space use, reduce costs, and increase operational visibility across all types of facilities and organizations” (Allen, 2017, p. 2). Smart environment applications promote a different type of spatial thinking that relates not only to the physical space, but also to the availability and quality of knowledge and social drivers as a design tool. Although their primary objective is socio-economic, in fact, these applications have created an alternate reality and a new technological boom.

The effects of this technological boom in architectural space is a new research field. Undoubtedly, the IoT initiated a major shift in our life and work styles. A few researchers, organizations, companies and institutions praise the contributions of Information Communication Technology’s (ICT’s) to optimal building management and functions (Engel, 2014). This new process has opened up a new world of possibilities, collaborations, problem-solving strategies and new narratives about human – building interaction.

Within this broad area of inquiry are several streams of research. One stream focuses on the spatial transformation effects of current state-of-the-art spatial technologies and the creation of novel, often hybrid, spaces. Nevertheless, it is unclear as to what extent the dynamics of this technological era can contribute to an alternative way of perceiving the built space, as this perception is related to the user. This new, exciting scientific field remains unexplored.

The role of the user within the IoT context has been an integral part of several research disciplines, as “user participation has been a critical factor in achieving system success” (Hartwick, 1994, p. 66). Sociologists, software engineers and environmental scientists often involve the user in their studies in order to develop human-centric approaches, as they have learned from past experiences that not doing so often results in undesired results as users either cannot or do not want to use or interact with these approaches.

Digital devices and digital social media are changing social structures, how individuals and groups interface, as well as power relations. For example, social scientists study urban users in the context of the global city, which “endogenizes global dynamics that transform existing social alignments” (Beer and Gane, 2004, p. 86). Software engineers study the social interactions that occur within smart systems and extract data allowing the construction of a ‘social observatory’, aiming to improve the IoT system itself. Behavioral analytics are quantitative data that reflect human-to-system and human-to-human interaction. In fact, they use data science to improve communication of people with the built environment. Environmental experts are concerned with user behavior associated with energy consumption, building processes and energy information. Levels of thermal comfort, ventilation and air conditioning data are part of the building information knowledge base that has contributed to the evolution of intelligent control mechanisms.

The common element of the above-mentioned research area is that researchers aim to shape strategies based on user data. Building mechanisms are analyzed, user behaviors are quantified and systems are advanced to better suit users’ needs. Most of these processes take place in the backend environment, without the users’ conscious participation in the building–system interaction.

In this study, the analysis takes place within a connected space — a smart ecosystem, including all possible building, typological and social contexts in which users interact with smart technologies — using ubiquitous computing, sensors and IoT. This space, seen from an architectural view point, is characterized by a new kind of spatiality, connectedness, and offers novel experiences to users.

Moreover, the advancements of technology enable the creation of an ‘intelligence layer’ in space, which involves the building and Until the emergence of IoT, this intelligence layer was just a vision, partially implemented by computer scientists and theoretically expressed and envisioned by computational architects. Since 2001 and until today, it has technological capabilities, being an add-on feature in space. In this study, a technological focus is a prerequisite for building the layer of intelligence , but to develop an interesting design strategy, the focus should move away from the digital tool, device or connectivity and reconfigure interactivity as an architectural element to be integrated into the design process. If the interaction within the smart space between its users and the environment becomes a product of architectural design, the spatial quality will increase. In order to have an intelligent-by-design effect, the interaction process should be intertwined with the design process of the physical space at the earliest stage possible—concept development.

The need to interconnect user-related knowledge derived by the Human–Computer Interaction field is expressed by a number of IT scholars, architects and scientists (Wilberg, 2015; Sengers et al. 2004; Achten and Kopriva, 2011; Lehman, 2018). Architectural design is a complex, non-linear, messy, yet empathic and user-oriented process that, by default, integrates a number of disciplines into the final architectural design product.

> Imagine a world without architects, where only engineers construct buildings. With a keen eye toward functionality, these engineers would make sure the buildings were sound, but something would be lacking. People would miss the richness of architecture—the designed connection to their lives, history, and culture. The designed experience of these buildings would be irrelevant to their social and personal concept of buildings. Yet this is the world researchers are inadvertently creating with ubiquitous computing. (Sengers et al., 2004, p. 14)

In this light, if we envision users as interaction agents who are conscious not only of the system and technology, but also of the smart ecosystem that emerges through this interaction, *how can we merge the interaction process with architectural design at its early stage? What is the optimal approach to integrate the knowledge acquired by user-related research into the concept generation phase of the architectural design process?*

Interaction designers have experimented with expressions of spatiality in game design, and in augmented, mixed and virtual reality. From an architectural point of view, the new spatiality

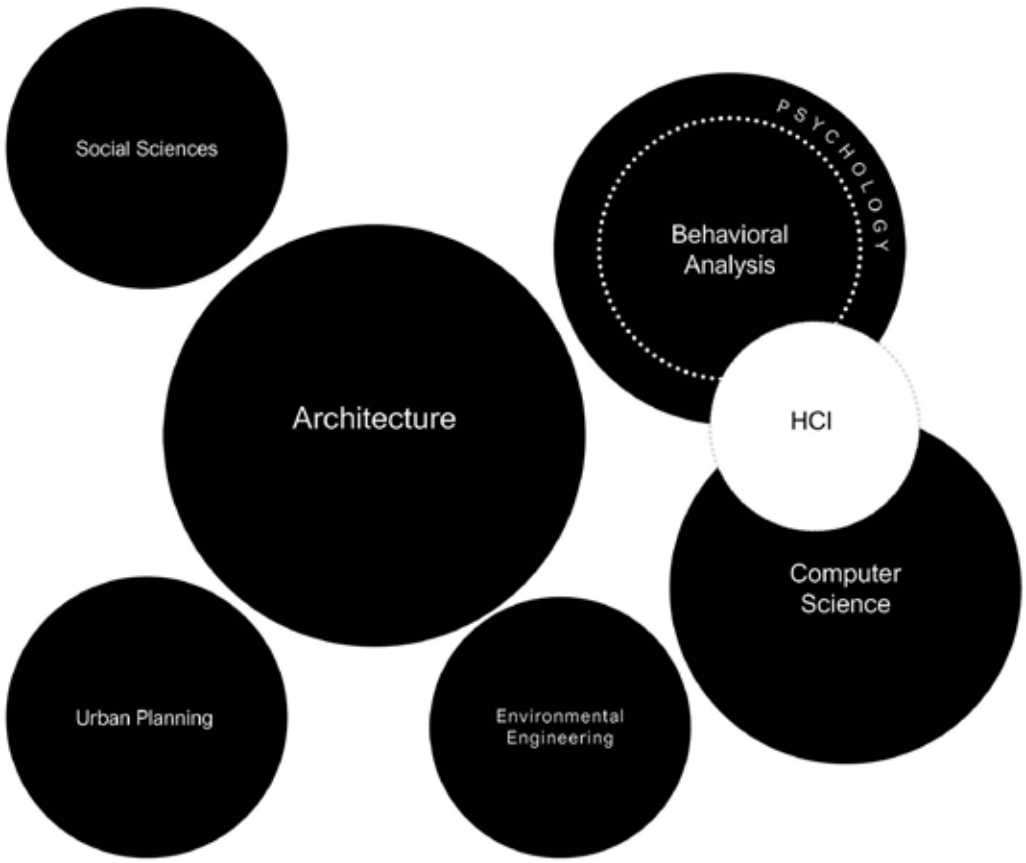


Figure ii
Disciplines related to the interaction between user, system and space.

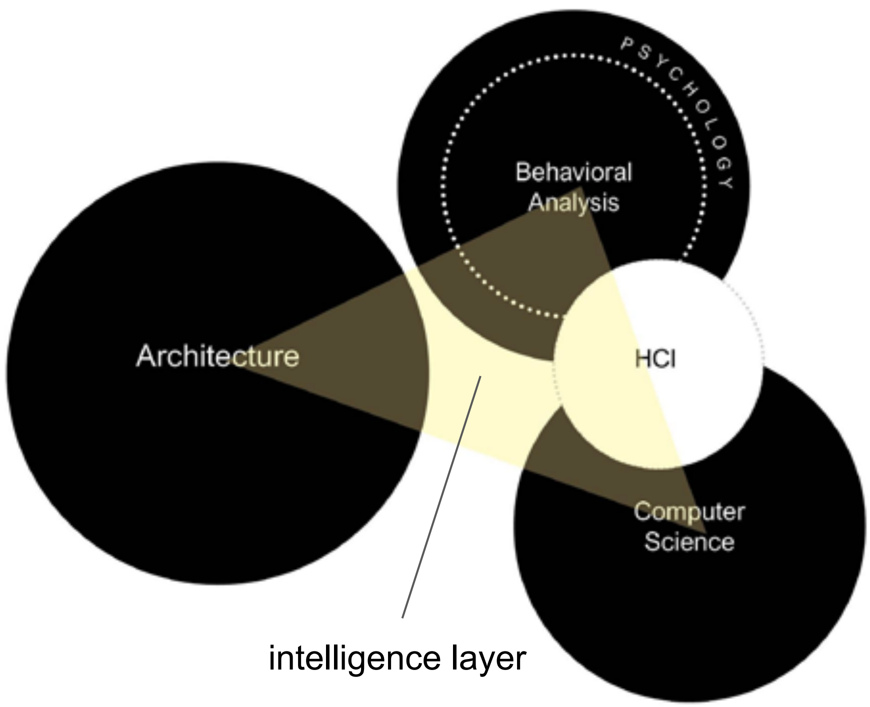


Figure iii
The emergence of the intelligence layer.

emerging via the integration of technology in spatial environments remains unexplored. Undoubtedly, bridging interaction with architectural design creates interesting synergies. However, a gap apparently remains in the design process. Architectural design is not a linear process, and the smart ecosystem is a highly complex entity, difficult to analyze, design and visualize. As such, it is extremely important to design a practice-based framework that acts as the vehicle for interactive design. A system that would connect the messy, non-linear, sometimes illogical process with the clean-cut hierarchical digital world. “While architecture and interaction design have traditionally dealt with ontologically different realms—the physical vs. the digital—this distinction is now being challenged” (Wilberg, 2015, p. 3). In this study, users, a very strong ontological element in both disciplines (architecture and interaction design), are perceived as the bridge that connects the gap between the two fields. Human-centric approaches in terms of metrics (e.g., usability, user experience) and the social needs of users (e.g., empathy, participation and engagement) will be analyzed and reconfigured into a new human-centric hybrid approach of designing the smart ecosystem.

Thesis Structure

The overall exploration of the current study is focused on the smart environment field of design-based interaction. It demonstrates a way in which smart environments enable the experimentation with new design streams on the built space. In this new philosophy of human-centric interaction, buildings are people-centric, dynamic environments that communicate with the user, who is in charge of deciding the form and degree of interaction he/she wants to have with the building. This Ph.D. thesis creates and shapes a new theoretical framework with multiple equations between user interaction and architectural design. This study includes five themed chapters.

The first chapter examines the historic significance of technological advance by drawing parallels between interaction and architecture. Firstly, it investigates the different kinds of interaction within smart environments that have emerged since the 1950s. It also presents how architects and designers have embraced technological advances by integrating them into design, representation and the overall spatial experience. For instance, before the emergence of the smartphone, the building system would ‘think in itself’ with little or no consideration of the human preference in the space. Historically, intelligence had been linked with automation, pre-programmed by automation experts, while human decision-making mechanisms had been at a relatively primitive level. Lack of interoperability among the existing technologies and systems, combined with the absence of communication channels between the user and the system create an obstacle for the agility, adaptability and versatility of smart home technologies. The turn of the twenty-first century witnessed a significant change, implemented slowly but steadily: IoT emerged as the system that solved interoperability and communication problems, opening up new horizons for smart environments.

The second chapter outlines the user-centric approach of 'smart' objects and systems by juxtaposing theories from the fields of economics, psychology, computer science and web design. It examines the multidisciplinary definitions of the user, the user impact on the built environment across different scales and the new paradigm in which users can act as innovators. This study will contribute to the shaping of the equation of transforming the average user into a smart user through the use of IoT state-of-the-art technologies. The first part of the chapter presents an array of user-related perspectives from the fields of informational technology (IT), social sciences and finance; then it investigates how the bridging of the three promotes science and creates innovation and introduces the user experience as the mediator between human-driven, design-focused disciplines and business-related fields, and explores how the user experience acts as a catalyst in shaping user-centered environments. The second part investigates the role of users in the built environment and the parameters of Human–Building Interaction.

The third chapter investigates how interactive environments embrace novel design spaces. I analyze four distinct design approaches for interactive architecture, subsuming it under the design methodological approach, formulated by Achten and Kopriva (2011). Specifically, the analysis aims at decoding the ways to translate interaction into spatiality, creating novel user-centric design spaces, either physical or virtual, through the use of new technologies. The body of existing literature focuses on the ways that smart spatial interaction improves the quality of life for individuals within the built space and the built space in general. In contrast, the approaches presented in this chapter focus on the integration of smart technologies into the design process and the facilitation of dynamic user-space interaction with simultaneous responses to user needs.

The fourth chapter presents a series of studies, conducted in four different building typologies: workplace, hotel, public building, and home. The four studies investigate one scale at the time, following an incremental, bottom-up approach, while building the methodological framework for translating the technological analysis into new spatial design approaches. The first study, which I've entitled EcoMotivate, presents the analysis of human–system interaction within the building in the context of the b-a-a-s (building-as-a-service) conceptual model. The design goal is to design for social awareness in the workplace, thus developing a design approach based on UX (User Experience) analysis. The second study takes place at the Ambassador's Residence Boutique Hotel in Chania, where I test the location analytics technology at a building's interior scale. The design goal is to rethink the hotel room based on connectivity to the IoT. The design approach followed in this case, employs a metaphor: the hotel is a 'butler'. In other words, the hotel room is redesigned based on reducing the information overload and delimiting the private space of the user. The third study, Smart Home, presents a case study in the historical center of Athens, Greece, and outline an alternative approach to smart home design and addresses the complex challenges of IoT integration in a more integrative, contextually relevant manner. Suggesting a more open, spatially conscious approach and a more collectively conceived IoT selection, the study advocates that when dealing with the complex challenges of everyday spaces for urban dwellers, a holistic approach to space design must be achieved. The fourth study is conducted at the Municipal Market of Chania, Crete, an indoor market consisting of shopping market, souvenir shops and restaurants. Here, I evaluate user behavior in a population of 33 participants (shoppers) by comparing their spatial experiences with and without having explored an ICT platform, called Crete3D. Through qualitative and quantitative methods, behavioral change is analyzed among users with and without access to Crete 3D, an online ICT-based innovative informative platform that holistically presents the building through seven periods of time and at five distinct scales, aiming to establish a theoretical framework of understanding user interaction with built space. This process enables knowledge transfer in a twofold way: it shows how to use metrics to evaluate user–building interaction and how users can quickly gain a deep understanding of the building in use. Using this knowledge in the interaction design process, the spatial environment of the Agora is then reconceived as a monument and as a commercial hub, using the approach of designing with narratives.

The final chapter draws upon the entire thesis, tying up the various theoretical and empirical strands in order to formulate a new methodological human-centric design approach based on the Achten–Kopriva model (Achten and Kopriva, 2011). As such, clusters of interdependencies are formed: technology – users – data, user – interaction – experience, typology – design goal – design approach, human-centric user methodology – prototype – novel design spaces.

Methodology

This study's methodological approach is a mixed methodology divided in two phases. The first methodological phase is based on the review of a considerable body of literature and empirical analysis of the interaction between user and technology. Specifically, the research is built on the narrative review of the evolution of interaction in technological, social and spatial terms. Following this premise, this research relates to existing knowledge and empirical analysis of users and human-centric approaches in various disciplines, with emphasis on information technology and human–computer interaction.

The second methodological phase consists of three zones. Initially, a methodological framework that connects interaction with architectural design (Achten & Kopriva, 2011) is analyzed. Then, four case studies are examined. The cases describe how architects produce new concepts and design novel spaces through interaction. The findings of the case studies analysis become the foundation for subsequent experimental studies in the four typological settings: the workplace, hotel, a municipal agora act as a commercial hub, a monument, and a home. The methodology for the experimental studies includes qualitative and quantitative data-acquisition, outcomes analysis, questionnaires and 1:1 interviews. The experimental studies act as testbeds for the validation of the methodological framework first analyzed, and the disruption of this framework to integrate human-centric approaches and incorporate valuable user data, which radically transform the concept-generation phase.

Thesis Innovation

This study's originality and innovation stem from the following points:

a) it delves deeply into the emerging synergy created by user-technology interaction with architectural design generation.

b) it validates and expands the Achten-Kopriva theoretical model (2011) by proving that all parameters defined by the methodological framework are interrelated and interdependent.

c) it confirms that the interaction and the architectural design are complementary and can operate in parallel. Their convergence enhances the design process by upgrading both the quality of the user-system interaction and the architectural design.

d) it highlights novel design spaces, emerging from the analysis of simple human – centric data, unlocking new levels of creativity and new strategies that must be designed, tested and implemented in the design process.

e) it synthesizes user types: visitor, tenant, tourist, building owner, architect, designer and computer scientist. This enables the human-centered process to merge with the architectural design process and highlights the significance of collecting simplified user knowledge that differs from experts' knowledge.

f) It promotes intelligent design vs default intelligence, proving that the interactive built space extends beyond the mere installation of sensors and actuators that enable interaction.

CHAPTER I

A historical analysis of user-system spatial interaction

Abstract

The first chapter examines the historical significance of technological advance by drawing parallels between user - technology interaction and architecture. Firstly, it investigates the different kinds of interaction within smart environments, which emerged since the 1950s. At the same time, it presents holistically how architects and designers embraced technological advances by integrating them into design, representation and the overall spatial experience. Before the emergence of the smartphone, in most cases, the technological system 'thinks in itself', taking little or no account of the human performance in interactions within a space. Intelligence is directly linked with automation, programmed by automation experts, while human decision-making mechanisms are at a primitive level. Lack of interoperability among the existing technologies and systems, combined with the absence of communication channels between the user and the system create an obstacle for the agility, adaptability and versatility of smart-home technologies. The turn of the twenty-first century witnessed a significant change, implemented slowly but steadily: IoT (Internet-of-Things) emerges as the system that solves interoperability and communication issues, and opens up new horizons for smart environments. While IoT solved interoperability and connectivity issues and somehow conventionalized Building Automation Systems, the lack of communication channel between user and system precluded any chance of cultivating human decision-making mechanisms, thus establishing system-generated decisions in smart environments. As smartphones gradually became central to modern way of living, new features were released and new dynamic connections between user system and space were unlocked. These new features constantly evolve at the technological, social and commercial level.

1950s – 2015: The Tower of Babel

Defining 'Smart'

What is 'smart' and how did it evolve? According to Sajal K. Das and Diane J. Cook, 'smart' or 'intelligent' is 'the ability to autonomously acquire and apply knowledge' (Das, S. et al., 2006). In any case, there is a clear relationship between smart space and intelligent information systems, cybernetics and artificial intelligence. As Negroponte argued in 'The Architecture Machine':

> Intelligence is a behavior. It implies the capacity to add to, delete from, and use stored information. What makes this behavior unique and particularly difficult to emulate in machines is its extreme dependence on context; time, locality, culture, mood and so forth. (Negroponte, The Architecture Machine, p. 1)

How is the 'smart environment' defined? According to Cook et al., the 'smart environment is an intelligent agent that perceives the state of the resident and the physical surroundings using sensors, and acts on the environment using controllers in such a way that the specified performance measure is optimized' (Cook et al., 2004). While a variety of definitions of 'smart environment' have been suggested, throughout this thesis, 'smart environment' is defined as 'a hybrid space that uses ICT (Information and Communication Technologies)and IoT (Internet of Thigs) in order to interact with users through technology'.

While the notion of 'smart' in architecture and the built environment was introduced around 1960, the roots of complex information systems and artificial intelligence also are rooted in the past. As Aristotle stated in, 'Politics',

Figure 1
A depiction of Talos, from Thomas Bulfinch's Stories of Gods and heroes, in Pickover (2019) Atrificial Inteligence, New York: Sterling Publishing.

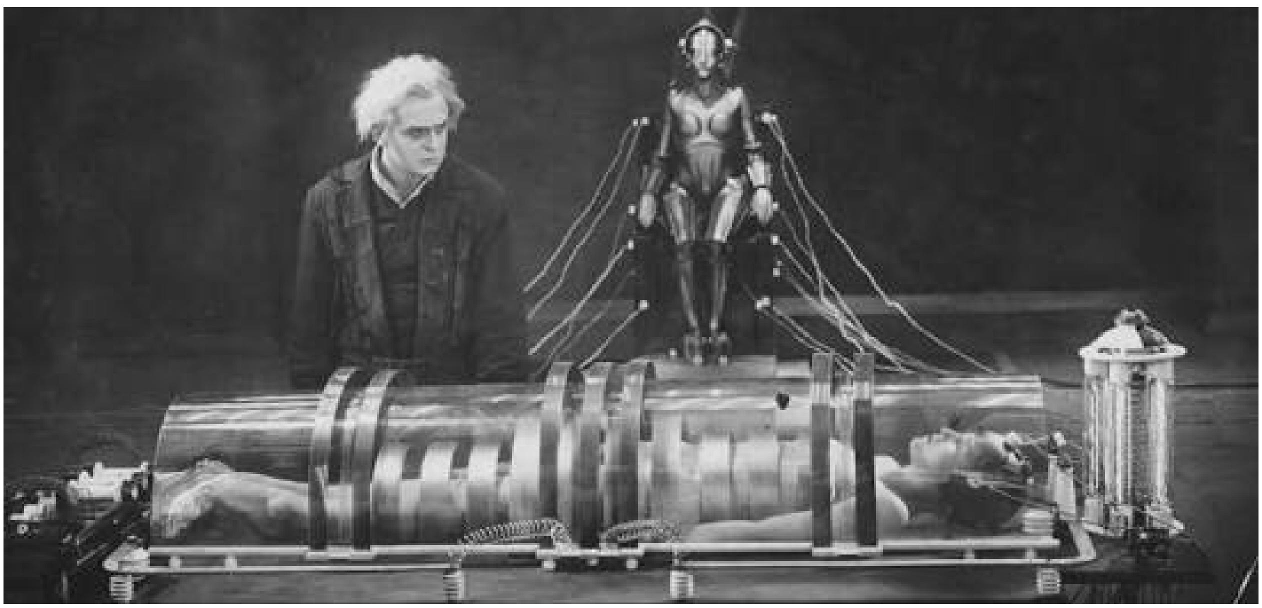
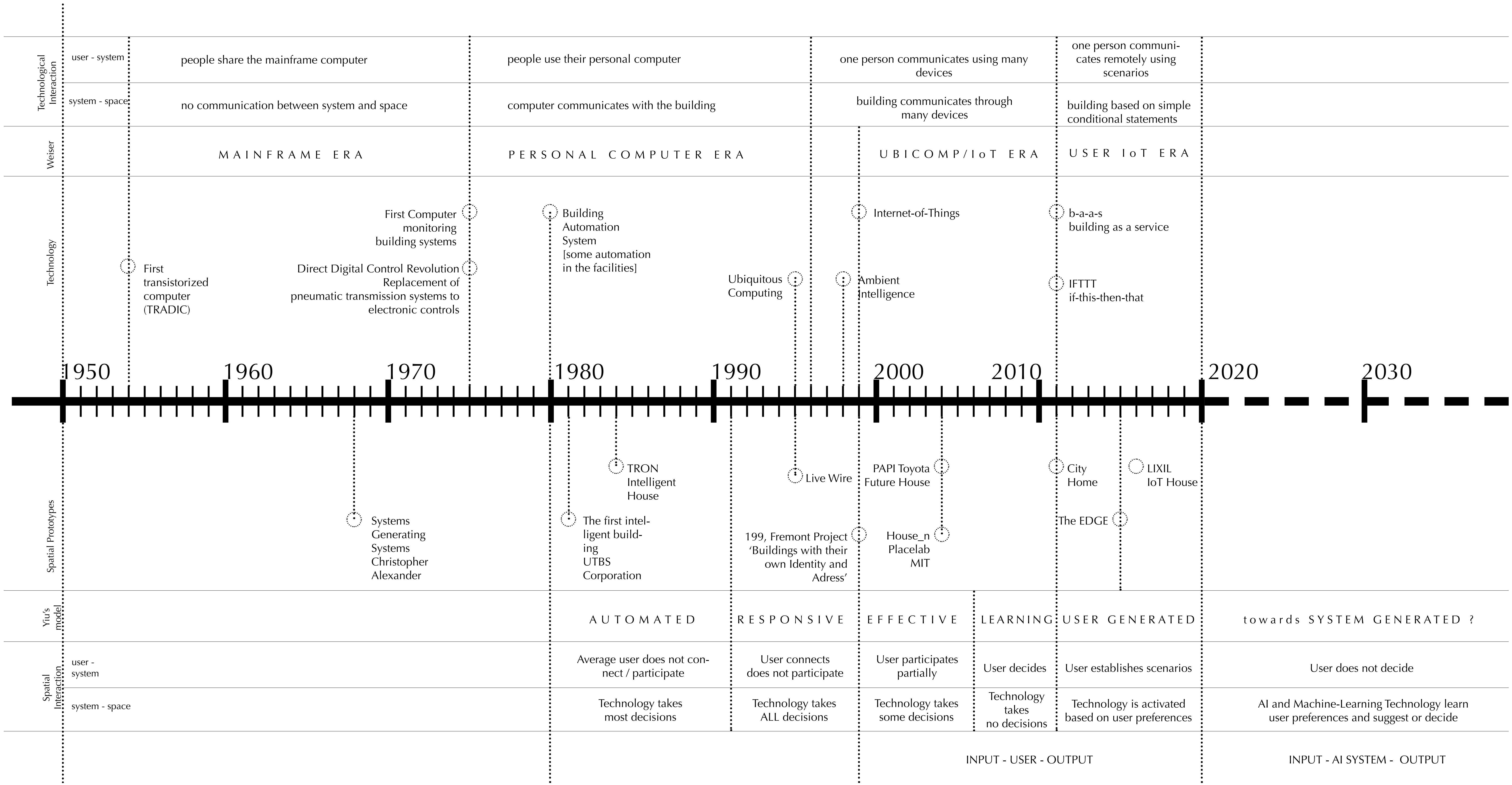


Figure 2
Maschinenmensch
Retrieved from: https://i0.wp.com/ideainventioncompany.com/wp-content/uploads/2017/06/img_1397.jpg?ssl=1


Technological Interaction
user - system
system - space
people share the mainframe computer
no communication between system and space
people use their personal computer
computer communicates with the building
one person communicates using many devices
building communicates through many devices
one person communi-cates remotely using scenarios
building based on simple conditional statements
Weiser
MAINFRAME ERA
PERSONAL COMPUTER ERA
UBICOMP/IoT ERA
USER IoT ERA
Technology
First transistorized computer (TRADIC)
First Computer monitoring building systems
Direct Digital Control Revolution Replacement of pneumatic transmission systems to electronic controls
Building Automation System [some automation in the facilities]
Ubiquitous Computing
Ambient Intelligence
Internet-of-Things
b-a-a-s building as a service
IFTTT if-this-then-that
1950
1960
1970
1980
1990
2000
2010
2020
2030
Spatial Prototypes
Systems Generating Systems Christopher Alexander
The first intel-ligent build-ing UTBS Corporation
TRON Intelligent House
Live Wire
199, Fremont Project ‘Buildings with their own Identity and Adress’
PAPI Toyota Future House
House_n Placelab MIT
City Home
The EDGE
LIXIL IoT House
Yiu’s model
AUTOMATED
RESPONSIVE
EFFECTIVE
LEARNING
USER GENERATED
towards SYSTEM GENERATED ?
Spatial Interaction
user - system
system - space
Average user does not con-nect / participate
Technology takes most decisions
User connects does not participate
Technology takes ALL decisions
User participates partially
Technology takes some decisions
User decides
Technology takes no decisions
User establishes scenarios
Technology is activated based on user preferences
User does not decide
AI and Machine-Learning Technology learn user preferences and suggest or decide
INPUT - USER - OUTPUT
INPUT - AI SYSTEM - OUTPUT

> ‘there is only one condition in which we can imagine managers not needing subordinates and masters not needing slaves. This condition would be that each instrument could do its own work, at the word of command or by intelligent anticipation, like the statues of Daedalus or the tripods of Hephaestus, of which Homer relates that ‘of their own motion they enter the conclave of Gods on Olympus as if a shuttle should weave itself and a plectrum should do its own harp playing (cited in Artificial Intelligence: an illustrated history).

Pickover describes the history of artificial intelligence since 1300 BC up to today. He offers two examples that illustrate the diachronic influence of automated systems in human experience. The first one relates to Talos, ‘the Greek huge bronze automaton whose job was to protect Europa – the mother of King Minos of Crete.… programmed to patrol the island’s shores by circling the entirety of Crete three times a day ’ (Pickover, 2019, p. 3). In Greek mythology, Talos, a giant automaton made of bronze, was responsible for protecting, executing orders and most importantly, upholding justice, thus he needed to use reasoning to ensure Crete’s safety.

While Talos secured the inhabitants’ environment, the ‘false’ Maria in the 1927 silent film ‘Metropolis’, directed by Fritz Lang, prompted the city’s lower-class workers to revolt. The Maschinenmensch, or machine person ‘emerged as a symbolic synthesis of humanity and the machine – equally the human becoming machine-like, being assimilated by its technological creation, as well as the machine becoming human, embodying our worst qualities and characteristics...’ (Lombardo, cited in Artificial Intelligence). Both Talos and the Maschinemensch promote the idea of human-like systems simulating the human body combined with the human complex reasoning. Also, both integrate the notion of human – machine interaction that unfolds in a static built space.

50s – 60s: Envisioning architecture as a system

During the 1950s, the human-like approach of complex systems was replaced by the futuristic visions of the automata. The first serious discussions on the interrelation between architectural space, computing and complex intelligent systems emerged during the 1960s. In fact, it was the perfect timing: on the one hand, the interaction between human and machine was a phenomenon that emerged as an interesting subject to be elaborated by architects and on the other hand, 'architects in the 1960s and 70s found themselves contending with more complex design problems than they had in the past' (Wright Steenson, 2010). Complex intelligent systems influenced the evolution of architectural design and laid the foundation for rethinking architecture as a system. In his 1968 article 'Systems Generating Systems', Christopher Alexander explicitly highlights the importance of the interaction among the system parts in relation to human behavior. 'In order to speak of something as a system, we must be able to state clearly: 1) the holistic behavior which we are focusing on; 2) the parts within the thing, and the interactions among these parts, which cause the holistic behavior we have defined 3) the way in which this interaction, among these parts, causes the holistic behavior defined.' In fact, this was the first time that interaction emerged as an agent for spatial change and behavioral impact.

70s - 80s: Building Automation becomes a reality

The evolution of applied intelligent systems in built space is directly associated with the replacement of pneumatic transmission systems to electronic controls in 1975, leading to the Direct Digital Control Revolution (Sinclair, 2019). According to Levenhagen and Spethman, 'Direct Digital Control is the use of computers or microprocessors in conjunction with sensors and actuators to provide closed-loop control (Thomas, 2007). At the same time that the DDC transformed the automation markets, the information technology also experienced a major shift. Dumb terminals connected to the mainframe computer were being replaced by the emergence of the personal computer in the early 80s. The first computer dedicated to monitoring building systems was installed in 1974 or 1975. (Sinclair, 2019). Nevertheless, at the time, changes were taking place at the system's operational level, leaving essentially the relationship between user and space intact. Spatial human performance was not yet considered as a component of the computer operational process. While interaction was not applicable at the time, envisioning a potential system 'smartification' through the application of the new technology had a serious impact on many disciplines.

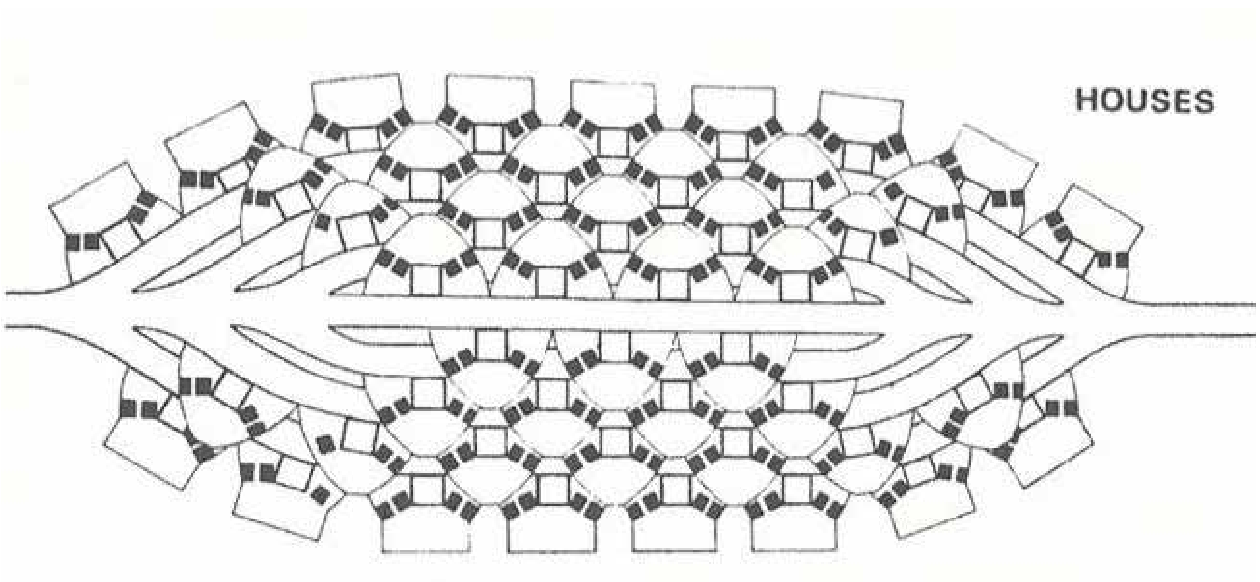


Figure 3
Alexander, C. (1960). *The City as a Mechanism for Sustaining Human Contact,* in Steenson, M.W. (2017). *Architectural Intelligence, p.40.*

The first discipline that was radically affected by the emergence of intelligent systems was the field of Computer Science. Foreseeing the need to use computers to communicate with people, a number of researchers sought to determine the most accurate methods to analyze and evaluate user behavior as well as examine the interaction between humans and computers, leading to the emergence of a multidisciplinary field of study defined as Human-Computer Interaction (HCI). Being a transdisciplinary field, dedicated at analyzing users, HCI borrowed theories from the field of psychology and, later, behavioral economics.

In the field of architectural research, there were architects that worked towards bridging up architecture and software. In 1975, Chuck Eastman published the paper 'The Use of Computers Instead of Drawings in Building Design' (Aish, 2017a), as well as 'Building Description System' (Aish, 2017b), describing the benefits of Building Information Modelling in Architecture. Robert Aish drew a parallel between computer application development and the architectural design, claiming that 'the software developer has to combine pre-existing ideas about software engineering, computational geometry, human-computer interaction, and data structures with his insights into the application domain – in this case the architectural design process' (Aish, 2017c). Likewise, in the field of architectural practice, architectural offices like SOM (Skidmore Ownings & Merrill) developed the Architecture Engineering System (AES), a software that had many innovative features, but was abandoned by the firm. These examples illustrate the convergence of computer science and architectural design in the field of computational representation, which gave birth to parametric design and BIM. At that point, architects with a focus to computation were not yet involved in the communication between user and computer or user and building through technology, but rather in how the new technologies alter the design process or the geometry of the built space. In the following years, the technological advancement influenced both the traditional design path that architects followed until then and the role of the architect in the design process. 'The computational shift promoted the design process over formal objects, moved the architect out of a central role in the design process, and generated architectural solutions beyond the capabilities of machine or architect alone' (Steenson, 2010).

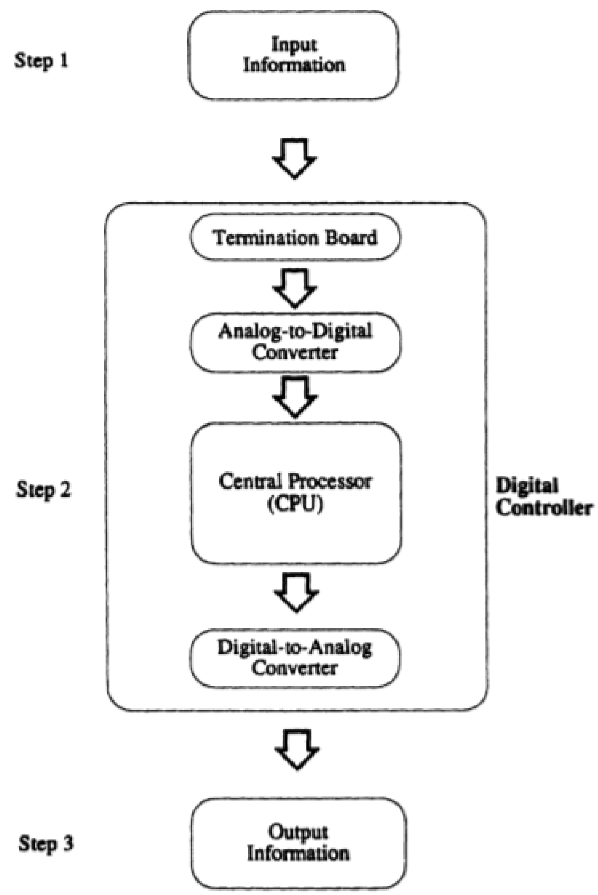


Figure 4
Coffin M.J. (1999) *Introduction to Direct Digital Control Systems. In: Direct Digital Control for Building HVAC Systems.* Springer, Boston, MA. https://doi.org/10.1007/978-1-4615-4921-5_1

80s – 90s: A new kind of space

It was not before the early 80's that the first intelligent systems in buildings emerged with the first versions of the BAS (Building Automation System). The initial phase embraced limited interaction with users, mostly at an experimental level through static control panels and touch switches. Average users were not able to manipulate the control panel; Although user – space interaction was still at a primitive level, the fact that each user could provide the system with his own 'input' at its simplest version, created a new automation vision, where human performance would be at the center of the spatial interaction. The rapid development of communications and computer technologies combined with the competition of high-end office buildings led to the emergence of the 'Smart Buildings' concept.

The introduction of the 'Intelligent Building' concept (IB) took place in 1981 by the United Technology Building Systems (UTBS) Corporation in the US. The first IB, the City Place Building in Hartford, Connecticut, was inaugurated in 1983, 'providing some automation in the facilities' (Yiu, 2008). The building was designed by SOM, but far too little attention has been paid to the merging of the building's intelligence with its architectural design. On 13th May, 1984, a New York Times article described a new type of building that could think for itself. It is not clear from the literature if human decision was considered as part of the system, or if the system took account of certain environmental parameters that activated the preset automation actions.

The TRON Project

The first complete showcase of a smart connected space was a smart home: the TRON Intelligent House, created in the framework of the TRON Project, in Nishi Azabu, Japan. The project, directed by Ken Sakamura, was inaugurated in 1984 and completed in 1989. 'Since its inception, the sole goal of the TRON Project has been the creation of a "total computer architecture" to serve as the foundation for building a computer-based society in the 21st century' (Sakamura, 2019). With a total of 380 computers, interconnected via the TRON (The Realtime Operating system Nucleus) Architecture system, at the time of being completed it was the most computerized structure

The Use of Computers Instead of Drawings In Building Design

In the sequence of illustrations starting at right, graphic displays on the computer are employed in the study and development of a design for a simple summer cabin.

Charles M. Eastman

Figure 5
Eastman, C. (1960). The Use of Computers Instead of Drawings in Buildings Design. https://www.academia.edu/8519182/The_Use_of_Computers_Instead_of_Drawing_in_Building_Design_1975

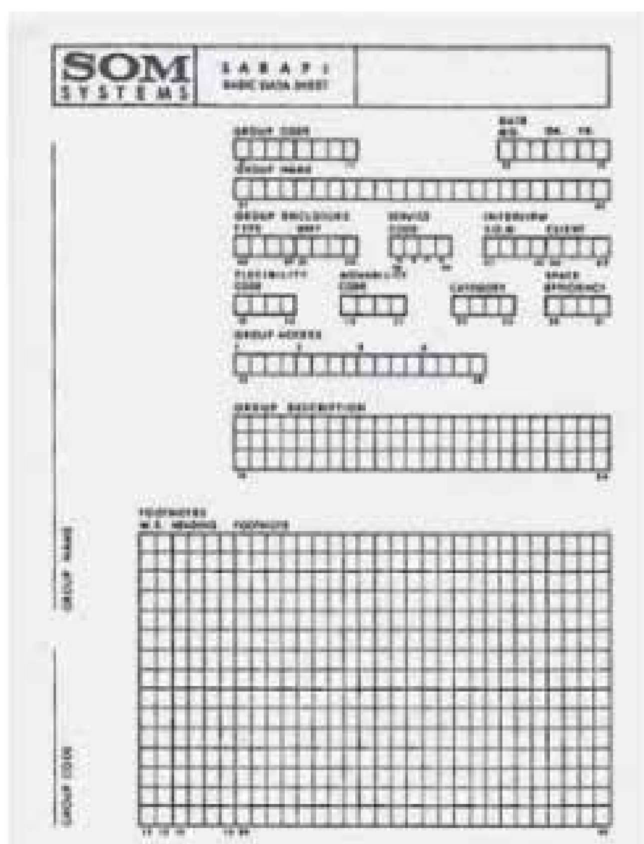


Figure 6
Architecture Engineering System (AES) by SOM Aish, R., Bredella, N. (2017). The evolution of architectural computing: from Building Modelling to Design Computation. Architectural Research Quarterly, 21:1, doi: 10.1017/S1359135517000185

of its type (Ritter, 2007). The house consists of ‘intelligent objects’, a term used by Ken Sakamura ‘to describe these microprocessor-embedded things that are able to respond on their own to changes in their environment’ (Sakamura, 1996). The TRON Project was divided into two sub-projects: the first one was the application projects, such as the TRON-concept Intelligent House and the other was the fundamental projects that were developing the basic elements of a collaborative distributed architecture.

In the TRON Intelligent House, the approach to the automation controls was based on the conversion of the structural, architectural and decorative elements into ‘smart objects’ through embedded sensors. All objects were connected to 10.000 computers through an HDFS (Highly Functional Distributed System) network. The network of intelligent objects integrated walls, ceiling, windows, lighting, floor, table, chair, air supply. The material elements were designed as receivers of external and internal information. To facilitate the human-building interaction, there was a central control panel and a general-purpose remote control. The functions applied in the TRON House were related to health monitoring, lighting and acoustics automation, plants irrigation and shell (windows and ceiling) transformation to adjust to the outside temperature and humidity. The house was equipped with indoor sensors controlling the temperature and other environmental indicators, as well as an outdoor sensor that transmits external environmental data to the system.

Almost three decades later, in 2004, the TRON Project team developed the second version of the TRON Smart House, called PAPI. What is interesting here, is the comparison between the two Smart House versions, presented by Sakamura at the TRON Symposium in 2015. Drawing the comparison of the two prototypes, the author highlighted that the conceptual framework and operational functions of the prototype remained the same, while the progress and availability of technologies, such as the semiconductor and network technology advancements enabled the better implementation. At the time of the Tron Intelligent House implementation, smart homes were still at an embryonic state, while during the PAPI prototyping the technology was already there. However, human interaction was still at a primitive level, since users had no control of the system, or the dynamic spatial elements.

The fact that the TRON Project integrated two parallel streams of innovation, focusing for the first time, not only on technological development but also towards the goal of the Computer Augmented Environment, rendered the building unique in terms of the use of technology in built

Figure 7 City Place Building in Hartford, Connecticut.
Retrieved from https://www.skyscrapercenter.com/building/city-place-i/3170

space. As Sakamura correctly mentions, 'the application projects use today's technology to simulate actual applications envisioned for the future when computers are everywhere around us, then carry out research on problems and technological needs. The fundamental projects, meanwhile, are developing the basic component technologies for realizing actual computerized environments' (Sakamura, 1996).

What is not yet clear in relation to the TRON Intelligent House is the design strategy to integrate all the state-of-the-art technologies. Regarding the design principles of the House, we know that they are largely based on empirical observations extracted by the building online showcase by the Ubiquitous ID Center In the video (0:45-0:49) it is mentioned that 'the house combines traditional Japanese materials, such as stone and wood, and has a simple and modern design' (Sakamura, 2010). Did the design rely exclusively on accommodating the technological space? How did the space creators decide, for example, to design the staircase in the middle of the house? Why did they choose Japanese traditional materials and how did they combine the high-end technologies with traditional architectural elements? While the TRON House is acknowledged as one of the major Smart Home precursors, little is known about the connection of technology to the architectural space. The lack of connection between design and technology integration reflects three issues: first of all, that 'smart prototypes' addressed issues strictly related to technological advance and the evolution of automation processes – secondly, that there has been little discussion by architects on the systematic research of the application of smart technology on the architectural design, and finally, the fact that 'just as architects turned to computers, engineers and programmers also turned to architecture' (Steenson, 2018).

The first issue raises questions about the kind and level of interaction that emanate from a highly connected space. Actually, the TRON House is the perfect example where, on the one hand, all objects are interconnected and technology is embedded in every inch of the house and on the other hand, the house is auto-programmed while the user remains a passive spectator of the automation process. Decision mechanisms are already embedded in the system. The infrastructural and immaterial layer of the house is preset; regular house users experience the new spatial possibilities without being part of the operational process. Only expert users – the creators and specialized IT experts can reprogram the space through the embedded static control panel. It is clear that, in this case, the authors emphasized the spatial flexibility triggered by technology

Figure 8
TRON Intelligent House.
Retrieved from: http://tronweb.super-nova.co.jp/tronintlhouse.html

without evaluating the human performance in space.

At the same time that the TRON Smart House initiative in Japan was oriented towards a holistic showcase of an intelligent domestic environment, in 1990, the lack of communication among different systems was evident. In order to make devices communicate with each other, electrical engineers established communication protocols. The protocols of communication were owned by different companies and were based on the code that a single organization or individual created. This caused the 'Tower of Babel' effect (Giarrusso, 2015), where many different languages, or in programming terms, many different proprietary protocols could not be synthesized in the same building. This fact led the meeting of 15 well-known European manufacturers of the electrical industry to discuss and resolve the communication gap that they were experiencing. It was then that they founded the European Installation Bus Association (EIBA), aiming at the maximum integration of the 'classical electrical installation in the rapid development of electronics' (knx.org). The KNX used the motto 'the worldwide standard for home and building control'. The KNX team prioritized and invested in the following subjects: hardware creation – by launching the twisted pair cable as a common transmission media, standardization – by agreeing on using the same system, and knowledge transfer – by organizing training courses on the correct use of the system. This constituted a great advance in the production of spatial interaction. Manufacturers realized that the prerequisite for interaction was interoperability. If building users or, at least owners and managers could not operate the new system, interaction could not take place.

The emergence of the interface

At the beginning of automation history, the system was programmed by experts, thus limiting its 'smartness' to interacting with environmental triggers. This limitation was attributed on the one hand to lack of software interoperability, and on the other hand to hardware challenges and emerging issues that had to be solved. Once the process functioned efficiently, the need for a means of communication between hardware, software and the user emerged. In 1990, Jonathan Grudin published at the SIGCHI Conference on Human-Computer Interaction a conceptual collage depicting the evolution of human-computer communication, which later served as the basis of

User Experience Research. In his collage, tiled "The Computer reaches out: The Historical Continuity of Interface Design", Grudin presents 'five foci of interface development' (Steenson, 2017, p.111), starting from the mainframe computer to the dot-matrix printing and ending to the invisible immaterial layer acting as the interface at the workplace.

The path to interoperability

In parallel with the Japanese and European technological evolution, in United States, the consensus view of automation engineers was that the legacy of proprietary thinking had impeded the natural migration of many of the benefits of open networking technology into building systems… Through accident or intent, building automation and controls systems have simply failed to embrace true open systems concepts effectively for building owners' (Fischer, 1996). In that context, Object-Oriented Protocols such as the BACnet (Building Automation and Controls Network) or the LonWorks replaced the Flat, Registered-Oriented Protocols. 'The BACnet was created for providing a universal way to convey data including but not limited to: sensing, actions, schedules, alarms, analog hardware and software values' (Lilis, 2017). BACnet and LonWorks were also approved by ANSI (American National Standards Institute) and established as control networking communications protocols, taking a major leap towards achieving seamless connectivity and a unified information model that would ensure interoperability and configuration flexibility.

Smart buildings and smart homes

Smart Prototypes enhanced by the technological evolution of the network gave birth to the emergence of Smart Buildings and Smart Homes. Both models emphasized on an increased control of HVAC systems and energy consumption, shifting the interest of manufacturers towards energy monitoring operations. Consequently, 'smart' was linked to energy control.

In the field of information systems, various definitions of 'Smart Building' are found. In fact, there exists more than 30 separate definitions of the term 'intelligence' when it is relative to buildings (Wigginton and Harris, 2002). The Intelligent Building Institute defines the 'Smart Building' as ‘one which provides a productive and cost-effective environment through optimization of its four basic elements including structures, systems, services and management and the interrelationships between them’ (M. Wigginton, J. Harris, 2002). According to BPIE, ‘A smart building is highly energy efficient and covers its very low energy demand to a large extent by on-site or district-system-driven renewable energy sources. A smart building (i) stabilizes and drives a faster decarbonization of the energy system through energy storage and demand-side flexibility; (ii) empowers its users and occupants with control over the energy flows; (iii) recognizes and reacts to users’ and occupants’ needs in terms of comfort, health, indoor air quality, safety as well as operational requirements.’ (Bean F. et al, 2017) As Nguyen and Aiello correctly observe, BPIE focuses on users and the optimal building interior environment, while IBI focuses on the occupant advantages and their ideal interior environment (Nguyen T., Aiello M., 2013). An SB is recognized as an integrated system that takes advantage of a range of computational and communications infrastructure and techniques’ (Cheng, 2009). The Cerda Institute in Barcelona defined the smart building as ‘system that support the flow of information throughout the building, offering advanced services of business automation and telecommunications, allowing furthermore automatic control, monitoring management and maintenance of the different subsystems or services of the building in an optimum and integrated way, local and/or remote, and designed with sufficient flexibility to make possible in a simple and economical way the implementation of future systems.’

With regard to residential typology, the term ‘smart home’ embodies a multitude of concepts. Researchers have turned the financial industrial model into a knowledge production model and concentrated a few observations regarding the ways that the knowledge, practice and experience have evolved into major factors for the creation of smart environments in built space.

Among these researchers, Harper (2003) propounded a theory regarding the evolution of the ‘smart’, defined ‘smart home’ as its predecessor. Smart Home as a term was explicitly defined in 1980 but dates back to the beginning of the 20th century. Initially, the term ‘Smart Home’ was created to describe the use of home electrical devices that could automate household. According to Harper, home automation that radically reduced the time needed, combined with the user familiarization with the new technological tools created entire research and development industries that led to the full home automation, known as ‘domotics’.

The informal definition of smart home in the Oxford English dictionary is equated with ‘a

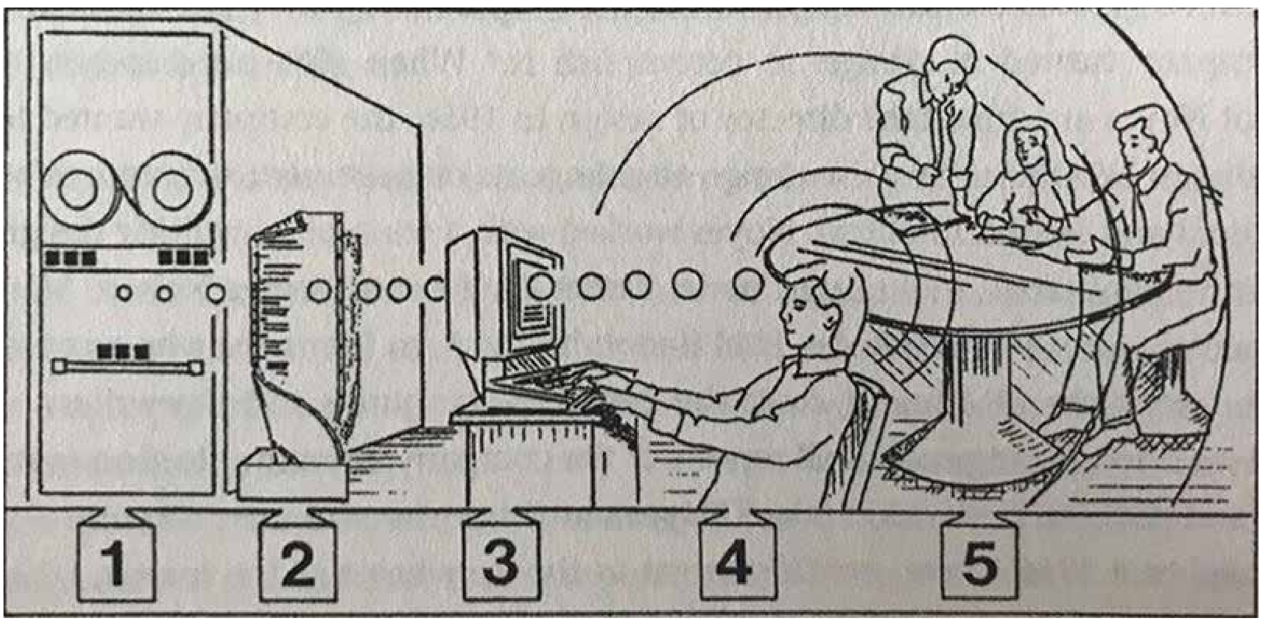


Figure 9
Grudin, J. (1990). *The five foci of interaction*. in Steenson, M.W. (2017). *Architectural Intelligence, p.110.*

home equipped with lighting, heating, and electronic devices that can be controlled remotely by smartphone or computer: you can contact your smart home on the Internet to make sure the dinner is cooked, the central heating is on, the curtains are drawn, and a gas fire is roaring in the grate when you get home'. This definition reflects the idea that smart is the automated. Eygeny Batov correctly claims that in this definition, 'all decisions are initiated not by a smart home, but by smart inhabitants' and that 'the potential benefits of smart buildings are wider than just a remote control' (Batov, 2015). According to Frances Aldrich, a 'smart home' can be defined as 'a residence equipped with computing and information technology which anticipates and responds to the needs of the occupants, working to promote their comfort, convenience, security and entertainment through the management of technology within the home and connections to the world beyond' (Aldrich, 2003).

Batov adopts the definition of 'adaptive home' presented by Michael Mozer: 'Instead of being programmed to perform certain actions, the house essentially programs itself by monitoring the environment and sensing actions performed by the inhabitants (e.g. turning lights on and off, adjusting the thermostat), observing the occupancy and behavior patterns of the inhabitants, and learning to predict future states of the house' (Mozer, 2005). Both definitions mention human performance and sensing technology as fundamentals of the smart homes. This contradicts the phenomenon of user dissatisfaction with smart technologies that will be further analyzed in the following chapter.

Common technological background towards different goals

It seems that smart homes are not perceived as part of smart buildings, but as an independent innovation stream that stands in class of its own right. The paradox is that while the demand for high-end office buildings in the 90s affected the emergence of smart buildings, smart homes evolved at a higher pace. The difference between the two concepts was mainly the shift of directions in terms of the final goal: smart buildings mostly used intelligent systems that controlled energy, while smart home technologies focused on facilitating activities of daily living, and ensuring proactive health and security, paying less attention to energy issues. The only overlapping goals of

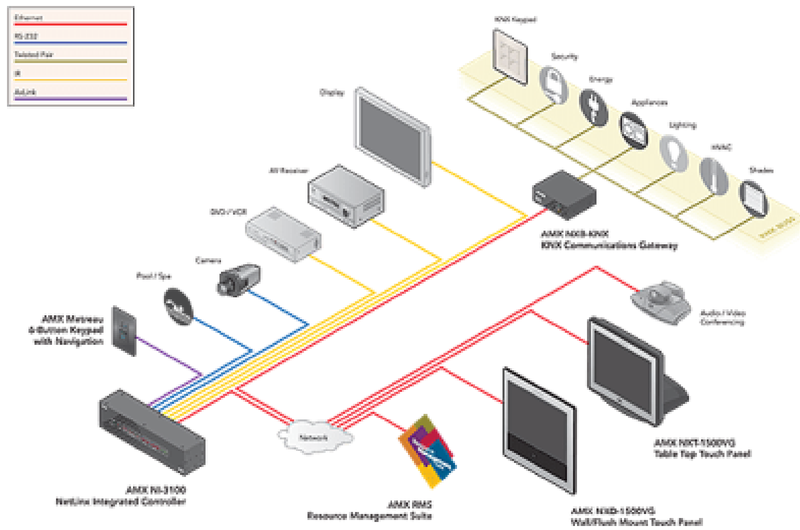


Figure 10 KNX Protocol Diagram
Retrieved from: http://www.automatedbuildings.com/

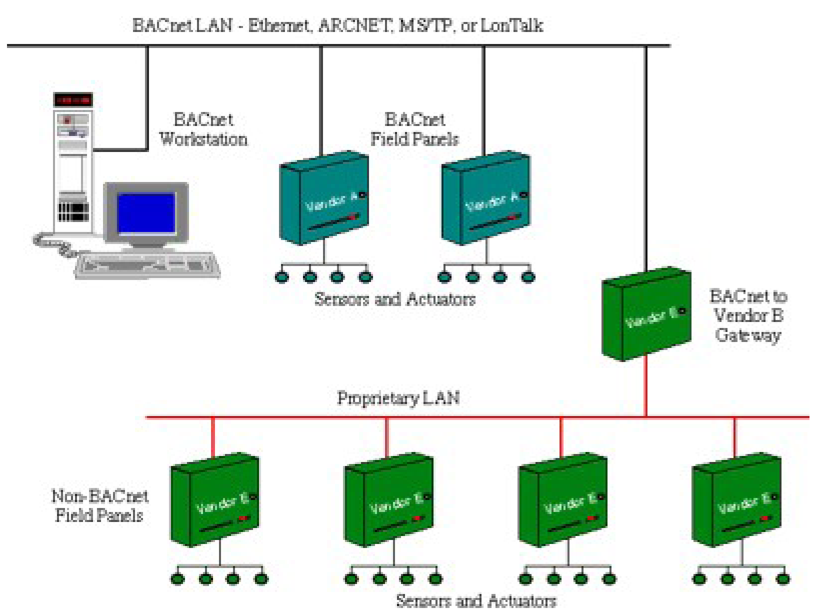


Figure 11 BACnet Protocol Diagram
Retrieved from: http://www.automatedbuildings.com/

the two concepts were interior comfort and indoor air quality monitoring. What remains different is different in the two concepts was the kind of intelligence. In smart buildings, the intelligence layer was seamless, while smart homes, in their effort to depict the future of assisted living, used explicit technologies.

While smart buildings and smart homes traced parallel paths, their evolution often overlapped while influencing and feeding into each other. By observing the historical timeline of smart interaction, it is evident that the same technological advances were used in each case towards different goals. Their evolution will be firstly analyzed in terms of their technological background and secondly, providing a comparative analysis of the interactions shaped by the technological setups under discussion.

90s: From Calm Technology to Ambient Intelligence

While interoperability, control and connectivity seemed to be the challenging issues of smart environments during the 90s, in 1995, Mark Weiser and John Seely Brown coined the term 'ubiquitous computing' or 'ubicomp' to express the future state of computer-based technology (Weiser et al., 1996). From the mainframe era, where many users shared one computer, computing had already advanced to the personal computer era, where 'one person and one computer [were] in uneasy symbiosis, staring at each other across the desktop without really inhabiting each other's worlds' (Weiser, 1996). The Ubiquitous Computing era, which Weiser predicted that would start in 2005 – and actually started even before 2000 - would be the era where lots of computers would serve one person.

For the first time, technology was rethought as a medium that would simultaneously calm and inform users. According to Weiser, 'the most interesting, challenging, and profound change implied by the ubiquitous computing era is a focus on calm…Calm technology engages both the center and the periphery of our attention, and in fact moves back and forth between the two (Weiser, 1996). Calm was conceived as the engagement of the 'center' and the 'periphery' of our attentions. Technology would be available at the periphery and would only get in the center of the user's attention when needed. The interesting fact in the notion of 'calm', was that Weiser intended to differentiate the diverse types of technology that were developed up to that time point and prove that every technological application is directly associated with human needs. A successful calm technology would increase familiarity (Weiser, 1996). We could argue that today's metrics of familiarity with technology, such as user engagement and user friendliness, have been extrapolated from the core idea of 'calm technology'.

Although at that moment it seemed absurd to combine information overload with calm technology, Weiser drew an analogy between ubiquitous computing and two other inventions that were seamlessly and holistically integrated in people's lives: writing and electricity. He also predicted that Ubiquitous computing will be seamlessly integrated into our lives, in a calm way. 'Writing and electricity become so commonplace, so unremarkable, that we forget their huge impact on everyday life..Previous revolutions in computing were about bigger, better, faster, smarter. In the next revolution, as we learn to make machines that take care of our unconscious details, we might finally have smarter people' (Weiser, 1996).

The Dangling String, by Natalie Jeremijenko was a live experiment of 'calm'. The experiment included a hanging plastic wire, a motor and an Ethernet Cable connected to the internet. Data transmitted through the Ethernet cable activated the motor, which in turn caused the wire to whirl in proportion to the amount of data. Less data put the string to the periphery of the attention, while more data pushed it to the center of the attention (Weiser, 1996).

Two years later, in 1998, at the Digital Living Room Conference, organized by Philips Research, Brian Epstein presented his vision towards a technological 'implicit, anticipatory model', where the development of computers would be personalized and based on human needs (Epstein, 1998). The unmediated fulfillment of needs, enabled by technology that 'already knows our needs and we do not need to tell it what to do', was the major future projection of 'pre-sponsive' technology, as he named it.

In describing this future kind of smart, human-centered technology, Epstein emphasized the importance of sensors that enable the understanding of the environment. The MIT Penntytags project, as presented by Epstein, represents a good example of cheap technology that smartifies 'dumb', in the sense of disconnected, everyday objects. In that case, researchers used low-cost sensors adjusted to everyday objects, aiming to create a label and network identity to personal items, that instantly become 'smart' and discoverable in the network (Epstein, 1998).

It was at that moment that ambient intelligence, the technological setup that anticipates human needs, was coined as a term. The fundamental elements of Ambient Intelligence, according to Epstein, are:

1. Embedded: Many invisible dedicated devices throughout our environment
2. Personalized: The devices know who you are
3. Adaptive: Change in response to you and the environment
4. Anticipatory: The devices anticipate and satisfy your desires as far as possible without conscious mediation (Epstein, 1998).

00s: The IoT era

In 1999, the term ‘Internet of Things’ was introduced by Kevin Ashton during a corporate presentation, aiming ‘to describe a system where the Internet is connected to the physical world via ubiquitous sensors (Goetz, 2011). While the term was never mentioned before, the operation was already known under the terms ‘Pervasive Computing’, ‘Ubicomp’ and ‘Ambient Intelligence’ (Sinclair, 2019). What is interesting here is the fact that Ashton highlighted the importance of the human factor in the digital environment. Specifically, in his article ‘That ‘Internet of Things’ Thing’, he mentions: ‘Conventional diagrams of the Internet include servers and routers and so on, but they leave out the most numerous and important routers of all: people. The problem is, people have limited time, attention and accuracy—all of which means they are not very good at capturing data about things in the real world’ (Ashton, 2009).

Internet connectivity had a ripple effect on the field of Smart Buildings. In May 1999, Ken Sinclair published an article on ‘Buildings with Their Own Internet Identity and Address’, describing the example of 199, Fremont Project, a building that summarized all the state-of-the-art IoT technologies on a web page. This was the first hands-on juxtaposition of the digital layer on the physical environment, providing users with useful information on the Operation and Maintenance of the Building. Technically, the main system that allows the interconnection between the building and the human capital related to it is the Intranet, the language that connects things to the Internet. ‘The high-speed inter-panel communication requirements for the building’s DDC system could

Figure 12
The Dangling String.
Retrieved from: http://nano.xerox.com/weiser/calmtech/calmtech.htm

use this same Intranet network using either TCP/IP, BACnet, LonTalk or custom protocol' (Sinclair, 1999). In that context, the 199, Fremont Project was the precursor of the building-as-a-service model that will be further discussed later in this Chapter.

IoT definitely marked an innovation in comfort, efficiency and safety in the building industry. Apart from the control features that it enabled, occupant comfort and energy savings were obvious benefits in the light of smart systems. However, what was not achieved at the time, was the interoperability between software and hardware. Thomas Hartman argued that 'any reluctance to embrace and expand the changes taking place toward convergence of the controls industry with the IT industry is almost certainly the result of an inability to fully grasp the huge opportunities that await those who develop functional products and applications within the resulting new standards' (Hartman, 2003). However, it was not always technology that altered the priorities of smart systems. The 9/11/2001 reinforced the significance of security in buildings and built space. 'In a post 9/11 world, security is not an appendage but an integral facility component' (McGowan, 2003). This was, in part, resolved with the emergence of Ethernet, around 2000, and, later with the Wifi.

In 2004, the first smart prototype represented in 2D drawings emerges. House_n was a research project, developed at the Massachusetts Institute of Technology in 2004. The research focuses on 'how the design of the home and its related technologies, products, and services should evolve to better meet the opportunities and challenges of the future' (house_n web). In that context, the research team developed the Placelab – 'an - an apartment-scale shared research facility where new technologies and design concepts can be tested and evaluated in the context of everyday living'. What is interesting here is the fact that the Placelab is perceived by the creators as a new type of scientific 'instrument' where new technologies and behavioral studies are tested and evaluated. The Placelab initiative is crucial for the narrative of smart user-centric design, as it is the first smart environment represented in a series of ten (10) 2D plan drawings, as in traditional house designs. The difference in the 2D plan drawings is that each one illustrates one smart layer while having the same background depicting the structural elements (walls, windows, doors) and furniture. Specifically, the drawings represent: 1) the Cabinetry Modules, 2) Location of Microcontrollers and Local Networks, 3) Visible Light and Infrared Cameras, 4) Environmental Sensors (CO, Co2, Temp, Hum., etc.), 5) Addressable 24-bit LED Lighting, 6) Microphones and Stereo Audio, 7) IR Transmitters for Location and Identity, 8) Switch sensors in cabinetry door, appliances, etc., 9)

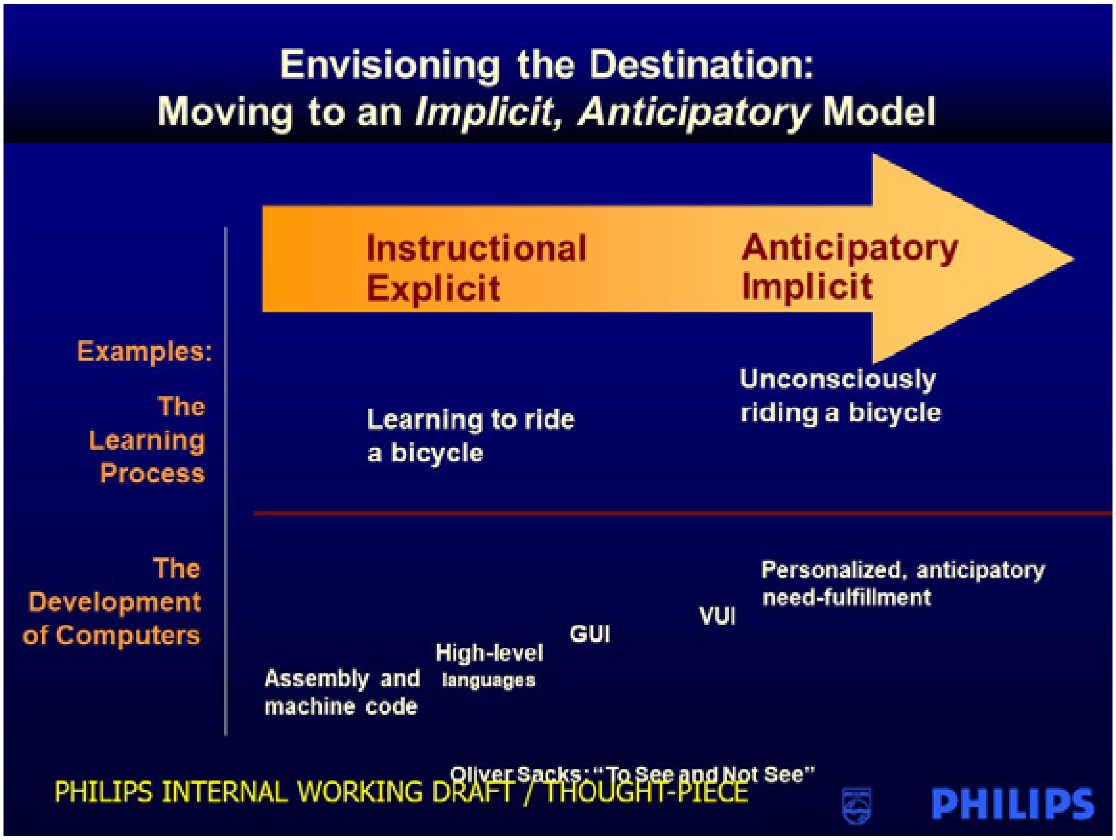


Figure 14
Envisioning the Destination: Moving to an Implicit, Anticipatory Model
Retrieved from: https://epstein.org/

Wireless sensors for Use of Movable Furniture and 10) Composite Plan showing all sensors. This is a simple, yet significant strategy of the integration of 'smart' into the architectural design process. In this case it is perceived as an extra hardware layer that enables certain functions and evokes interactions between user and space.

In 2001, Microsoft Research established the Easy Living Lab, aiming at classifying the different types of perception that a smart environment can use. Specifically, the smart environment was created to sense the state of space and detect commands from users. According to the authors (Krumm et al., 2001), the scope of their study was to demonstrate many different uses of perception in a living room. In fact, Krumm, Shafer and Wilson (2001), analyzed the sensing tasks of the smart environment and categorized them under two major cross-referenced groups: context vs. intentional communication (through UI) and people vs. object sensing type.

In terms of user behavior, the authors point out that they 'must be careful not to automate too much for fear of invoking an undesired behavior and frustrating the user'. We can argue that the Easy Living Lab elaboration analysis constitutes the first attempt to add the notion of perception into the functioning of the smart environment. As such, the significance of this methodology lies in the fact that it clearly segregates the automated from the user-generated spatial interaction of the user.

The first phase of the dot-com era was related not only to exchanging information within

The Major Trends in Computing	
Mainframe	**many people share a computer**
Personal Computer	**one computer, one person**
Internet - Widespread Distributed Computing	**. . . transition to . . .**
Ubiquitous Computing	**many computers share each of us**

Table 1
The Major Trends in Computing, Retrieved from: http://nano.xerox.com/weiser/calmtech/calmtech.htm

Figure 15
House_n.
Retrieved from http://alumni.media.mit.edu/~emunguia/pdf/IntilleLarsonETAL05.pdf

digital environments, but to creating communication paths between users through the abstract digital space. The term coined for this digital space was ‘Digital Cloud’. The Cloud was initially used to ‘express the empty space between the end user and the provider’ (Foote, 2017). Then, the idea of storing data in the Cloud emerged. ‘Cloud will be where the applications run and where the data is stored. We will be able to access the cloud with a web based and/or a desktop-based application (Uzmezler, 2009).’ Cloud Computing triggered the IaaS (Infrastructure as a Service), the PaaS (Platform-as-a-Service) and the SaaS (Software-as-a-Service) models that focused for the first time in providing custom services focused on the needs of businesses.

In 2011, Kent Larson, the leader of the House_n initiative, presented the CityHome prototype. Here, the automations were used to explore the different layout transformations that a 200-feet apartment could produce. Each occupant engages in a process to personalize the precise design of the wall units according to his or her unique activities and requirements (Larson, 2011). The CityHome was active until 2016.

Figure 16
Placelab interior views
Retrieved from http://alumni.media.mit.edu/~emunguia/pdf/IntilleLarsonETAL05.pdf

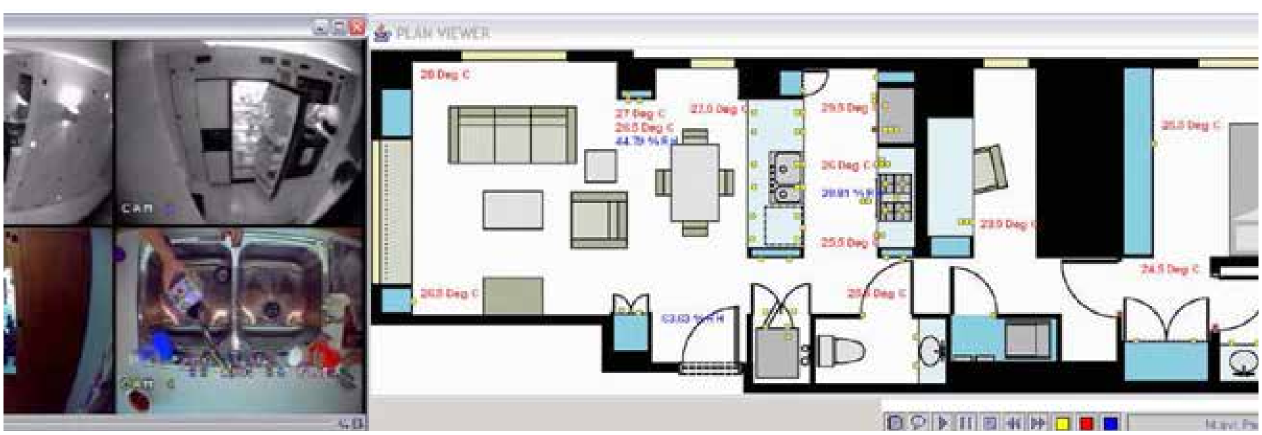


Figure 17
Placelab interaction representation
Retrieved from http://alumni.media.mit.edu/~emunguia/pdf/IntilleLarsonETAL05.pdf

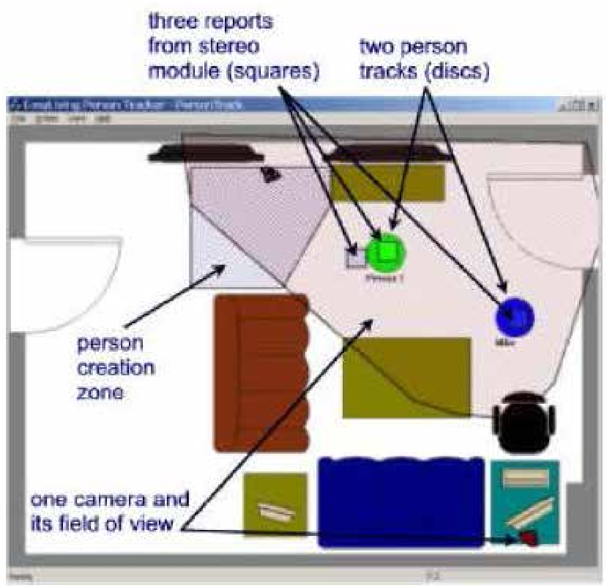


Figure 18
Easyliving Lab, Technology Description
Retrieved from https://www.microsoft.com/en-us/research/wp-content/uploads/2016/12/perception_for_ubicomp.pdf

Figure 19
Easyliving Lab
Retrieved from https://www.microsoft.com/en-us/research/wp-content/uploads/2016/12/perception_for_ubicomp.pdf

2015 - 2020: Smartphone as the enabler of the smart ecosystem

Until the smartphone era, users in experimental smart environment prototypes used to interact with space through their movement and gestures or via built in systems, such as switches, buttons and sensors. The environment was pre-programmed in most cases, taking little or no account of user preferences. This fact alone constituted a fundamental limitation for user interaction. This condition was gradually reversed by the emergence of the smartphone. The first smartphone was developed in 1992 and integrated functions, such as music, calendar and internet access. However, it was not until the first i-phone release in 2007, that technology became widely used by people through their phones. Soon, the potential of combining IoT possibilities with the smartphone operating system surfaced. By 2015, humanity had entered the 'there-is-an-app-for-everything' era.

At that exact point, the Edge, 'the Smartest Building in the World', as mentioned on a Bloomberg article, was inaugurated in Amsterdam, Netherlands. The Edge integrated state-of-the-art technologies that 'are invisible, work intuitively and support comfort'. It was for the first time that the smartphone became the connector between the building and the user. While this was a great step towards interoperability of software and hardware, the whole process aimed at monitoring energy consumption and not creating a substantial interaction between user and space, like House_n. The CEO of the building's Real Estate developer, Coen van Oostrom claimed that 'We think we can be the Uber of buildings… We connect them, we make them more efficient, and in the end, we will actually need fewer buildings in the world'. (Randall, 2015) The Edge combined technology with sustainability, producing 102% of the energy it uses and certainly more electricity that it consumes. Having 28.000 sensors, it reduces energy by 30%. In terms of sustainability, the building capitalizes on the maximum daylighting, rainwater collection, ground thermal energy storage, hybrid ventilation and solar energy acquisition through solar panels.

In 2016, Sakamura, the creator of the TRON Intelligent House and the PAPI Toyota's Future House in 2004, designed the LIXIL IoT House, where all house components are directly connected to the cloud. While the 'designer' of this house was still an electrical engineer, the approach to design is different: here the IoT component is produced by the material manufacturing of housing components. The difference between the first two prototypes (Tron 1.0 and Tron 2.0 - PAPI), and the Tron 3.0 was that instead of using a LAN or WAN to connect the components with the system, objects are directly connected to the cloud.

IoT interconnects 'things' between them and with their environment. In that respect, IoT facilitates user connectivity and extends user role in the automation process, by allowing active human participation and decision making. Undoubtedly, it belongs to the pervasive technologies that ensure greater levels of ubiquity, accessibility and control (Barbas et al). In the emerging world of IoT propagated technology integration into built space in more than one way and produces more than one effects. As William Mitchell predicted in his book 'Me++', 'we shape our technologies, then our technologies shape us, in ongoing cycles that produce our everyday physical and social environments' (Mitchell, 2004).

The emergence of the building-as-a-service

In breaking down smart space into its fundamental elements, the distinctive features are: hardware, software and the network (Batov, 2015). In this 'still image', the digital innate qualities of the above-mentioned features that enable interactive user - space feedback loop are:

1. Real - time data: Through sensors acquiring real-time data from the building, we can convey data related to the user occupancy and flows within the building, densities, external and interior environmental data (temperature, humidity, etc.), lighting and movable building parts movements. On the one hand, sensors transmit data to the cloud; on the other hand, we can create two-way processes between the building system and the user's requirements. This condition may be exemplified by automating the lighting when everyone leaves, or decrease the temperature in case of maximum occupancy.
2. Device interoperability: Through IoT, almost any device can connect to the internet and communicate with another device through the cloud. This was impossible in the past,

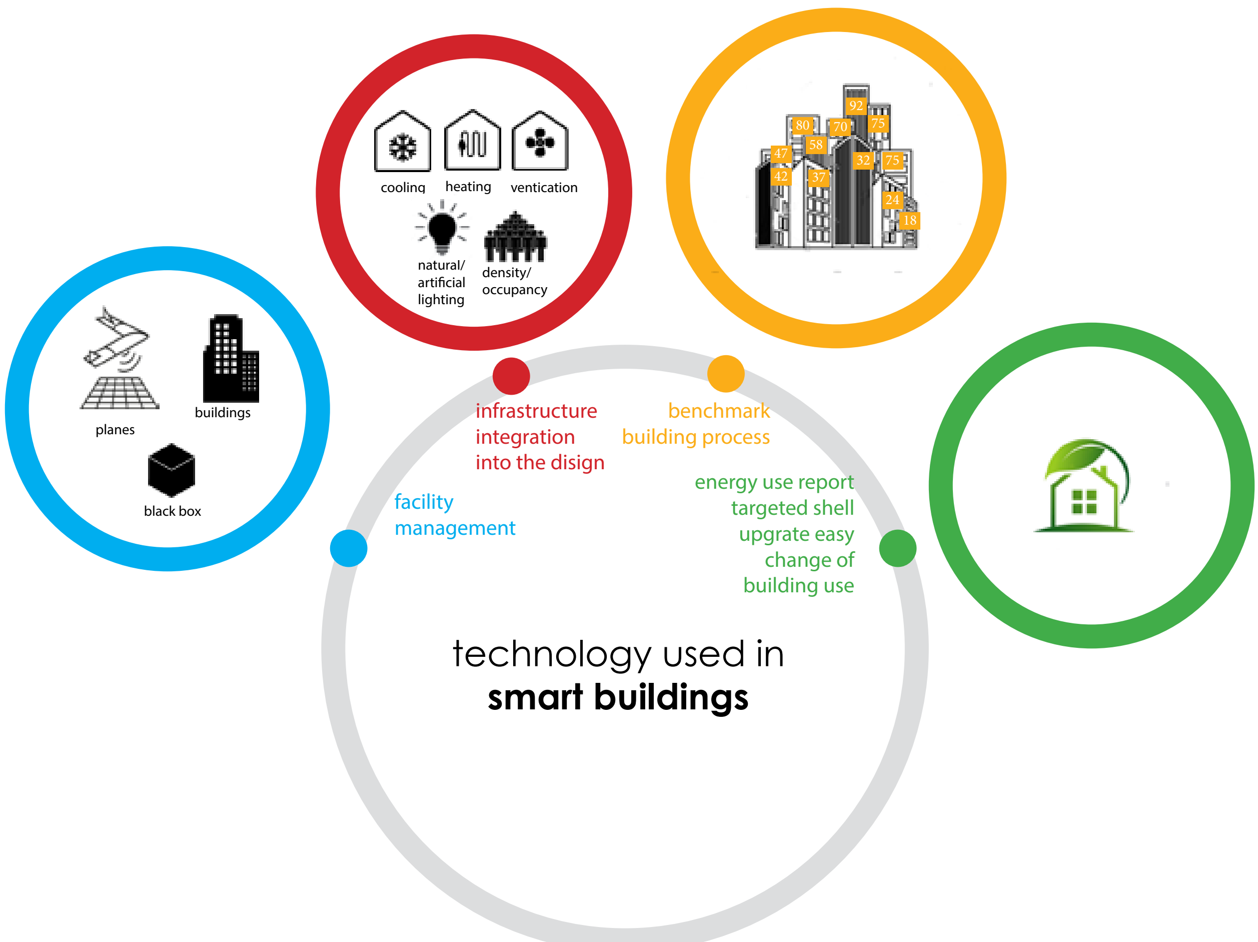


Figure 22
Building-as-a-service model

due to the proprietary and, later, protected protocols that rendered device communication impossible.

3. Human – Computer and Human – Building Direct Interaction: The average user is able to use and understand advanced technologies. In that context, users are not people that live or work in the building, but rather people that use the building, understand the connection between them as human 'sensors', the building and the digital layer and are able to execute processes through a digital interface - currently their smartphone.

While these features could not be considered as building innovation per se, by grouping them into one unified platform, a new model is created. It is the building-as-a-Service model. As John Fleming mentions in his article 'Buildings-as-a-Service: Streamlining Building Management' (Fleming, 2019) 'BaaS lessens the pressures of time and resources by transferring everything to a highly capable third party'. In practice, the highly capable third party is the digital cloud, where all data from connected devices are constantly synchronized and stored. The b-a-a-s model follows the models of the Platform-as-a-Service, such as Dropbox, the Software-as-a-Service (Google Apps) and Infrastructure-as-a-Service (Amazon Web Services). The Building-as-a-Service model focuses on satisfying user needs by performing the following functions:

1. Providing real-time data on the internal and external conditions of the building – weather, distances to the destinations, traffic, as well as building maps.
2. Tracking energy consumption of the building and the occupants, both in groups and individually.
3. Identifying and tracking users within the building enables automated accessibility, human flows real-time tracking. This information can be used in order to coordinate building's demand response as well as directed and real-time updated evacuation in emergency conditions.

The main functions of the b-a-a-s building model are summarized below:

1. Data-oriented facilities maintenance and operation: In smart buildings, the building

maintenance forms part of the building's database. By connecting the BMS (building management system to the cloud, a series of interesting equations emerge. Most importantly, the cloud becomes equivalent to the airplane's black box – a space where life-cycle building data are stored.

2. Smart Building Benchmarking: The process of building benchmarking is necessary in order to calculate energy footprint by using the same metrics. 'Benchmarking is the practice of comparing the measured performance of a device, process, facility, or organization to itself, its peers, or established norms, with the goal of informing and motivating performance improvement' (EERE, 2019). Through the performance benchmark for smart meter analytics (Liu, 2015), building data will be automatically grouped in larger data sets. By automating the benchmarking process, the comparison of the energy footprint among buildings of different materiality, scales and uses will be automated.

3. Systems Tracking: Since the building is designed as a conglomeration of material elements and immaterial systems connected to and through the network, facility managers are able to track all data related to the building parts. In that context, any material or system failure is recorded and tracked by the building / facility manager. This allows for a targeted building renovation to restore the defective building parts.

Much of the research up to now focuses on the functional features of smart environments, analyzing the benefits related to building operation and maintenance (Zheng, 2014), occupancy (Hailemariam, 2017) and energy saving (Marrone, 2016). There is no doubt that the findings of the research are very important, insofar as they take account of the social aspect of space, and specifically the novel interactions that emerge.

Ecological change

In the era of the TRON Intelligent House, the advance of technology was crucial for the development and execution of the Smart Environment. Interconnectivity had to be experimented as a challenge on its own. All prototypes under discussion, were guided by a technologically-driven perspective, emphasizing on embedding state-of-the-art sensing technologies and integrating automation processes. It was only after 2010 that prototypes shifted towards human-centered processes and user interaction became a key parameter of the system.

Nowadays, technology has evolved enough to allow the design and execution of a smart environment not as an experimental study, but through a design process. However, it is inaccurate to claim that interaction of one prototype to the following one was the same. While the technological setup technically didn't change, interaction experienced an ecological change. Neil Postman, in his talk on the 'Five Things We Need to Know About Technological Change' he argues that:

> 'Technological change is not additive; it is ecological; I can explain this best by an analogy. What happens if we place a drop of red dye into a beaker of clear water? Do we have clear water plus a spot of red dye? Obviously not. We have a new coloration to every molecule of water. That is what I mean by ecological change. A new medium does not add something; it changes everything. In the year 1500, after the printing press was invented, you did not have old Europe plus the printing press. You had a different Europe. After television, America was not America plus television. Television gave a new coloration to every political campaign, to every home, to every school, to every church, to every industry, and so on' (Postman, 1998).

Smart space is in constant technological change, generating different kinds of interaction between users and technology. Interaction emerging in different connected contexts is also ecological, in the sense that it is not equal to the interaction triggered by the aggregation of more connected devices.

The fundamental change lies in the evolution of smart space communication. Until the emergence of smartphones, which acted firstly as a connecting interface and later, as a sensor, the input was provided to the system, while after 2015, the input was provided to the users. In the first generation, space fueled the system with specific input and the

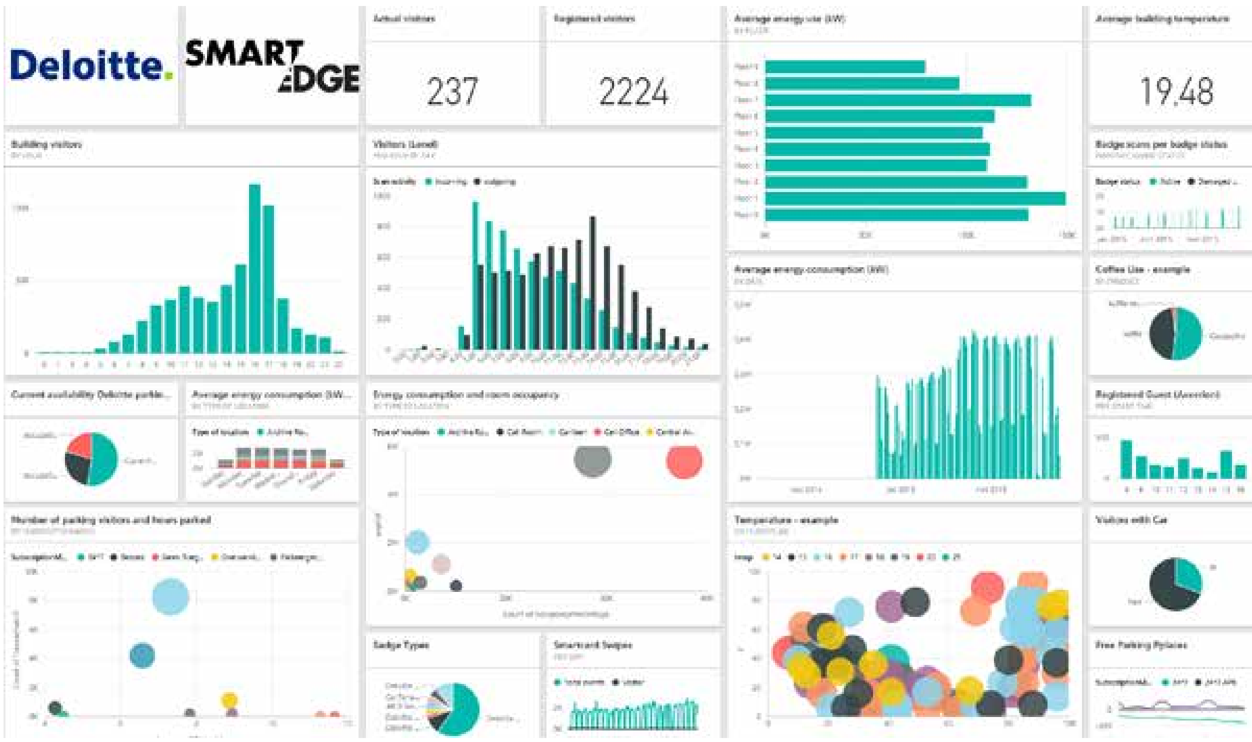


Figure 20
The Edge Analytics, (Randall, 2015)
Retrieved from: https://www.bloomberg.com/features/2015-the-edge-the-worlds-greenest-build-ing/

Figure 21
The Edge, exterior view (Randall, 2015)
Retrieved from: https://www.bloomberg.com/features/2015-the-edge-the-worlds-greenest-building/

system processed this input, programming space independently from the space user. The self-directed took decisions and programmed space. This kind of process included a 'system-oriented smartness' (Streitz et al., 2005). Later, smart prototypes such as House_n and Cityhome showcased the potentiality of user interaction and included primitive characteristics of this kind of operation. This was the era that the building connected and the user gained some information on the building through the network. The occurrence of smartphones triggered a radically different kind of interaction. The input was provided to users using the system as a medium that did not filter any decision mechanism. The system informed the user on the available options and the user decided. The next step, where we are now, was the reprogramming of the system based on user preferences, expressed through simple conditional statements that shaped personalized user preferences and scenarios based on multiple parameters: spatial, environmental, personal. During the first era, the system informed, while during the second, it simply connected users with the space. In the third era, the system informed users; currently, it can follow user preferences. This process encompasses a people-oriented smartness (Streitz, 2005). Nowadays, we witness a novel DIY culture of smart things that enables users to build their own network of heterogeneous sensors and seamlessly connect them to their smartphone applications. Instead of static points of spatial control, users now can control devices via touch screens and switches, voice and sound; remote control is already a default function; and preset scenarios considering parameters such as location and time, are embedded into the application software.

While recent technologies have successfully integrated human decision mechanisms, the evolution of AI and machine-learning processes have triggered a new trend: 'the complete automation of previously human operator-controlled activities' (Streitz et al. 2019). This shift is mainly attributed to two facts: on the one hand, technology has been optimized insofar as to adapt very quickly to human preferences without committing errors; on the other hand, 'humans are considered to be the cause of errors and not viewed as subjects capable of intelligent operation and supervision of the environment' (Streitz et al., 2019). To what extent should full cognitive automation be cultivated over human control? How are users and user interaction affected by the new reality of interaction?

2020 - future: who should own the loop?

From Automated Space to Learning Space

In examining historically smart prototypes, it becomes evident that there is more than one level of smart. In this eternal feedback loop between people and technology, Prof. Yiu identified four distinct phases of how Intelligent Buildings interact with users since the creation of the smart building model (Yiu,2008). During the 80s, the Automated Building Model was generated, where the achievement of building automation was emphasized. The achievement of Building Automation gave little power to users and it was a system that decided through preset decision mechanisms. The next phase, during the 90s, gave birth to the Responsive Building Model. The system had to be responsive mainly to environmental changes, in order to ensure flexibility and efficiency. What was contradicting, however, was the fact that the system responded to external and internal factors without considering user preferences. Responsiveness was the product of interaction between the programmer and the system, not the system and the user. As a result, user had no control over the decision mechanism. The third generation, in the late 1990s, led to the Effective Building Model (Harrison et al, 1998). It was then that the idea of intelligent building shifted away from building responsiveness and technology gravitated towards the enhancement of building users' efficiency (Yiu,2008b). This shift highlighted the gap between the theoretical model of the Effective Smart Building and its implementation. The idea that users could appropriate technology according to their preferences remained a theoretical model. What changed, was the level of accessibility, due to the integration of software into smartphones. In 2006, Yiu suggested the Learning Model, where 'the systems have to continuously recognize, learn and adapt to the changing activities and user requirements of the inhabitants' (Clements-Croome, 1997). This explorative model, according to Yiu, resolves issues that emerge during the building's lifecycle and is able to develop intelligence to maintain the building, just like living organisms develop a clever immune system to survive (Yiu,

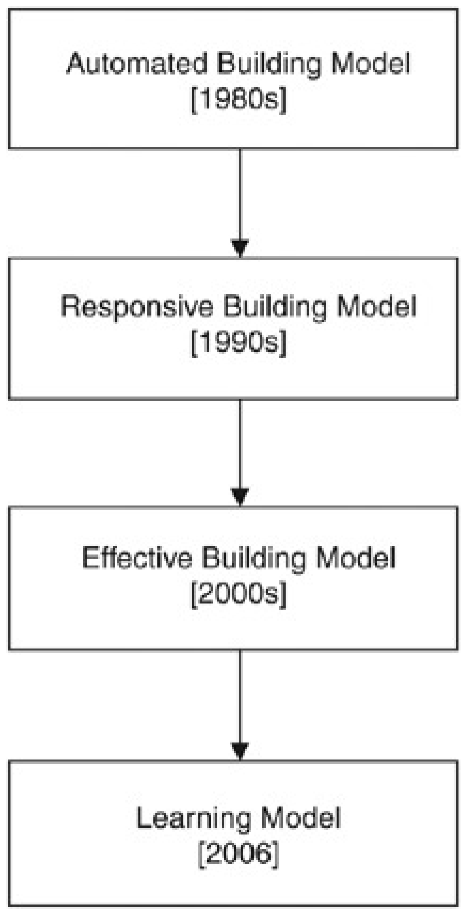


Table 2 The Intelligent building model
Yiu, C.Y. (2008). Intelligent building maintenance — A novel discipline, *Journal of Building Appraisal*, 3(4), 305-317 [online]. Retrieved from: https://link.springer.com/content/pdf/10.1057%2Fjba.2008.9.pdf

2008b). What remains unclear in this classification, is whether users are considered as ‘smart’ and already familiar with technology or if the system somehow identifies their needs and perceives them as passive recipients of the state-of-the-art technology. In this case, the building learns from users. However, it is the system that learns from users and not users that learn from the system. This reassures the spatial ‘smartification’ through system empowerment. The different models of Smart Buildings, presented by Yiu, were shaped on the one hand in the framework of the emergent new technologies and on the other hand by social, political and financial dynamics in constant transformation. The human factor was one of the most influencing dynamics in this field. Smart space users execute multiple functions: by inhabiting the space, they act as receivers and senders of information, enabling the system feedback loop; they are in the center of interaction.

Technology as the enabler of interaction

Until the IoT era, the creation of smart spaces was largely influenced and at the same time restricted by technological advance. Lack of technological resources is reflected in TRON Project, where Professor Sakamura created two different clusters of research and development to satisfy the requirements of the smart home prototype. Nowadays, technology has advanced enough and offers the tools to achieve user – space interaction. However, ‘smart buildings are not just about installing and operating technology or technology advancements. Technology and the systems in buildings are simply enablers, a means to an end’ (Sinopoli, 2010). The above-mentioned models of smart interactive models use technology in different ways, hence all of them use a key assumption: that data will be efficiently turned into valuable information and that users are familiar with technology, rendering spatial interaction unobstructed.

In smart spaces, technology acts as a connecting net that provides space with cohesion and continuity. It adds an intelligence layer that creates direct connections between the systems and its users. According to William Mitchell, this new intelligence layer is conceived as a living organism that consists of four components: the brains [ubiquitously embedded intelligence], the nerves [effective communication of digital telecommunication networks], the sensory organs [sensors and tags] as well as the knowledge and cognitive competence [software] (Mitchell, 2007). The distinguishing feature of this new living organism is that can be implemented only through human interaction with the above components.

In other words, technology becomes important at the moment that people can benefit from its existence. 'As we automate buildings and get to a connected world, this is a reminder about how the people who use the buildings be it homes, malls, office space, airports need the technology personalized and adaptable to their needs, as Autonomous Vehicles are' (Jamthe, 2019). Technology is important; however, neither is it necessarily 'smart', nor does it always create interaction. 'Many of the new IoT applications will intimately involve humans thus humans and things need to operate as a whole' (Leppänen et al, 2016). To achieve maximum interaction, a successful human performance should be achieved.

Undoubtedly, the bearer of that information is the user that reacts with the system, absorbs data, turns it into valuable information. Drucker (1979) argued that the substance of smart spaces is information flow and dissemination, which is intrinsically linked to the knowledge obtained by user processing. How can we reassure optimum collaboration between users and technology? Interaction in smart space takes place through the juxtaposition of two distinct layers: space – technology interaction and user – technology interaction. These two layers coexist and interrelate with each other, activating decisions that are provoked either by the user or by the technology. The outcome of their correlation generates spatial interaction. Human performance is defined as the metric that reflects user engagement, satisfaction and learning variables of user - space interaction.

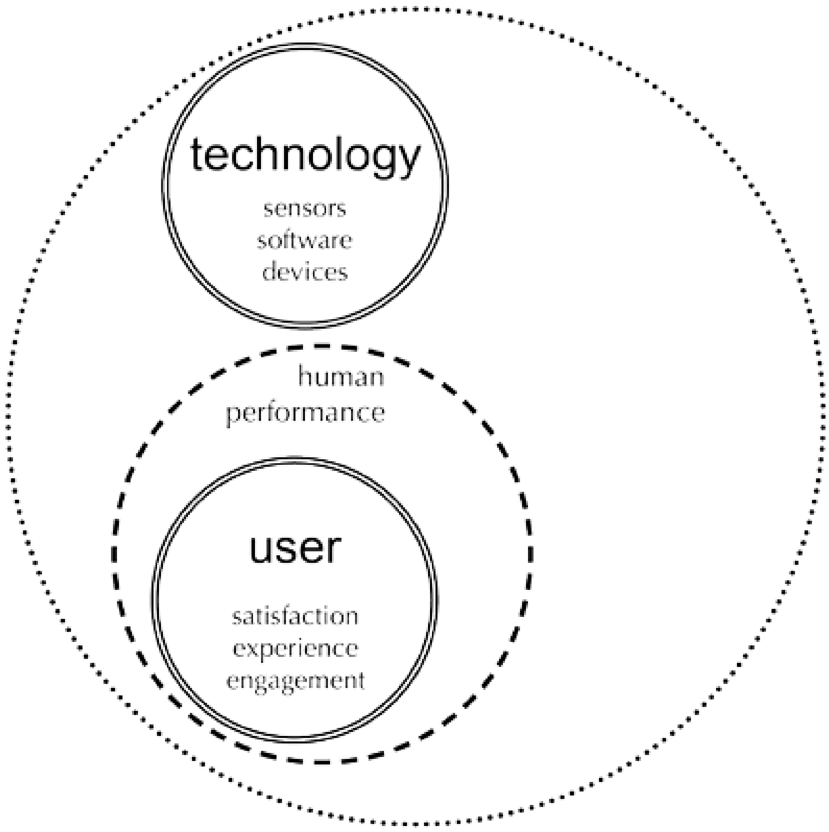


Figure 23 Technology as the enabler for interaction

Input - Processing - Output

To understand how human information processing works, the correspondent model from the Air Traffic Control (ATC) is adopted and juxtaposed to built space. By theorizing user – space interaction in supra-smart environments such as the airplane - although at a different scale and context - this model seems to accurately illustrate the way the human mind operates. It includes four stages: Sensory Processing, Perception/Working Memory, Decision Making and Response Selection. The first two stages refer to the acquisition of information and the perception and manipulation of processed information. The third and fourth stages include the cognitive processing that drives the decision point and the implementation of action or response consistent with the decision choice (Parasuraman et al., 2000). The system's automated model also uses a similar model that consists in: information acquisition, information analysis, decision and action selection, action implementation and adaptive automation.

What is interesting in the human – system juxtaposition is that both interactions follow the input – processing – output (IPO) model. 'There are similarities in the ways that humans receive information and computers receive data input' (Miller, 2016). Users follow the human information processing model, while technology uses 'its equivalent in system functions that can be automated' (Parasuraman et al., 2000).

User-technology and technology-space layers act in parallel and are supposed to act complementarily towards optimum user – space interaction. What is not yet clear is who should decide and under which circumstances. How should technology and human decisions be formulated to ensure maximum human performance? In other words, in which cases should the user decide and in which ones would technology activate the human-decision mechanism?

Identifying modes of interaction

Having examined the historical evolution of smart environments, it seems obvious that all prototypes sought to enable a kind of interaction, that was always dependent on technical factors, such as interoperability, connectivity and accessibility. In this section, four different types of interaction are extracted, through the identification of the two fundamental dynamic factors of the environment: human decision-making and system automation processes. The diverse types of correlation of these two factors have shaped the following types of interaction:

Operation	System	User	Activation Medium
Input – System - Output	Takes most decisions	Takes some decisions / connects - does not participate	Static points / Control Panel for expert users
	Takes some decisions	Takes some decisions / partially participates	Static points / Screens
Input – User - Output	Exists on standby Takes no Decisions Preset Operations	Takes all decisions through instant actions	Dynamic points of control / Smartphones and tablets Remote Control
	Exists on standby No Decisions Preset Operations Able to perform consecutive actions based on user preferences.	Takes all decisions – establishes personal preset scenarios	Dynamic points of control / Smartphones and tablets Remote Control Scenario-based Commands

Table 3 Interaction Modes

System-based and user-based interaction

Studying the history of smart environments in terms of user involvement in the decision making, two kinds of interaction were extrapolated. The first one was system-based, that followed the input-system-output model; in this case, the system was self-directed following embedded preset parameter. The system-based model co-occurred with the automated and effective model, according to Yiu's analysis (Yiu, 2006). The second model was user-based and followed the input-user-output model. Historically, user gradually started gaining control of the system and participated into a more direct and efficient interaction with the environment. This model coincided with the effective and learning model presented by Yiu. Similar to this classification, Norbert Streitz (2019) detects two kinds of smartness: the system-oriented, importunate smartness, and the people-oriented, empowering smartness. A considerable amount of literature has been published on the issue of automation versus human control. Most research is conducted in the field of vehicles, specifically associated with airplanes and autonomous vehicles, as well as with Lethal Autonomous Weapons (LAWS) where a possible automation failure or an unfortunate human handling of the system would have deadly consequences. Streitz (2019) draws our attention to the term 'disengagement' in the field of self-driving cars which 'includes every time a human driver must quickly take control, either because of hardware or software failure or because the driver sees a problem coming'. In the following section, the system-based model and the user-based model will be further discussed in terms of the emerged disengagement and overall consequences on built space.

Fully automated, system-based smartness

The interaction between system and human in the field of automation is extensively analyzed in the field of Air Traffic Management. Within this scientific field, the impeccable human system interaction is a prerequisite for the system development, as human control and cognition is needed in cases of emergency. Sheridan and Verplank (1978) were the first to acknowledge that automation is not 'all or nothing' and formulated a theoretical model of ten degrees of automation, as expressed in Table 1. In this model, the highest level of automation lies the tenth level, where ‘the computer decides everything and acts autonomously, ignoring the human. Sheridan and Verplank’s model was developed at the time that automation was at a primitive level. During the 90’s and the 00’s there was a shift towards adaptive automation (refers to systems in which both the user and the system can initiate changes in the level of automation, (Scerbo, 2015)). Despite the latest transition of automation systems towards capitalization of users in the system process and the, Norman Streitz (2019) argues that in the future, the system’s refined intelligence will totally exclude people from the automation loop. ‘Humans are rather considered to be the cause of errors and not viewed as subjects capable of intelligent operation and supervision of the environment’. From his point of view, the idealization of Artificial Intelligence is not new, as it ‘has experienced several hype cycles as they are common in the field of emerging technologies’.

History shows that before the integration of smartphone as part of smart environments, a kind of system-based model was used due to lack of technological support. Nowadays, technology has advanced to the extent that it can support a wide range of spatial system-based activities. In the system-based model, the system self-operates, taking decisions without a human in the loop. This self-operation is based on AI sub-systems that collect and analyze data and act in a twofold way: on the one hand, they activate the decision-mechanism through (human-generated preset rules); on the other hand, they work on a trial-and-error basis in order to generate new mechanisms to interpretate data through AI techniques, such as machine-learning.

Excluding the humans from the loop and control generates a number of issues. The first set of issues is related to system deficiencies that technology is not able to cover. The second set of issues is user-related and concerns the degradation of human skills that takes place when the role of user is destabilized in the system.

System Issues

In that context, Streitz (2019) examines the ‘Smart-Everything Paradigm’ and empirically identifies three distinct flaws of the fully automated system that have serious implications on interaction between humans and built space. These are:

a. Inability and error prone behavior of AI

b. Rigid behavior

c. Missing transparency

a. Inability and error-prone behavior of AI: To prove the inability of AI to achieve full instrumentation of built space, Streitz (2019) uses the example of Autonomous Vehicles. He maintains that humans can securely trust autonomous vehicles, only when their automation levels range between level 4 and 5, at the same time that, according to scientists, by 2030, the achieved condition will not exceed level 3. By conducting a long-term experiment on a commercially available car equipped with the currently available camera-based technology for speed-limit detection, Streitz (ibid.) claims that the system was correct only in about 50% of the different traffic situations. This fact is strengthened by the statistical data from the US. Carmakers testing self-driving cars in California, where the disengagement reports traced a self-driving car failure every 3h in 2016.

b. Rigid Behavior: Rigid system behavior is manifested in various aspects of everyday life. Recommendation systems are usually programmed to take account of the user's last online activity and offer recommendation for its future repetition, disregarding the fact that, in most cases, users will neither travel to the same place that they visited, nor buy the same product that they bought the previous day. The lack of user control culminates in the case of automated call services, where the increased level of automation prevents users from receiving the services that they need.

c. Missing Transparency: Artificial Intelligence functions based on parameters embedded and controlled by humans. As such, the first setup is completely controlled by humans. Things get complicated when the AI system evolves. The evolutionary process of AI uses techniques such as Machine-Learning, Deep Learning and Neural Networks, that support the learning process of the system. The system evaluates the outcome through a trial-error process that constantly refines results by using human data. This implies that once the system is setup, user becomes the judge of the system in a superficial way, without deeply understanding how the system operational evolution. This condition is called as AI black box (Cassauwers, 2020) and is unquestionably one of the major issues of the current era of Automation.

User Issues

A key problem with much of the literature in relation to human response to holistic system control is the phenomenon of complex user issues associated with human information processing. Endsley and Jones in their book ‘Designing for Situation Awareness: An Approach to User-Centered Design’ trace the factors that impede interaction and human processing in the field of systems automation. The factors are:

- Attentional Tunneling: users pay attentions to certain system features, thus ignoring other important ones.
- Requisite Memory Trap: Some designs tax working memory to the point where SA is decreased due to overload.
- Workload, Anxiety, Fatigue, and Other Stressors: Psychological and physical stressors can negatively affect information intake by making it less systematic and more error prone.
- Data Overload: The way data is processed, stored and displayed all affect how data is organized and presented to the user. These factors can contribute to overload.
- Misplaces Salience: Salience may help or hinder SA depending on the context of use. Designers must be careful to use it appropriately.
- Complexity creep: this phenomenon may undermine the user’s ability to correctly interpret information presented and to project what is likely to happen.
- Errant Mental Models: Lack of standardization and use of modes can activate errant mental models in user’s minds and cause them to misinterpret the meaning of cues.
- Out-of-the-loop Syndrome: Too much automation can push the user out-of-the-loop, causing them to lose SA in regards to the status of the elements under systems control.

Parasuraman (2000) focused on the consequences of human operator performance in the resulting system, after the automation implementation. Specifically, he identified the following factors:

1. Mental Workload: the technological layer is required to facilitate human operations in space,

by organizing and representing useful information. Users in smart environments are recipients of diverse and dense amounts of information

2. Situation Awareness: Technology often distracts users, who ‘tend to be less aware of changes I environmental or system states when those changes are under control of another agent. Consequently, a successful technological layer provides users with indicators of their location and orientation within space, or provide information on the metrics of the smart environment.

3. Complacency: When users are over exposed to technology, they tend to show over-trust to the system capabilities. For example, people establish a strong connection with their smartphones and tend to use smartphone features as much as possible

4. Skill Degradation: Technology is able to perform repeated actions with extreme accuracy and consistency. If human decision is totally excluded, users will not be able to perform the certain action in the same way, thus losing their skills. A typical example of skill degradation is automated mapping directions. According to psychologists, ‘Street View users can lose that experience of where they are and it just becomes a very automatic 'I need to get from here and I need to get to here'... so it becomes a routinised mechanistic way of behavior (Jaffe, 2013).

Establishing user-centered interaction

Full automation has been proven to fail in multiple cases, due to the aforementioned system issues. ‘Research on human interaction with automation has shown that it does not always make the job easier’ (Scerbo et al., 2010). Which is the optimal mode of user-system interaction?

From the user point of view, there exist three modes of user control: direct control, supervisory control and shared control (Sheridan and Verplank, 1978). Direct control refers to user authority over the system, or in Sheridan and Verplank’s model, the lowest automation level. In that case, people are overall responsible for the behavior of the system and AI is not leveraged at all. The value of the system lies in the cases where either the user does not know or is vulnerable thus not able to take responsibility of the system. In residential spaces, for example, in the case of a handicapped person, the system can take control over the user. The second mode refers to the supervisory control, or in Sheridan and Verplank model, the seventh level of automation: ‘the system executes automatically, then necessarily informs people. This mode also renders people passive spectators, as they only supervise and get informed, without actually having any authority on the system. The third user control is the shared one, where both user and the system have control and take responsibility in conjunction. The shared mode corresponds to three different automation modes: Level 3, where the system narrows the selection down to a few; Level 4: the system suggests one alternative, and Level 5: executes that suggestion if human approves. The existence of multiple variations of shared control raises the question: who should own the loop, and under which circumstances?

Who should own the loop?

The increase of automation independency and self-directed decision making has heightened the need to understand who is (or will be) in charge of the decision mechanism and to what extent we are able to keep humans in the loop right now in smart spatial environments. This is a theoretical question that, historically, has undergone a lot of analysis in economics, social sciences and technology. Brynjolfsson and McAfee (2015), Co-Founders of the MIT's initiative on the Digital Economy, present a different point of view in their article: 'Will Humans Go the Way of Horses?'. The authors draw parallels between the role of humans in the Fourth Industrial Age and the fate of horses in the Third Industrial age (or the first Digital Revolution), wondering if automation and its implications on everyday living will 'finally sweep out of the economy' (Brynjolfsson et al, 2015). According to the authors, the first reaction would be that of Wassily Leontief: 'The role of humans as the most important factor of production is bound to diminish in the same way that the role of horses…was first diminished and the eliminated' (Leontief, cited in ibid.) But humans have a distinguishing feature that is currently irreplaceable: mental abilities, such as common sense. Moreover, humans have an additional attribute that renders them powerful: they are (at least so far) the creators of all AI technology. AI does not provide a guarantee of performance – it operates under the rules of probability. But these rules always have a glitch, commonly translated into two fundamental system factors that are difficult to quantify: predictability and reliability. Until now, there is not one single system holistically rated as 100% reliable. This system glitch, 'the perhaps' (Pasquale,

2015) that the system is not able to predict, is a good reason why people should always own the loop. Moreover, people have different habits, needs and preferences, and even the most adaptive system is not able to fully adapt to them.

Privacy in smart environments

Concluding that people should stay in the loop, the next question should be 'how could we make this happen?' There are a number of implications that should be considered before establishing roles. Let's take the example of privacy. Norbert Streitz (2019) argues that there are two levels of privacy: the privacy by default and privacy by design. In that context, Pasquale (2015) presents the example of bank data. Banks promise to their client that they keep their data secure and private. However, the way that they keep their clients' data private is differentiated from the ways the use to keep their own data private. The first way can be associated to Streitz's privacy by default; the second corresponds to the privacy by design. Google made it to the top of tech companies by secretly securing its 'secret sauce' – the complex algorithm it used to rank sites (Pasquale, 2015). Undoubtfully, the privilege of privacy is quintessential prerequisite to avoid the fate of the horse. The distinctive feature of 'privacy by default' over 'privacy by design' is the lack of human control over the internal mechanisms that generate the results. Extrapolating the privacy paradigm into ubiquitous environments, we can argue that control is also a factor that can be found at 'default mode' and at 'by design' mode. Control is a factor that can be designed and predicted, thus unlocking human potential to gain knowledge of the system parameters instead of struggling to understand how the system works. 'Control by default' only involves people (programmers, building experts, owners, stakeholders) that contribute to the original setup, thus without further disseminating knowledge. These people, for example the creators of a smart home system, are considered producers and do not fall into the pool of users. 'Control by design', in contrast, plays a major role on the democratization of information, since it communicates knowledge to the majority of people and renders them responsible for the decision mechanism.

How can we establish a 'Control by Design' ecosystem without abolishing the AI achievements and without 'ending up being the horses of the second digital turn, as Mario Carpo (2017) defines it. We take for granted that open sourcing would never be available, as smart technologies use proprietary protocols that companies do not reveal. How is control translated into social terms? Let's take the example of hackers, trying to access a network. The first thing to do is to understand how the system works. In other words, they gain knowledge of the system and its settings.

Interaction as a driver of design

The analysis of the types of interaction between user and system throughout time demonstrates an array of new parameters that influence interaction. First of all, system flexibility and adaptability activated the role of people in controlling the system. Communication protocols were established through the emergence of IoT systems and user direct connectivity through the domestication of the smartphone. Questions such as '*Who should own the loop?* Or '*How does the system guarantee people's privacy?* are extremely significant, hence technical and related with automation. From an architectural point of view, new technologies should focus on how people interact with their environment and what type of new relationships emerge through this kind of interaction.

According to Henri Achten, there is an array of architectural concepts of smart environments, such as 'intelligent buildings, building automation, sentient buildings, smart homes, responsive architecture, adaptive buildings, kinetic architecture and interactive buildings' (Achten, 2010). While most of these concepts investigate interaction from an architectural point of view, they consist in prototypes that, in most cases, are not integrated into the building design holistically. 'The term "interactive architecture" is a bit misleading, because interactive buildings as such do not exist' (ibid.). In other cases, they become too technical (ie. Building automation) and ignore the human presence in the loop. The common denominator of these concepts is change. 'Although change is a constant factor in architecture, allowing change or designing for change still poses difficulties' (ibid.) Achten relates change to building performance and highlights the importance of designing for change.

In technical terms, interactive architecture is based on the components of automated systems: sensors, controllers, actuators and materials. The distinguishing feature of the interactive system is that ‘it takes the user into account’ (ibid). In this case, how can architecture influence the design of the system and its components? Achten presents four consideration areas for the design of interactive systems. The first area is the kind of engagement. How does the building engage people? In this area, four types are identified: the building as a perfect butler, as a partner, as environment or as wizard. The second relates to the technological components. The third is associated with the kind of technology: passive, autonomous, reactive and agent-based. The fourth consideration area encompasses the design methods, classified under the model of Analysis, Concept Generation, Simulation and Assessment. The above consideration areas will be further analyzed in various contexts in the third chapter.

Conclusions

Having analyzed the evolution of technology and its future potentialities in the field of smart spatial environments, it becomes obvious that IoT combined with the wide use of smartphone technology triggered an ecological change of interaction, where instead of feeding the space with input and expecting a preset output, it fuels users with knowledge and a set of tools to change experience and perception on the space they interact with. By establishing user-centric automation, users are enabled to be in the loop, participate in the decision mechanisms and generate valuable data for architects, designers and experts of space. Interaction has undergone a lot of change during the last century. Before the emergence of IoT, computer scientists struggled with hardware challenges and issues, while architects envisioned interactive environments, unable to be implemented, thus dystopic. Hence, in our era, the existing technology and evolution in the field of computer science can act as enablers of architectural design; a new kind of design where change becomes an architectural concept and dynamic elements are used to create novel user experience.

The common denominator of the smart spatial systems is the interaction of the systems or the environments with the users. Throughout this study, users are defined as people that are able to use and adapt to the technological advances. Technology is a fundamental component in smart environments, and interaction is the natural consequence of the human presence. If users are not familiar with the technology, then they are not able to interact with their environment. If interaction is not possible, the chain of smart entities is either misused or encounters total failure. Imagine an evacuation application, able to capture every building point real-time through sensing technology and cameras at the case of an emergency. The application system notifies users about the current state of the building after the emergency and shows the safest and quickest path to a safe outdoor point. If users don’t have the fundamental knowledge of how to use the application, or have not familiarize themselves with the application interface, interaction with the system does not take place and spatial interaction fails. Users of smart environments have to become ‘smart’. In order to elaborate on this argument, the kind of needed interaction, user adaptability and overall behavior have to be further analyzed. In the following section, the kind of interaction triggered by smart environments will be discussed.

CHAPTER II

User - centered multidisciplinary approaches

Abstract

This chapter focuses on the role of users in various disciplines related to smart environments. The first chapter presents an array of user-related perspectives from the fields of informational technology (IT), social sciences and finance; then it investigates how the bridging of the three fields promotes science and creates innovation. It also introduces the world of User Experience that serves as the mediator between human-driven, design-focused disciplines and business-related fields; it also has been catalyst in shaping user-centered environments. The second part investigates the role of user behavior in Architectural Design, as well as how architects empirically conduct User Experience studies prior to the design process.

Users in Informational Technology, Social Sciences and Innovation

Defining 'User'

This part presents the definitions of 'user' in fields related to digital environments and smart contexts. 'User' is a broad term with diverse definitions in different disciplines. How is the user defined in digital environments and smart contexts? Researchers in various disciplines have defined the term 'user' from both the theoretical and empirical perspectives.

The Online Oxford Dictionary defines "user" as "a person that uses something". According "Designing Buildings Wiki" (2019), "a user can also be referred to as an end-user, which indicates that the 'end' is the completion of building, i.e., when it can be used for its designed purpose…A common domestic building end-user is a resident, that is, an individual who uses the building as a residence on a permanent or long-term basis" ((End User). The type of users will depend on the use class of a building. For example, the users of an office building are those who work there; users of a school building include pupils, teachers, and support staff, and the users of a hotel building are hotel guests and employees. In computing, users are familiar with the digital environment, but not with its technical aspects: "a user is a person who utilizes a computer or network service. Users of computer systems and software products generally lack the technical expertise required to fully understand how they work" (Wikipedia, 2019, User (computing). In economics, users are associated with the authority to access the digital system: a "user is an entity that has authority to use an application, equipment, facility, process, or system, or one who consumes or employs a good or service to obtain a benefit or to solve a problem, and who may or may not be the actual purchaser of the item" (Business Dictionary, 2019, user).

The first field to examine users and suggest user-centered strategies was library information processing. T.D. Wilson, in his paper, “On User Studies and Information Needs”, presents five aspects of the user: a) communicator, b) information seeker, c) user of formal information systems, d) recipient of information services and e) user of information (Wilson, 1981). For example, building users are, by default, considered “occupants” or “end-users” who live and work within a building. On a larger scale, citizens are users who live within an urban or suburban space and interact with the urban or suburban tissue and the technologies embedded in it. Mora et al. argue that urban users or citizens can act as a) users that test ICT solutions and provide feedback; b) developers of new digital services of public interest for assembling the platform of ICT solutions to urban issues; and c) residents help frame innovative strategies by reporting on their ideas, needs and knowledge (Mora et al., 2019).

Evolution of Users

In the first chapter, the evolution of human–system interaction in smart connected spaces was analyzed, proving that users of spatial environments gained exposure to IT experts and behavioral scientists after the IoT era began in the 00’s. This phenomenon moved the primary focus towards leveraging new technologies and designing the technical system as a unit of physical space, independent of human action. Observing the parallel evolution of the conceptualization of users in information technology (IT), it becomes evident that in the same way that smart spaces became influenced by technological advancements, the notion that users in smart spaces are also affected by the parallel evolution of the user in system design. Kuutti (2001) traces the evolution of the concept of user in IT and describes

how developers first perceived humans, and how their change in perception changed the design of technical systems in four successive decade-long waves beginning in the early 1970s.

1970s: In the first phase of development, during the 70s, the conceptualization of the user was influenced by organizational theory whereby managerial approaches and users were perceived by developers as ‘a cog in a rational machine’. Human actions were seen as predictable and as an entity that machine developers could meticulously manipulated to facilitate machine function and primitive automation processes.

1980s: The second wave was introduced by the fields of ergonomics and cognitive psychology. While automation was advancing and becoming more and more complex, users were seen as "information processors" similar to computers, but "hopelessly slower and more unreliable" (Kuutti, 2001, section 2)

1990s: The third wave of influence came from anthropology and microsociology (i.e., a primary level of analysis that examines the nature of routine human social interactions). It was deeply inspired by Human–Computer–Interaction (HCI) studies that delivered "working methods to design better systems" (Kuutti, 2001, section 3)

2000s: The fourth wave emerged through consumers' demand for smart products. The introduction of mobile phones and their ubiquitous use not only for communication but also for self-expression (e.g., 'selfie' photos transferred to social media sites) shaped a new era where developers came to see users as human beings with needs and sentiments seeking fulfillment and expression.

In the same vein, Frison et al. (2018) examines the evolution of HCI and identifies three distinct waves of cultural usability that further expanded in the 1980s, 90s and 00s.The fourth wave is associated with the interdisciplinary approaches, such as User Experience and Behavioral and Social Sciences that influence HCI. This latest approach is balanced between business-related disciplines such as marketing that focus on the quantification of experiences (e.g., usability metrics and experience rating), and social sciences and design-focused disciplines that analyze social interaction and seek user involvement.

Post smartphone era users

Smart systems did not substantially interact with users until the late IoT era in the early 2000s. The wide use of smartphones in everyday life catalyzed the communication of people with smart spatial environments. While we do not know yet if and how much users evolve socially, culturally and cognitively through their use of smart systems, smartphones and smart devices definitely offer new capabilities to users and to the design of human-occupied space. The Internet is itself a dynamic technology that is constantly evolving as users adopt and reject new features,

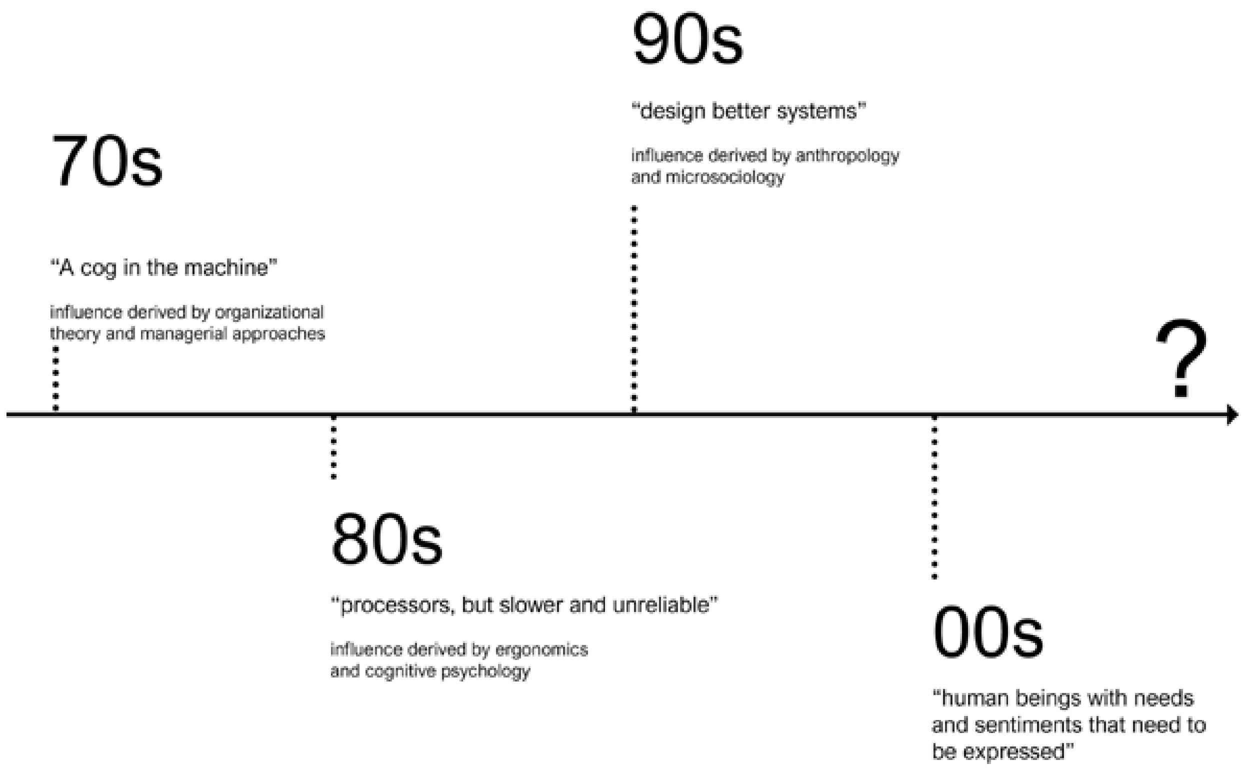


Figure 23
Evolution of Users in Informational Technology

devices and applications and use them in ways that are often unanticipated….. We call those who adopt this new approach ‘next generation users’. In contrast, first generation users remain anchored to one or more personal computers in the household or workplace for accessing the Internet. The analysis shows how this emerging pattern of access is reshaping the use and impact of the Internet, such as in supporting the production of user generated content. The analysis also shows how next generation access is socially distributed; creating a new digital divide that reinforces socioeconomic inequalities.

Technology affects the ways in which we think, learn and interact, thus it changes the form of common social practices, both in terms of daily living, social interactions, shopping, traveling, working, marketing our businesses, and finding mates. Through the use of portable devices such as laptops, tablets, and smartphones, we can work from home, at a café, in an airplane or train, or even at the beach, thanks to the nearly ubiquitous wi-fi, and cloud access through multiple devices. Most people under 40 today cannot imagine life without portable smart devices. Those who have integrated smart devices into their work/home lives are defined as Next Generation Users (NGUs) and are “more likely than first-generation users to go to the Internet first for all kinds of information” (Dutton and Blank, 2011, 2014, p.35) (Calzada, 2015). They are also familiar with and comfortable meeting strangers on the internet, ‘friends’ who they may never meet physically. This social change is based on the premise of quick and direct technology appropriation, which has become more intuitive and effortless. It was only 30 years ago that most computer operating systems, and consequently consumers, switched from MS-DOS (Microsoft Disk Operating System), which was the main operating system for IBM PC compatible personal computers during the 1980s, from which point it was gradually superseded by operating systems offering a graphical user interface (GUI), in various generations of the graphical Microsoft Windows operating system. At that time, user manuals were crucial for technology appropriation. Nowadays, instead of using manuals and needing extensive knowledge to use new technology, most functions are automated and require minimum user effort, such as pressing the on/off button or connecting a device to the internet. Home assistants, such as Alexa, Google Home and Siri facilitate everyday needs by responding to users’ voice commands.

Dutton and Blank (2014) study the social implications of the evolutionary pattern of access to Internet via a) Technical Rationality: they argue that since the emergence of closed applications

Table 2. Configuring and appropriating concepts of cleanliness

Cleanliness and the shower	Configuring the user	Domestication and appropriation
Macro—socio-technical landscape		
Social acceptability, models and thresholds of 'normality' relating to the frequency and form of washing	Social, moral and medical norms	Social order is reproduced through daily practice
Meso—socio-technical regimes		
Conventions and technologies of the bathroom, for example theories of germs and hygiene or developments of style, décor and infrastructure	The bather's body is defined by the bathroom, the suites of technology it contains, and the habits and routines inscribed in them Boundaries of dirt, smell, danger and disease, etc. are reproduced in this context	The same technologies (e.g. the bath or the shower) can be used for different 'purposes': for relaxation, for hygiene, for waking up The shower's script appears to be relatively open. However, it is less open when understood in relation to the logic of the bathroom as a whole
Micro—novelty and innovation		
Inventing new shower technologies, baths, and bathroom designs	Devices offer contrasting experiences: invigorating showers, whirlpool baths, etc. each positions the user in a certain way	Individual habits vary within accepted social limits: people develop their own routines and meanings

Table 3
Users as shapers of their environment: the case of water increase in the UK
Shove, E. (2003) 'User, Technologies and Expectations of Comfort, Cleanliness and Convenience', Innovation: The European Journal of Social Sciences, 16:2, pp. 193 – 206.

that restrict users from writing code, thus rendering users less sophisticated throughout time; b) Domestication: the process of adopting and integrating technologies into everyday routines in ways that follow and reinforce existing practices, and (c) Reconfiguring Access: in the process of technology appropriation and object domestication, users often reinvent objects and technologies, employing them in ways not expected by their developers. This notion is related to the user innovation theory (von Hippel, 2011) further discussed in the following section.

NGUs are defined as “people who access the Internet from multiple locations and devices, using wireless connection” (Dutton and Blank, 2014, p. 1). Moreover, according to these authors, the introduction of the Wi-fi connection to the public in the early 2000s is the main difference between First Generation Users and NGUs. NGUs have three distinctive characteristics: 1) they find that the internet is an experience technology (Dutton & Shepherd, 2006) and are more likely to invest in new technologies, 2) their attitudes represent the common point of view for people who are using the Internet, and 3) they project a variated ‘personal data comfort’ that is influenced by their willingness to reveal personal data over the Internet.

Future Users

In 2001, Kuutti identified three concepts of the user that could have been applied but were not; for different reasons have been underappreciated and neglected. I present Kuutti’s three user concepts to highlight how the late technological evolution acts as an enabler of new user qualities:

- Users as shapers of their environment
- Users as learners
- Users as becoming something else by using an internet connected device or system

Users as Shapers of Their Environment

Almost two decades ago, Kuutti (2001) argued that “the user’s active, transformative existence in the material world has still got less notice”. Users undoubtedly shape their environments. In fact, the social relationship between users and technology hinges on two premises. Firstly, users are deeply influenced by this social environment. “Their actions are to some extent scripted by” (Latour, 1992, Shove, 2003) the technologies with which they interact. Secondly, users clearly influence the evolution of technologies by changing their living and purchasing patterns and discovering new ways of interaction and participation.

As for the first premise this user technology–user path constitutes a feedback loop. Firstly, technologies influence how people do things, as well as the outcome of these activities. Then, people acquire access to information, services and technologies, and even to themselves, by being able to read and understand their living patterns. For example, the screen time, developed in the Mac OS allows users to track their screen time. Finally, users find new ways to figure out new ways to access to technologies and often reinvent technologies by redeploying them in ways not intended by their developers. “The ability of the Internet to reconfigure access can be used to reinforce existing social arrangements.… Like helping friends stay in touch, helping people meet new people etc. From this perspective, technology does not simply fit into existing practices, but it changes them” (Graham & Dutton, 2013 /p. 39). Dourish argues that social media, which includes thousands of sites for social interaction, are places where behaviors emerge; he coins the term ‘ecologies of participation’ to describe the diverse, collective uptake of different media concurrently (Dourish et al., 2011). Countless examples prove that users constantly contribute to technological change. This phenomenon happens in two ways: the first is bound to the evolution of living patterns at a micro-scale; the second relates to the reinvention of social practices by users, and has a ripple effect across societies that transcend geographic borders.

At the micro-scale, the phenomenon of technological evolution as a response to current living patterns was observed even before the entrance of Web 2.0. Shove (2003) describes the example of how Herrington predicted the radical increase in water consumption between 1991–2021 in the UK, due to the combination of the radical (Shove, decline in the use of the bath and the increase in the everyday use of the shower. This prediction was accurate due to the accurate grasp of technology appropriation, which occurred through detailed empirical studies. This also proves the constant feedback loop between users and technology: the future is shaped by the parallel evolution of technology and conventions of practice, which in turn are based on the level of appropriation by users.

The emergence of wireless connectivity catalyzed this phenomenon, enabling the non-intrusive integration of the technology layer into material spatiality. Wireless sensors can be installed anytime in static space and can instantly connect with users. Users obtain and offer knowledge from an external layer that is ubiquitously connected and constantly updated. In the post-IoT era, people are familiar with living in digital space. Calm technology (i.e., technology that operates in the periphery vs. the center of users' attention) ¬¬has facilitated the subtle background placement of applications and sensing technologies. The miniaturization of devices and sensors facilitates their seamless space integration. Calm technology is combined with connectivity promoted by speed, as 3G, 4G and 5G connectivity.

5G's shorter wavelengths mean that signals will not be able to cover long distances and will be more easily blocked by physical objects. So instead of relying on mobile phone masts, 5G necessitates the installation of 10 to 100 times more antenna locations than 4G or 3G in the form of small cell devices… these are critical not only for delivering the speed and capacity promised by this next generation of wireless, but also for supporting the increased number of devices that will be connected to the network in the future. (Dalrymple, 2019, The Government)

As such, technology has advanced to such an extent, that users are enabled technically and socially to shape their environment.

Users as learners

People are constantly being educated on processing and assimilating data. Users are continually being familiarized with "the IoT by their experience of smart consumer products, and made subjects of the IoT in different contexts such as work and home" (Griffiths, 2016). Big data is defined as "extremely large data sets that may be analyzed computationally to reveal patterns, trends, and associations, especially relating to human behavior and interactions" (Oxford Dictionary, 2019). They reveal significant information about people, spaces, processes and connections. Data awareness emerges from the interaction of users with the system that occurs at the micro-scale of everyday life, where users realize of the impact that IoT has on them. Understanding the data impact opens up new horizons in developing behavioral 'intelligence' at a personal level.

Users as becoming something else by using a device or a system

Within the context of data-driven systems, built space can be monitored in real-time; user actions within and beyond buildings leave electronic memories and "digital breadcrumbs" (Winsborough, 2017) in the cloud. We can argue that today, each one of us has a digital twin acting as our digital mirror—our computerized replica that keeps track of all behaviors, emotions and preferences.

> A digital twin is a digital representation of a real-world entity or system. The implementation of a digital twin is an encapsulated software object or model that mirrors a unique physical object, process, organization, person or other abstraction. Data from multiple digital twins can be aggregated for a composite view across a number of real-world entities, such as a power plant or a city, and their related processes. (Gartner, 2019, paragraph 1).

At the building level, how does this apply to future smart contexts? Ken Sinclair (2018) describes the term building emotion, when discussing the creation of an emotional interactive relationship with the inhabitants and the physical building.

> "Emotion" is the noun used to describe the creation and depiction of a mindful interactive relationship that conveys the conversation between the inhabitants and their physical building. It is a virtual identity, a feeling, a learning, an interactive piece, a virtual brick, and mortar that hosts the buildings' emotion. Emotion is a natural instinctive state of mind deriving from one's circumstances, mood, or relationships with their environment, which is the combined purpose of the building and its inhabitance. The Building Emotion would likely be hosted in the cloud with interaction from the edge devices and needs to be available to every building to create its own emotional personality (2018b, section 2).

Users and data

What kind of user data can we acquire through existing technologies and what kind of insight does each strand of information offer?

Data of users

The smart ecosystem offers a twofold advantage: it satisfies users' needs in the built environment (e.g., thermal comfort, control, 'set and forget' functions, etc.) by establishing a dynamic relationship between users and the built space; it also gathers users' digital footprints that contribute to the offline mapping of user behavior. "With significant data on the actual use of the space, we can perform new types of post-occupancy evaluations, often overlooked in the practice of urban design and architecture" (Brand, 1995, cited in Offenhuber). According to Geertz (cited in Loukissas, 2019) "Across the domains of science, cultural history, journalism, and real estate, data constrain how people interact with subjects of their interest, whether they are plants, books, news stories or properties".

Four categories of user data are identified in the literature based on user willingness to reveal data, their structure, their connectivity status and their 'factor of objectivity'. Specifically, user data can be classified as:

Active/Passive: meaning voluntary/involuntary data; voluntary: data that users are aware of generating and involuntary, passive data that is primarily extracted from applications and social platforms without users' awareness.

Online/Offline: Online and offline data are dependent on user connectivity status. Online data is involuntary and is collected when users connect to social media, use their smartphones, etc. whereby they leave their digital traces online. Offline data refers to voluntary data accumulated through targeted interviews and questionnaires on user experience (further discussed in the next chapter).

Objective/Subjective: User location, occupancy and energy consumption are examples of objective data, while user perception and sense of orientation are subjective data.

Quantitative/Qualitative:

In fact, online, quantitative, passive data are easier to acquire than qualitative data, which is harder to obtain, leaving us with a dearth of the latter, voluntary and involuntary offline data. Scientists intend to bridge this gap by developing algorithms that turn raw data into valuable information. For example, by aggregating location data combined with the time parameter, we can extract user flows within a space. Similarly, by overlapping energy consumption with occupancy, we can extract user living and working patterns.

Users as data

The outcome of user-related information depends on user–system interaction, knowledge and user willingness to reveal personal data in digital space. By studying users, we can see that human capital contributes to knowledge in multiple levels, ranging from simple data generation to user innovation. Poblet et al. (2017) distinguished four different levels of user contributions in the case of disaster management. Poblet's pyramid of anthropocentric data is extrapolated to four ubiquitous levels that encompass human capital. The first two levels, crowd as sensors and crowd as social computers, leverage the phenomenon of passive, involuntary data generation by online human activity. The second two levels, crowd as reporters and crowd as micro-taskers encompass active, voluntary user activity and require an additional level of knowledge and motivation, i.e. at the crowd as reporters level, users have to spend time and have basic knowledge of the smart system to make the report.

Crowd as sensors: The emergence of the smartphone as an adept tool that users keep near or on them while at home and outside the home, offers constant tracking of user location and building occupancy. The smartphone has not only radically changed the status of human communication, but also acts as a multi-sensor node with embedded internal sensors, such as GPS, accelerometers, gyroscope and magnetometer. Location-tracking data collection processes are mostly based on this phenomenon (as is further discussed in the second case study in Chapter 4).

Crowd as social computers: In the post-social era (starting around 2008), users generate data by

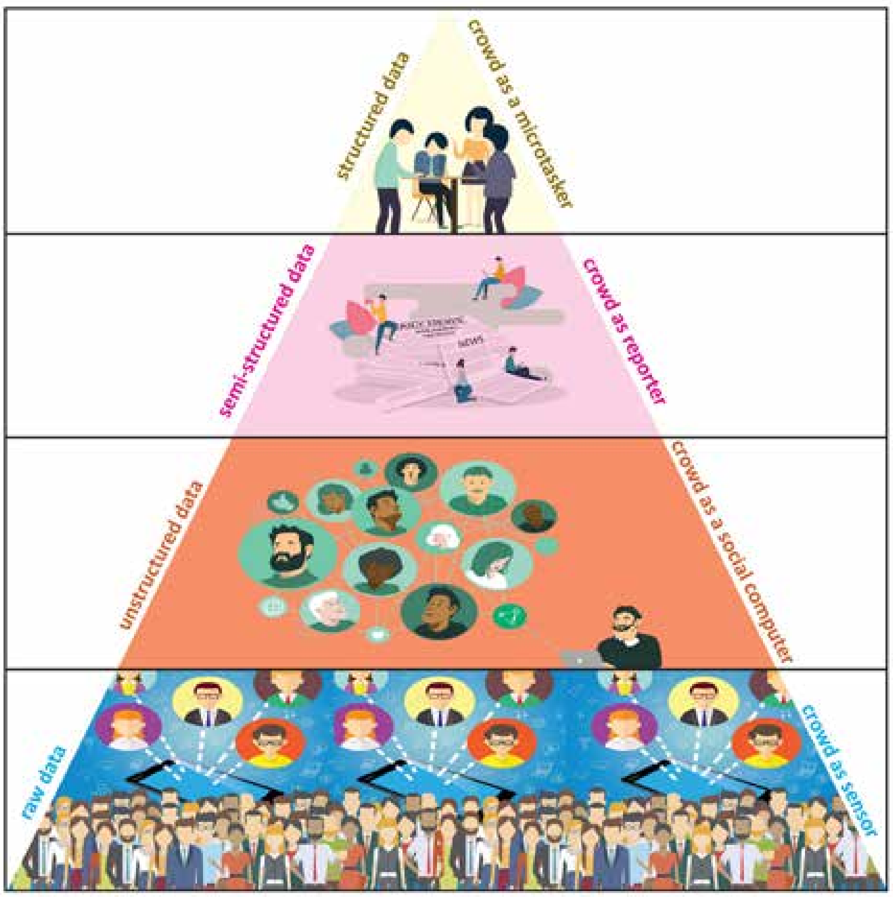


Figure 24
Users as Data in Disaster Management (redesigned)
Poblet, M., Garcia-Cuesta, E., Casanovas, P. (2017) Crowdsourcing roles, methods and tolos for data-intensive disaster management. Inf. Syst. Front, 1-17.

using applications such as social media (e.g., Facebook, SnapChat, WeChat, TikTok, Instagram). The added value of this kind of data is that it includes more social qualitative content about the places that people inhabit, the products they use, their ages and friends' ages, their thoughts and feelings on social and political issues, and their employment. Facebook and Instagram are full of users' feelings and intimate aspects of their lives. The indirect consequence of this phenomenon is the massive passive involuntary generation of big data on millions of users across the globe including user data flows, and patterns of behavior and connectivity percentages without actively involving users.

The crowd as reporter: During important events, both positive or negative, users are asked by the system to generate information on their current status. For example, during terrorist attacks, Facebook asks users to mark themselves as safe or unsafe. In that case, individuals are aware that their data are being recorded and they voluntarily release this information. Poblet et al. also refer to hashtags representing user actions as supplementary semantic information promoted to facilitate data analysis.

Crowd as micro-taskers: Users are asked to perform specific tasks that either complement the system, such as adding human-generated information on a map or contribute to the machine-learning algorithm. Users participate with a voluntary objective and subjective information.

Users and Innovation

One can argue that the first two categories – crowd as sensors and crowd as social computers encompass user data, while the latter two include user-generated information. What happens when users are not fully satisfied with the available products? Yet, there are enough cases where users are product producers and not testers. For example Dropbox founder Drew Houston conceived the Dropbox concept after repeatedly forgetting his USB flash drive while he was a student at MIT. Although there is consensus that systems are designed for users, it is observed that, in some cases, systems or system attributes are designed by users in an unusually informal way, which is discussed below. In that condition, users enter the circle of innovation. Having gained significant momentum in the economic field globally, the process of innovation is extremely complex and has been conceived as an ‘open process’ platform in the sense that “all information related to the innovation is a public good — non-rivalrous and nonexcludable” (Baldwin, 2011). A small percentage of users have entered the innovation process hoping to reshape existing technologies into tools that satisfy their needs. This process is called User Innovation and is further explored below.

History of User Innovation

In 1998, Etzkowitz and Leudesdorff stated that innovation is the result of interaction between three factors: academia, government and firms. “A ‘triple helix’ of academic-industry-government relations is likely to be a key component of any national or multi-national innovation strategy in the late twentieth century” (Etzkowitz et al., 1998). During the following years, the notion of ‘user’ or ‘human capital’ was introduced through the formulation of the ‘Quadruple Helix Model’ (Carayiannis and Campbell, 2009). While there was a common consensus about the lack of human capital as a leverage of innovation, there were various contradicting approaches on how to incorporate the fourth innovation factor. Several attempts have been made in order to reshape the Quadruple Helix (QH) Model and establish a concrete model. The QH model was new in innovation and not widely used in practice or in research and was nearly nonexistent in innovation policy (Arnkil et al., 2010). Carayiannis et al. introduced the quadruple and subsequently the quintuple helix of innovation. What is common in all models after the triple helix of innovation, however, is the human factor as prerequisite for innovation creation.

The correlation between users and innovation was introduced by von Hippel in 1976. In his article, “The Dominant Role of Users in the Scientific Instrument Innovation Process,” von Hippel presented the study of 111 scientific instrument innovations and proved that approximately 80% of them “were in fact invented, prototyped and first field-tested by users of the instrument rather than by an instrument of the manufacturer” (von Hippel, 1976). He questioned the traditional innovation process, where the manufacturer tries to identify what the customer (user) wants, by collecting information, which is scattered and sparse. Then, “the customer tries the product, finds flaws and requests corrections” (Thomke & von Hippel, 2002). The final product is the result of various iterations between the user and the producer. In this innovation process, two issues are identified: first, the final product is an outcome of scattered user information and does not fully respond to users' needs; secondly, the iterations between user and producer are time-consuming, thus extending the time until the final product is set.

Based on that study, von Hippel and Thomke (2002) coined the term user innovation, which describes a democratized innovation led by users. More than defining a new theory, user innovation tends to be based on an observation and empirical research of a shift that represents a correlation between facts and emerging theories. What is interesting, here, is the criteria that Hippel used to distinguish users from manufacturers. Users are firms or individual consumers that expect to benefit from using a product or a service, while manufacturers expect to benefit from selling a product or a service. In that context, a company can act as both a manufacturer and/or a user, depending on its relation to the product. This classification of users is fundamental for the democratization of innovation in two ways: users benefit directly from the innovations; moreover, as the innovation does not enter immediately in the profit loop, users are eager to share their innovation with other users, thus creating an open feedback loop. This 'open innovation', according to von Hippel, refers to open information commons, free shared knowledge bases, usually online, [however a brick and mortar library can also be considered an open information commons because they offer 'free information' to the public grounded in the belief that free and freely exchanged information can serve as a public good and serves to democratize information.

User-centric open innovation can be perceived as another leap forward in the democratization of information. There is also a clear analogy between the informational shift that occurred during the 1980s, at the time that proprietary and protected protocols were replaced by open protocols. That shift acted as the information superhighway for communication, while the current shift acts as an accelerator for creative thinking and "reveals an unprecedented social efficiency" (von Hippel, 2005).

What is also interesting in von Hippel's User Innovation analysis is the expansion of the term innovation, to include technological disruption. In that context, technique innovation is differentiated from equipment innovation, in that most user innovations "are based on existing, unmodified equipment", and focus on hardware or software creation. According to von Hippel (2001) empirical studies suggest that 10% to 40% of users engage in developing or modifying products.

Lead Users

In the framework of User Innovation theory, users who innovate represent a small percentage of the user population, called Lead Users. 'Lead Users' are members of a user population with two distinct characteristics: 1) They are at the leading edge of an important market trend(s), and face these needs ahead of many users; 2) They anticipate relatively high benefits from obtaining a solution to their needs (i.e., an innovation), and so may innovate (von Hippel, 2005). Churchill et al. (2009) make a clear distinction between lead users and 'early adopters'; the latter are among the first users to purchase an existing product or service, highlighting the distinct feature of user innovation: users innovate because they face a need for products or services that do not yet exist on the market.

The observation of users involved in innovation enables the identification of information that is difficult—in terms of cost or methodology—to acquire, transfer and use. This kind of information is called 'sticky information' and the level of difficulty in transferring it is called 'information stickiness' (von Hippel, 1994). According to von Hippel, the factors that add stickiness to information are associated with the nature of the information itself, the amount of information that must be transferred, and the attributes of people engaged in this process. Firstly, the information transferred is, in most cases, tacit by nature. von Hippel highlights two distinct characteristics of technological information: first, "even in modern industries, the indefinable knowledge is still an essential part of technology" (Polanyi cited in von Hippel, 1994); second, technological phenomena create both specific and general knowledge. While the latter is easy to transfer, specific knowledge is often restricted from the innovation exchange, as it is often difficult to acquire. Information can also get sticky when it consists of immense amounts of information bits that contain different variables. Lastly, information stickiness is directly related to human skills in terms of acquiring and using the new knowledge. Given that innovation intersects various fields, lead users are not always familiar with the technological skills required to acquire knowledge. For example, an architect using a

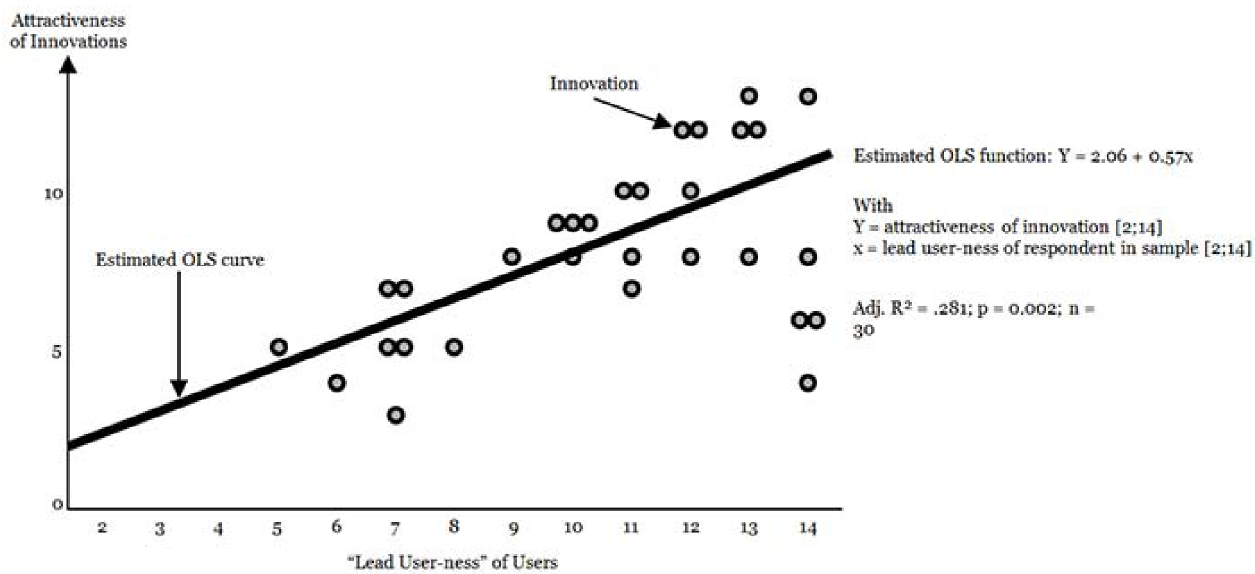


Figure 25
Lead User - ness of users (Von Hippel, 2005)

design software might know what commands are needed to create a design, but not understand how to use the programming software required to change the commands. In this example, sticky information is the consequence of lack of a common interdisciplinary language. This lack is also obvious in the communication between users and experts for two more reasons: first, the iteration between users and experts happens once or twice, not long enough for users to fully evaluate a product, and second, experts tend to conceive ideas in terms of context based on their own knowledge, perspective and experience.

User Innovation Toolkits

How do users innovate? Do they have any special skill or do their needs lead them to do so? After all, "necessity is the mother of invention." von Hippel suggests methods for equipping users with tools to carry out need-related product development tasks (von Hippel et al., 2002). In user innovation done in cooperation with manufacturers, users "actually abandon their increasingly frustrating efforts to understand users' needs … and they outsource key need-related innovation tasks to the users" and give the users innovation toolkits that contain sets of user-friendly design tools that help users to innovate new product for themselves. These toolkits are "specific to the design challenges of a specific field or sub field, such as integrated circuit design or software product design. Within their fields of use", enabling "them to develop producible custom products via iterative trial-and-error." (Von Hipper and Katz, 2002). In essence users create a preliminary design, simulate it, evaluate, and then iteratively improve it until satisfied. Manufacturers who engage in this assume that since users know precisely what they want, they can more readily achieve it than the manufacturers' themselves. In fact, toolkits provide a common ground while allowing for a task repartition that enables users to transfer knowledge easily. von Hippel uses the example of pizza to illustrate his argument: in the process of pizza recipes, the ingredients of the dough and the sauce are considered as standard and user can only alter the design of toppings; in this case, users are not confused by ideating in two or three levels, as an expert would do, but concentrate

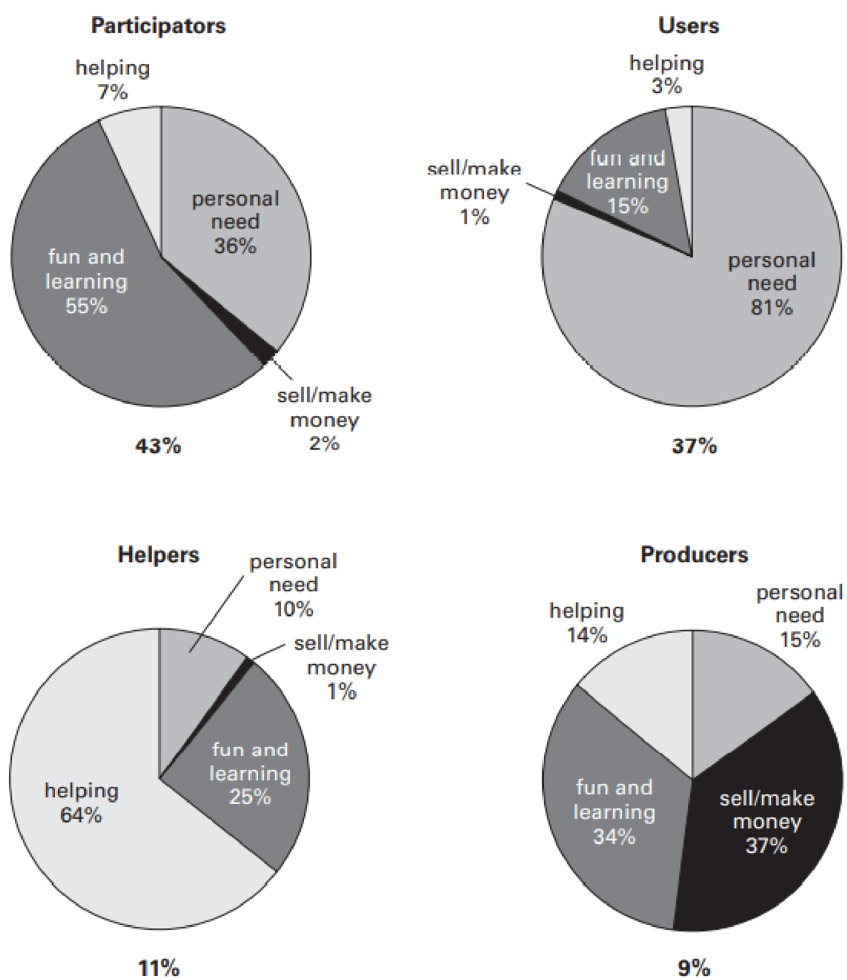


Figure 26
Evidence of Free Innovation (Von Hippel, 2017)

on innovating in one aspect of the pizza design. Toolkits for User Innovation should have the following attributes: 1) they should allow for trial-and-error cycles though simulation to allow test and evaluation of their designs; 2) they should provide user-designers with a solution space, capable of providing new designs; 3) they should bridge the gap created by the lack of common language between the disciplines by providing user-friendly toolkits that enable users to design in a common language; 4) they should include libraries with pre-designed custom elements to facilitate the design process; and 5) they must be able to communicate the design in the users' language and translate it to the language of designers who will execute the design. These toolkits allow for maximum user freedom and ensure the optimal design process.

Smart or smartified users?

The integration of multiple agents in this new kind of interaction such as objects, spatial elements and devices increases the complexity of the environment. “In the same way that the Internet expanded interaction among people from one-to-one and one-to-many to many-to-many, the IoT expands interaction between people and products to include much more complex interactions between people and products and newly possible interactions among products” (Hoffman & Novak, 2015). This phenomenon triggered the human impact to system-space interaction, which grew exponentially with the help of the smartphone. The transition of IoT to wider networks, such as the Web of Things (WoT) and the Internet of Everything (IoE) creates the notion of multi-agent interaction and encompasses humans as an interactive component of the smart environment. “IoE brings together people, process, data and things to add greater depth and relevance to network interactions, which uses that information to drive new opportunities and efficiencies—an ecology of smart devices, working together” (Babar, 2016, paragraph 2). However, there is still a lot of criticism on the anthropocentric direction of the IoE beyond its definition. “Although people are listed as part of the IoE equation, this does not necessarily mean that IoE is following a human–people–citizen-centered design approach” (Streitz, 2019).

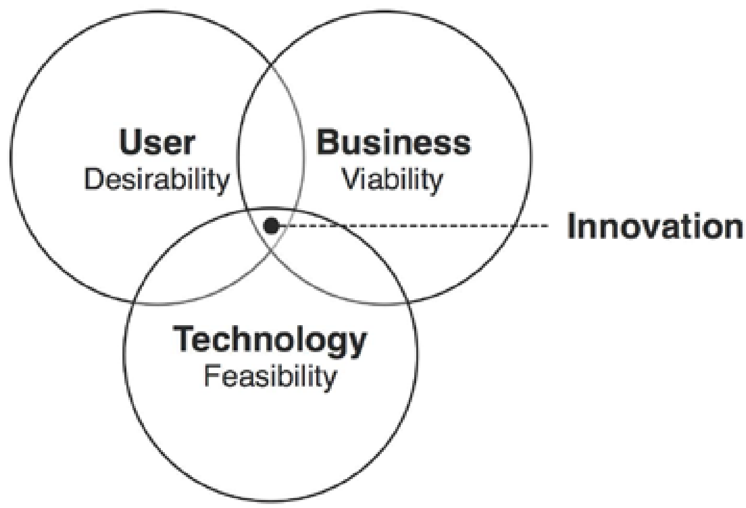


Figure 27
Criteria for Successful Innovation (Brown, cited in Mueller and Thoring, 2012)

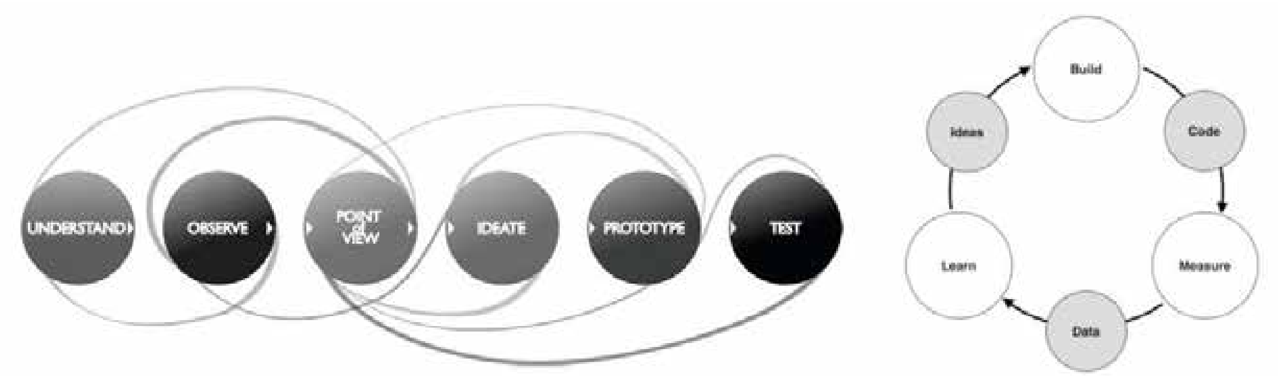


Figure 28
Design Thinking vs. Lean Startup (Mueller, R., Thoring, K., 2012)

Technological Appropriation by users

At this point, I would like to address a number of misconceptions about ‘people smartness’ and discuss the substantial difference between the notion of smart people and technological appropriation by users.

First, the concept of a ‘smart environment’ is often confused with that of smart people, as it has been widely implied as a condition where people interacting with systems become smart. This concept is commonly known as the Smart People concept: Smart People is also a popular concept with commentators who suggest that smart technologies can help integrate the social and human capital within a city (Allam, 2018). We label people living in the city or using its facilities as ‘smart’ in that they own portable devices connecting with existing ICT networks. This contradicts the fact that 43% of Europeans still lack basic digital skills and 28% of European internet users still have no software-related skills (DESI, 2019). In fact, people in smart environments have direct access to communication and knowledge through connectivity, thus are converted into active participants in the smart environment.

The second common misconception is that ubiquitous environments increase people’s smartness. While in most cases, people become accustomed to new technologies that appear useful, to argue that human abilities to promote and improve smart environments are conjured up by technology is unjustifiable. “By transliterating from a person to a city, we can state that a smart city is a city where the human capital, (and more in general each individual/citizen) owns not only a high level of skills (possibly innovative ones), but is also strongly motivated by continuous and adequate challenges, while her/his needs are reasonably satisfied” (Giovanella, 2014, p. 83). However, this definition seems idealistic and cannot be holistically extrapolated to smart built spaces, in the sense that within the majority of current smart contexts, users are familiar with technology and capable of following specific digital processes to satisfy their needs. Yet, this knowledge cannot be considered a high-level skill. While it is evident that smart technologies connect users and space in a clear and more direct way, it is unwise to speculate that having access to these systems renders users ‘smart’.

Yet the multitude of interactions emerging in smart environments heavily depends on user smartness and opens up new horizons in deciphering the social layer of built space. The common denominator of smart environments is that users receive bits of information through the digital world and process this data. Powell (1990) argues that “the value of information depends on the human ability to interpret it” . Through their interaction with smart systems, users obtain novel qualities, which that are further discussed in the third chapter. All users contribute to data generation, while knowledge is enriched by just a small percentage of users. Finally, a small portion of users can combine knowledge and experience with technological expertise to produce innovation.

Users in the Product Design Innovation Process

How can users actively contribute to the innovation process? What is the optimal moment in the process when they can share their knowledge? User-centered approaches have been framed to create innovative design and business concepts by involving customers, potential users or other stakeholders in the development process (Mueller, 2012).

There are two basic innovation processes, Lean Startup (Ries, 2011) and Design Thinking. Lean Startup requires ‘customer development’ parallel to ‘product development’ to find and understand customers (Mueller, 2012). It uses the build–measure–learn feedback loop and establishes the Minimum Viable Product (MVP), a minimal subset of the product, and its features needed to run in a specific experiment and collect data, so that users can proceed to the next step of learning (Nikolova, 2017). In fact, the Lean Startup model builds a basic, though primitive, in terms of elaboration, product and then tries to get continuous user (customer) feedback that can be measured before learning the optimal way to move to the next step of development.

Design Thinking follows a different feedback loop; while it also focuses on users in the innovation process, it uses a five-step feedback loop—empathize, define, ideate, prototype, and test—where the iteration follows a nonlinear path. Specifically, the iteration between understanding and observing user needs takes place until the user’s Point of View is well defined and provides an efficient and accurate solution to user needs. Once the POV is defined, the ideation, prototyping and testing follow a linear path. The iteration cycles many times through the three final steps (ideate, prototype, test) but does not affect the steps beyond the definition of POV.

Brown establishes three criteria for successful innovations. An idea must be desirable, feasible and viable (Brown, 2009). Desirability is associated with the users' preferences, feasibility is connected with the existing technology or its advancement and viability with the business model.

Mueller and Thoring compare the two user-centric approaches and extract their fundamental similarities and differences (Mueller & Thoring, 2012). While both are based on user feedback, the Lean Startup approach uses the 'fail fast and try again' concept, while design thinking focuses on the 'fail early to succeed sooner' concept. User research plays an important role in design thinking and is extensively used in the synthesis and ideation steps. On the other hand, lean startup is based on business ideas and does not include any qualitative user research, that is, who the users are, what their needs are. Lean Startup integrates users in the 'measure' step, by classifying them into 'users', 'influencers' 'decision makers', among others. Collectively, these two processes outline a critical role for user involvement in the innovation process using different ways. Mueller and Thoring (2012) merge the two methodologies to create Lean Design Thinking, an approach that integrates user research at the beginning of the process and testing is used only at the end of the process.

User Experience Research

Understanding how users perceive and react within the smart ecosystem is crucial for the creation and improvement of the interactive experience. Towards this end, recent developments in the field of Human–Computer Interaction have led to an increased interest in engaging users as much as possible. To cover this need, computer scientists have created a multifaceted umbrella term, 'user experience'. IDF coined the term 'ser experience' (UX) design, which is "the process of creating products that provide meaningful and relevant experiences to users. This involves the careful design of both a product's usability and the pleasure consumers will derive from using it' (IDF, 2017). User experience can be seen as a more holistic approach to usability, encompassing the notion of creating a positive experience for users by tweaking experiential factors. UX consists of three interrelated entities: user, product and interaction. In order to measure UX in Human–Computer–Interaction, scientists conducted user research, a field of study that has been proved to be indispensable in the design of computer-based systems, as well as in product design. For example, user research prompted Samsung to change its TV design strategy to focus on making more minimalistic designs that fit into the customer's homes by conceiving the product as a piece of furniture more than an object to use for its technical capabilities (Mortensen, 2019). The ultimate objective of user research is for developers and designers including users is to understand the users and their needs and preferences, and to illustrate and design what users say, think, do and feel. This, in UX terms, is defined as an 'Empathy Map' (Gibbons, 2018).

The complexity of understanding users

Forlizzi and Battarbee (2015) underscore that understanding UX is a complex process while "designing the UX for interactive systems is even more complex" (Forlizzi and Battarbee (2015) cited in Hellweger, 2015) while "designing the UX for interactive systems is even more complex" (Hellweger, 2015). Specifically, Hellweger investigated how user experience is viewed and perceived in practice by qualitatively analyzing 173 blog entries and demonstrated that, while interaction and product are the most discussed issues, the user dimension receives the least attention (Hellweger, 2015).

At a human level, user experience as a field of research provides a framework to understand how users behave, either through their actions or their intentions. UX is the vehicle to bypass cognitive biases and understand user actions and needs beyond the surface. In fact, user needs are divided into instrumental and non-instrumental (Mahlke, 2007). The instrumental (utilitarian, functional or pragmatic) are related to the use of space; that is, users need to sleep at home, or sit at a desk in the office, or work-out in a gym, or learn and teach in a wired classroom. The non-instrumental (or hedonic) are associated with the pleasure, enjoyment, fun or non-task related activities. Related mechanisms have been developed aimed to identify, classify, evaluate and link user needs with user actions. Borrowing terms from the field of psychology, what users say and do depicts user behavior, while what they think and feel belong to their intent. Psychologists have extensively studied the relationship between behavior and intent. In fact, "numerous correlational studies indicate that intentions predict behavior" (Sheeran, 2016). The gap between intention and behavior has received considerable critical attention not only by psychologists, but also economists, leading to the establishment of the field of Behavioral Economics. Ariely (2008) has extensively analyzed on the so-called ‘intention-action gap’; while his work explores user behavior in an economics context, his findings and insights make an important contribution to user research on behavioral aspects of the average user. At a macroscale, Ariely’s experiments are critical for in-depth user behavioral assessment of users as they “slow human behavior to a frame-to-frame narration of events, isolate human forces, and examine those forces in more detail” (Ariely, 2008). At a microscale level, Ariely (2008) tests human behavior in relation to a number of factors that silently affect behavioral expressions. Among these factors, the ones that correlate with, and subsequently could provide further insights into user behavior in the built environment, are relativity, dynamics of imitation, distraction, expectation and lack of honesty.

Relativity is the force that affects the comparison mechanism, which directly influences human decisions. For example, in order to buy a product, users tend to compare it with a similar one and rate it according to certain personal criteria. Ariely’s study (2008) focuses on the decoy effect, demonstrating the paradox of a user’s choice when establishing a third option between two pre-existing options, steering the user’s attention towards the target option. The dynamics of imitation relate to what behavioral economists have established and called ‘behavioral herding’, a phenomenon here people tend to shape their attitude based on other people’s previous behavior, or even on their previous own behavior (self-herding). This observation advances our knowledge about happiness and satisfaction. In fact, according to a related study, “the probability of an individual’s self-rated happiness increased by 25% if a friend living within a mile became happy” (Fowler et al. in Kameda et al., 2015). Apparently, users’ social environment influences their behavior as well.

While Ariely investigates the oxymoron of human behavior, Barki and Hartwick (1994) highlight the difference between user participation and user involvement in a system. In fact, they suggest that the key differentiator between the two terms is the subjective psychological state of the user that prompts involvement in acting within a system. On the other hand, user participation is linked to expressions ranging from direct or indirect interactions, formal or informal expressions, performed alone or shared (Barki, 1994). These two constructs hold the same meaning in the information systems field and have been confused with user attitudes, measured using a procedure that identifies an individual's position on a bipolar affective or evaluative dimension (e.g., bad/good) (Fishbein et al. in ibid,). It can thus be suggested that user participation refers to the action, user involvement, is reflected by a psychological condition that existed before participation and user attitude relates to the individual's judgement of a situation.

Designing through User Experience

According to user experience researchers, there are various ways to assess user experience, such as 1:1 interviews, focus groups, surveys, usability tests, A/B tests (where a group of users is split into different audiences), analytics, customer feedback, diary studies and so on. The main parameter that needs to be tested in the framework of this research is user engagement. According to Attfield et al. (2020), some primary factors that positively affect user engagement are focused attention, positive affect, aesthetics, endurability, novelty, richness and control, reputation trust, expectations about the environment and user context.

Given that user experience research bridges various disciplines such as computer science, psychology and product design, establishing a theoretical framework to enable communication between researchers and users and assess outcomes was necessary. The question is how are UX researchers integrating the knowledge derived by UX Research into their design?

Rogers et al. (2020) suggest framing UX research on three levels: the user level, application level, and system level. By unfolding the different interactions as interplay between the actors of the aforementioned three levels, designers can easily read the interdependencies and improve the design process.

What are the different types of interaction in smart systems? According to the conceptual framework of interactive design defined by Preece, Rogers and Sharp (2019), there are four models of interaction based on user-related activities that take place during the interaction:

Instructing: the user issues commands to the system

Conversing: the user asks the system questions

Manipulating and Navigation: users interact with virtual objects or the virtual environment

Exploring and Browsing: the system provides structured information about specific subjects

Pastel (2020) identified two more conceptual interactions:

Passive Instrumental: the system provides passive feedback on user actions

Passive informative: the system provides passive information to users.

User-centered Approaches in the Built Space

Interaction, Space and Place

Having explored strategies for designing based on user-centric, it is necessary to acquire techniques and extrapolate processes that can contribute to the design of interaction in the smart ecosystem. User experience research has a strong commonality with Human–Computer Interaction and Architectural Design: empathy. All three require empathy to build the strategy.

However, there is a major difference between user experience analysis and architectural design. The smart ecosystem is spatial, and by default related to place. Here, it is crucial to make a fundamental distinction between space and place in the context of the smart built environment. Harrison and Dourish (1996) state that “space is the opportunity; place is the understood reality” and identify four properties of space. The first is ‘relational orientation and reciprocity’, which relates to our common orientation to the physical world. The second property is ‘proximity and action’, which enables people to interact with objects closest to them and this reveals insights into their activities. For example, when people gather around a table, it becomes clear that they gather to participate in a certain activity. The third property is ‘partitioning’. In other words, a lack of proximity restricts activities and regulates the extent of interactions. The fourth property is ‘presence and awareness’, which reminds us that space includes not only objects such as artifacts, tools and representations of our work, but also our activity that structure our activity. Harrison and Dourish (1996) also argue that “Space is the structure of the world; it is the three-dimensional environment in which objects and events occur, and in which they have relative position and direction”.In other words, they explain, “we are located in space but we act in place; as such, ‘place’ is invested with understandings of behavioral appropriateness, cultural expectations and so forth” (Harrison & Dourish, 1996). Another important distinction between space and place is the social context, according to Harrison and Dourish, “the Place is in Space”; in other words, place transforms space socially and culturally, thus is part of it. Moreover, they define the place in terms of its social context and built space, suggesting that place derives from a tension between connectedness—the degree to which a place fits well with its surroundings—and its distinctiveness—the degree to which a place reinforces, or even defines, the pattern of its context (Harrison and Dourish, 1996). In that context, the impact of human presence and activity is crucial for turning a space into a place. Two processes help turn a space into place: adaptation and appropriation —or the way that people learn to interact in a place. These two processes emerge both in physical and in computational (or media) spaces, according to Harrison and Dourish (1996). Connectedness and distinctiveness are of extreme significance, as they manifest the difference between a digital environment and a digital spatial environment—a digital ecosystem.

Evaluation of Spatial Environments

In understanding the relationship between people and place, the first question that emerges is: at what stage of the architectural design process should the analysis be conducted? The cycle of the built environment entails planning, implementing and occupying buildings and the majority of existing research focuses on the evaluation of the building after it is populated by people (e.g., workers, families, visitors, students). Approaches such as the building performance evaluation theory and the process protocol research (Cooper et al., 2004) encompass top-down models that exclude the micro-perspective of the building user's experience. In contrast, are the bottom-up approaches that focus on evaluating the built environment based on user feedback, such as the post–occupancy evaluation (Zeisel, 2006; Zimmermann, 2010), and the participatory design andevidence-based design approach involving the users in the design process. The bottom-up approaches assume that human behavior is influenced by the built environment.

Based on social research, psychologist and architect Jacqueline Vischer (2004), argued that integrating human behavior into the pragmatic context of designing and constructing buildings is, by nature, a contradictory and complex process and should be located between environmental determinism and social constructivism. Borrowing elements from environmental psychology, environmental determinism is based on the premise that the physical environment influences users'

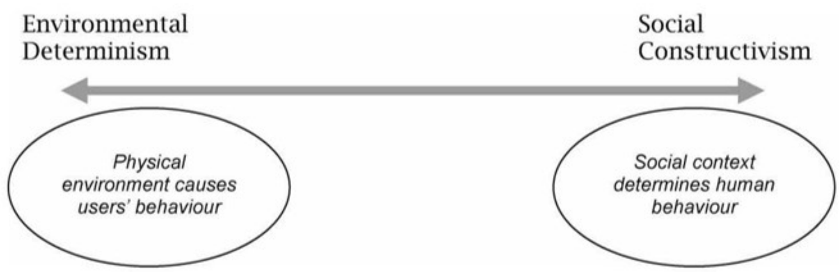


Figure 29
Environmental Determinism vs. Social Constructivism (Vischer, 2008)

behavior. A diametrical theory, social constructivism, is based on the view that human behavior is shaped by the social context. As such, behavior "results from learned social norms and patterns and is not influenced by the physical environmental context where it occurs" (Vischer, 2004) Bridging the gap between the two theories, Vischer (2004) concludes that "human behavior is influenced by the built environment in which it occurs — how could be otherwise? — but is not determined by it" Vischer introduces the theoretical framework of Building User Experience (BUX), which combines the user's perspective on the creation process and the outcome, which the user perceives as a product. This contributes to a better understanding of how the environment affects human behavior, how users act in their environments and thus influenced them, how these two influences redefine the user–building relationship (Vischer, 2004).

The extent to which the environment affects us is inconsistent and not measurable. Vischer (2004) concludes that the exact location of the theory of the built environment, which some assume lies between environmental determinism and social constructivism, cannot be readily extrapolated. However, the interesting part of environmental psychology is that it considers the context where users act, perceive and communicate as an important factor of human behavior. "It is a characteristic feature of environmental psychology that in any environmental transaction, attention should focus on the user of the environment as much as the environment itself" (Moser & Uzzell, 2003) Studies from the environmental psychology perspective assume that the physical characteristics of the environment, such as noise, pollution, the layout of physical space, vegetation and open space such as parks and playgrounds, along with social factors that affect human behavior. Psychologist Kurt Lewin's work in topological psychology (1973) was the first to show how the contextual environment affects users through a geometrical map of necessities, reasons and objectives. Lewin established three levels of representation: the physical environment of (e.g., the room, the house, the neighborhood), the social environment (social surroundings, place in society) and the psychological environment (individuals' anxieties, fears, deviations, fantasies).

According to Moser and Uzzell (2003), there are three perspectives on the relationship between users and their environment. The first is the deterministic and behaviorist approaches combined, which argue that the environment has a direct impact on individuals' perceptions, attitudes, and behavior; the second is the interactionist approach, which sees a two-way influence whereby the environment impacts users, who in turn respond by impacting the environment; and

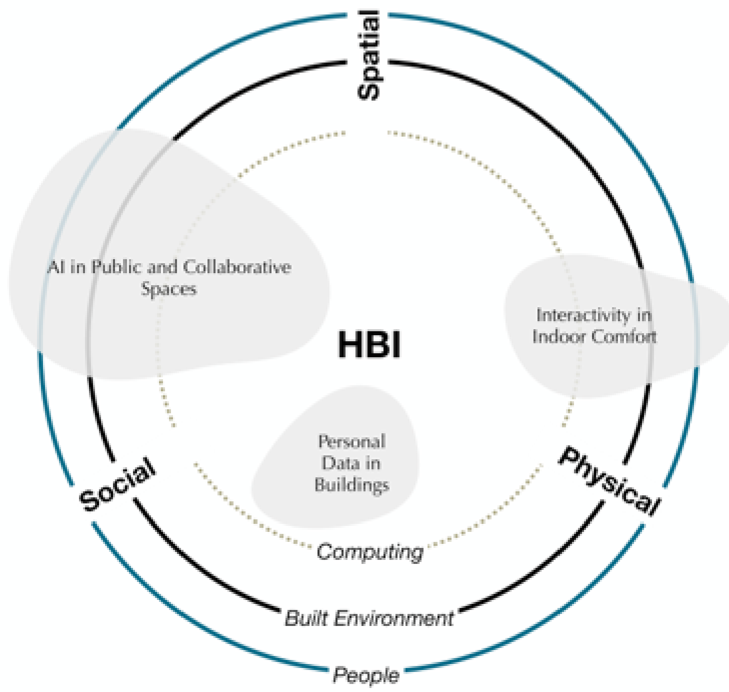


Figure 30
Human - Building Interaction

the third perspective, the transactional perspective, which views a continuous exchange and reciprocity between the individual and the environment, and the primarily active and intentional role of the individual acting on and in the environment (Bonnes and Secchiaroli, cited in Moser and Uzzell, 2003).

Uzzell and Mozer establish four levels of spatial reference that enable the investigation of people–environment interactions:

Level I: Private Spaces (individual level): personal and private space, dwelling, housing, workplace, office,

Level II: Public/Private Environments (neighbourhood–community level): semi-public spaces, blocks of flats, the neighbourhood, parks, green spaces;

Level III: Public Environments (individual and community levels, inhabitants): involving both built spaces (villages, towns, cities) and the natural environment (the countryside, landscapes, parks, etc.), and

Level IV: The Global Environment (societal level): the broader environment, both the built and the natural environment, and natural resources.

As such, the environmental context in which perceptions occur, attitudes are formed and behavior takes place also has a temporal dimension. We cannot understand space and place without considering time.

Human-Building Interaction

As mentioned in the first chapter, in the historical tracking of user-system interaction, Human–Computer Interaction has been fundamental to the evaluation of user interaction with smart environments. However, the interaction between users and buildings is different in nature compared to the interaction between users and computers. According to the Interaction Design Foundation, Human–Computer Interaction links computer science, cognitive science and human factors engineering. The interaction between humans and their environment becomes even more complex when a system mediates between users and the space that shelters them. Despite the fact that technology integrated into built environment is exponentially increasing, “computers and buildings have quite different purposes and operate in distinct ways…While the output of interaction with computers is mostly intangible (something is computed), interaction with buildings is mostly tangible and irreversible" (Savic, 2017). This new, emerging field of interaction between users and buildings is called Human-Building Interaction, which explores and designs interactive opportunities for occupants (users) "to shape the physical, spatial and social product of their built environments" (Alavi et al., 2016).

HBI is the foundation of interactive design, ubiquitous computing and architecture and urban design. In fact, HBI is perceived "as an interdisciplinary domain of research interfacing Human–Computer Interaction (HCI) with Architecture and Urban Design… [as] it frames HCI research and design within built environments" (Alavi et al., 2019). HCI has been the focus of many interdisciplinary studies, benefitting from psychology and social research findings. According to Hamed S. Alavi (2019), three major forces drive the

the current evolution toward human-building interaction: 1) recent advancements in sensing and communication technologies that enable the integration of computerized elements into physical infrastructures (e.g., NarrowBand IoT), 2) developments within architectural practice that include reactive, interactive, and self-modifying architectural elements, and 3) ecological and sustainability concerns that call for lasting, human-centered environments.

HBI analysis is important because: 1) it generates a new kind of data regarding the relationship of users and buildings they work, live, play, socialize and dine in, and 2) establishes knowledge about the type of data that can be acquired and thus, is valuable.

To gain insight into users, it is crucial to analyze their operational mechanisms as well as the factors that affect their actions. Actions include the reflection on human decisions. Researchers have shown an increasing interest in identifying users' actions by constructing human-decision mechanism theories. Human decision making in the built environment is associated with external factors, such as building properties, the physical environment and temporal events, as well as with internal physiological, psychological and social factors.

Conclusions

This chapter analyzed two parallel processes: on the one hand, the role of user in various disciplines and the available tools to collect and analyze user experience, thus rendering people active participants of the design process; on the other hand, the existing patterns used in the architectural design process and the distinctive features that differentiate built space from any other kind of environment.

Following that premise, this study has produced three findings. First of all, it forms the first step towards enhancing our understanding of users and their impact in the design of systems, products and spaces. Having explored users in various frameworks, the idea that they actively contribute to the process of analysis, collection, feedback, and even innovate is validated. In our era, users have huge potential, both being active or passive in the smart environment. By being passive, they offer valuable digital traces; by being active, they can and radically transform their environment. When users are empowered, they can produce unique and specific knowledge beyond empirical observations and quantitative data.

The second finding refers to the correlation and comparison of methods to analyze user. It seems that in the field of Human-Computer Interaction, the main research scope is the analysis of the user, considering the gap between intent and action. User Experience Research equally focuses on how people feel, what they think, what they say and what they do, each time analyzing their needs within a specific framework. The instrument used to analyze users is adapted by psychology and behavioral sciences. In contrast, user experience in the built environment is underappreciated and limited to the analysis of basic spatial attributes, such as circulation and occupancy. Due to the environment complexity, to further analyze users and conduct user experience research in built space, it is necessary to create a dynamic system of collecting data and obtain this very specific user knowledge. This condition can be reached by juxtaposing the toolsets provided by the UX Research stream and the current technological capabilities offered by IoT, which are further explained in the first chapter.

The third finding relates to the value of human-centric approaches in connection to the contradicting nature of design-oriented and technology-based disciplines. Through the example of the lean design process innovation developed by Mueller and Thoring, it is proved that, despite the contradicting nature of the processes used in data science and design, there are strategies to bridge the gap between linearity and iteration, creativity and scientific data analysis.

CHAPTER III

Designing Interactive Environments

Abstract

Having analyzed the history of user-system interaction, it seems that the issue of spatial interaction in smart environments has grown in importance in light of the latest technological advances. The most intriguing part of this evolution in the framework of architectural design is that technology opens up new horizons and contributes in the emergence of new possibilities in space. This chapter investigates how interactive environments embrace novel design spaces. This happens through the analysis of four distinct design approaches for interactive architecture. Specifically, the analysis aims at decoding the ways to translate interaction into spatiality, creating novel user – centric design spaces, either physical or virtual through the use of new technologies. The body of existing literature focuses on the ways that smart spatial interaction improves the quality of people and built space. In contrast, the approaches presented in this chapter will be adjusted on the integration of the smart technologies into the design process and the facilitation of dynamic user-space interaction with the simultaneous respond to user needs.

User - centered Smart Environments

Smart technologies uncover infinite possibilities that built space offers to its users. Technology is rapidly advancing, allowing for an unprecedented abundance of digital tools, software and systems. However, 'the most crucial task before us is not one of putting in place the digital plumbing of broadband communications links and associated electronic appliances, nor even of producing electronically deliverable "content," but rather one of imagining and creating digitally mediated environments for the kinds of lives that we will want to lead and the sorts of communities that we will want to have' (Mitchell, 1995). Mitchell postulated a socio-economic model that would respond to social needs through technology. This exact process of synchronization with user needs led to the emergence of smart environments. Smart environments incorporate two layers: the built space (material) as well as functions (immaterial). Interactive environments are orchestrated in a network of complex actors. Within this network, smart technologies which contribute to various patterns of user-space interaction. 'From an HCI perspective, a smart environment is based on embodied interaction involving physical movements of occupants and spatial aspects of the environment' (Kim and Maher, 2020).

Michael Weinstock holds the view that 'a whole form may be incorporated as a component of a system that has a higher level of organization and complexity – and what is 'system' for a process can be 'environment' for another process' (Weinstock, 2010, pp. 32). Likewise, the building is perceived both as part of the urban system and as an 'environment' itself, that consists of multiple agents, infrastructure, web-based systems, people. 'Smart ecosystem is a conceptual extension of smart space from the personal context to the larger community and the entire city (Yovanof and Hazapis, cited in Nam and Pardo, 2011). Extending Weinstock's view, built space is a sub-component of the smart ecosystem and, at the same time, an environment for its sub-components. Built space is of paramount importance for people. Taking with numbers, people spend more than 90% of their time in interior spaces (US Environmental Protection Agency). Buildings are responsible for nearly 40% of energy related CO_2 emissions and could reach 50% by 2050, while they represent more than 50% of global wealth (UN Environment Global Status Report, 2017). According to Lehman (2011), buildings focus on creating better user experience, beyond covering the funda-

Idea category	Ideas generated **without** PLEX stimulus (N=10)	Ideas generated **with** PLEX stimulus (N=10)	Ideas in total
Experiences to area	5	**19**	**24**
Gaming and Entertainment	5	**19**	**24**
Crowdsourcing and social applications	8	**14**	**22**
Services and events	**18**	11	**29**
Signage and guidance	**13**	8	**21**
Smart traffic	**15**	4	**19**
Total	**59**	**75**	**134**

Table 4
PLEX Cards (Ojala et al., 2015)

mental criteria of sheltering and protecting (Lehman, 2011). At the same time that smart spaces are rethought as environments enabling better user experience, they also constitute part of larger smart systems. Smart technology is scale less, thus allowing for a direct interaction of users with the building. 'A space can be smart by storing and exploiting knowledge about which people and artefacts are currently situated within its area, who and what was there before, when and how long, and what kind of activities took place' (Streitz, 2019). This condition renders interactive buildings a testbed for architects and building experts to delve into deciphering the interaction between human and environment, user and space.

There is an unambiguous relationship between people, interaction and space both in smart physical environments. Space is transformed from a static to an interactive one through the appropriation of technology by the users. In this framework, there is an unquestionable need to adopt a user - centric approach towards decoding and analyzing user preferences, behavior patterns, experience and perception of the novel designs.

In most recent studies embracing the analysis of smart environments, user behavior is associated with space properties and environmental attributes. Although these attributes link user and space, they focus mostly on energy consumption issues. 'There is often a significant discrepancy between the designed and the real total energy use in buildings, in which a complex array of factors play a significant role, including the user / occupant behavior. The reasons for this discrepancy are generally poorly understood, and often have more to do with the role of human behavior than the building design.' (Paone et al., 2018).

Barrett Davies Zhang and Barrett (2015) found that user experience in classrooms is affected by three dimensions, or design principles: the naturalness principle, linked to light, sound, temperature, air quality and to the environmental parameters that are required for physical comfort; the individualization principle, linked to ownership, flexibility and connection – factors identifying how well the classroom meets the needs of a particular group of children; and stimulation which is related to the appropriate level of complexity and color, or how exciting and vibrant the classroom is. The authors use a multi-level model (MLM) to prove that 'the scale of the impact of building design on human performance and wellbeing can be identified' (ibid). In the same vein, Kirsten Gram - Hanssen proves that user behavior is at least as important as building physics by studying data acquired by 8.500 detached houses in Denmark (Gram - Hanssen, 2014).

In the field of interaction design, there exist multiple studies, spatially diverse. Buildings, cars and smart prototypes become the experimental spaces where different types of interaction are investigated in vivo. Human- Computer Interaction and User Experience Research constitute the fundamental theoretical frameworks to embed interaction into the design of space. The idea of these studies lies in identifying novel design spaces or novel ways to read existing space through the appropriation of new technologies. According to Lehman (2011), what is important in the understanding of human behavior in buildings is the correct identification an analysis of the sensory perception. 'Sensory perception is an active process, whereby people use their senses to actively move about a scene…the brain is an adaptive organ – one that uses its systems to contextually and emotionally make sense of what it 'touches'. Because of brain plasticity, building occupants have the ability to learn and adapt to new conditions.

Pettersson conducted a study concerning the interaction design concepts for autonomous cars. By forcing users to ideate through suggested metaphors related to the human-system interaction, new interesting concepts on future autonomous vehicles emerged (Pettersson, 2018). In a two-phased user study of traveler experiences in the railway station area of the city of Tampere, Ojala et al. apply Experience-driven design (EDD) by defining user needs as well as target experiences. The study aims to contribute with bottom-up approaches to the smart city design by using PLEX Cards to enhance user experience in the railway station area.

Schnadelbach et al. (2012) built a 'breathing building prototype', called ExoBuilding and proved 'that it is clearly possible to consider buildings or parts of buildings that act as biofeedback environments, creating an architectural environment with a medical purpose'.
Battarbee and Koskinen (2005) elaborate the pragmatist approach to User Experience where experiences are thought as 'momentary constructions that grow form the interaction between people and their environment' (Forlizzi and Ford, cited in ibid.). Expanding further this approach, they coin the term 'co-experience' to investigate the consequences of interaction of people with people and of people with technology, proving that 'user experiences can only be understood in context' (ibid.). Similarly, Achten (2019) argues that we tend to describe interaction as something occurring between a user and the system, while actually it takes place between more than one user and the system.

From a technological point of view, smart environments are based on three technological

ICT everywhere	**Advanced interaction**	**Algorithmic intelligence**
Embedded information and communication technologies	Natural interaction	Context-awareness
Communication networks	High level concepts in interaction	Learning environment
Mobile technology	Environment evolving gradually both by design and use	Anticipating environment

Table 5
The three technological development paths required for Intelligent Environments (Kaasinen et al., 2013)

Figure 31
The viewpoints of user expectations of intelligent environments (Kaasinen et al., 2013)

pillars, according to Kaasinen et al. (2007). 'The first one is algorithmic intelligence that contributes profoundly by enabling automatic functions that have features like context sensitiveness, learnability or anticipation. The second technological pillar is advanced interaction, including intuitive interface technologies, high level (visual) concepts, and constructiveness. The third technological pillar is ubiquitous technologies composed of elements like embedded information and communication technologies, comprehensive networks and mobile technologies. '

Of course, interactive built space expands beyond just installing sensors and actuators enabling interaction. From an architectural point of view, the embedded technologies on the one hand enable new kind of dynamic spaces and on the other hand novel interactions between users and space. These new relationships between humans and systems in space have to be further investigated by architects both as architectural phenomena and as new social circumstances. 'Smart environments reflect recent architectural phenomena that embed computation in built environments, providing dynamic spaces to support a range of humanistic functions…These architectural concepts reveal different perspectives of smart environments such as purposes, functions, building components, and interactivity' (Kim, J., Maher, M.L., 2020).

Case Studies

In the following part, four distinct design approaches will be analyzed, aiming at drawing parallels among the three technological pillars and their architectural implications. The examples present certain types of interactions within smart environments and establish the attached theoretical frameworks initially for understanding and subsequently for designing them. While being elaborated by different scientists and architects, all studies fall under the umbrella of the model elaborated by Achten and Kopriva (2011). This model, unlike all other approaches divides the whole interactive design process into four phases: Analysis, Concept Generation, Simulation and Assessment. The main question here is “how should my building behave?” (Achten et al., 2011). The model contributes in two directions: firstly, it identifies methods to assess User Experience in interactive built environments and then establishes a valid theoretical framework as a basis for their architectural design.

Design Approach I: Designing through UX Research

What

The first design approach is based on the juxtaposition of User Experience Research Methods and the architectural design of a retail space. Elaborated by Kai Hansen and Thomas McLeish (2015), this approach takes account of the data and empirical observations on user behavior, aiming at leveraging ubiquitous computing principles and User Experience Research potentialities.

Why

The authors highlight that the retail typology uses a 'well-defined architectural language' (ibid.), in terms of program. As such, it serves as a testbed for discussing how interactive technologies can alter user experience and how reading space through the prism of UX generates a two-way communication channel between interaction and architectural design. Following this premise, the way that users interact with space can inform the architectural reconfiguration of the specific space, but also add generic in terms of location and site, knowledge on retail space design and correspondent interaction patterns.

How

First of all, Hansen and McLeish (2015) identify two streams of interaction. The 'Observe and Respond' stream is related to simple observation of user behavior and the activation of decision mechanisms based on the 'if this, then that' relationship that triggers action and enhances the

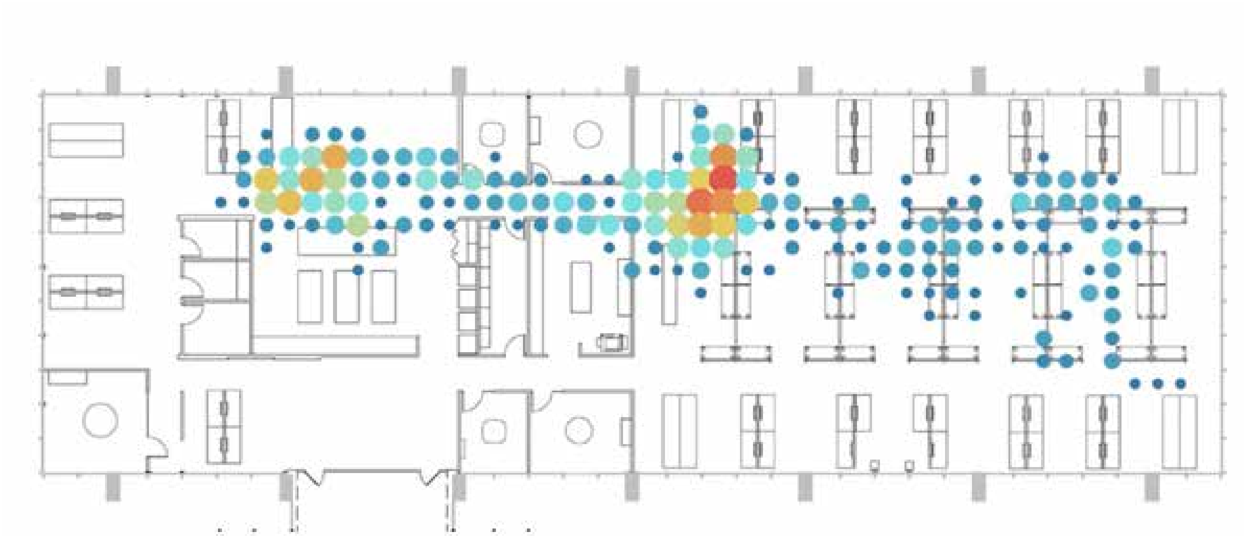


Figure 32
Aggregated indoor positioning data showing general procession and moments of engagement (Hansen and McLeish, 2015)

physical experience. The action consists in notifications and alerts on the user's mobile through the interconnected interface. Triggers are mostly based in location and proximity to Beacon's and preinstalled sensors used to convert static objects into connected ones. A basic scenario depicting this basic kind of interaction includes the user passing near a product on a shelf within a predetermined proximity threshold, triggering a push notification sent to the user's phone by the system. The second stream of interaction, called 'Observe and Broker' is a more complicated process that uses multiple sets of data to ensure the accuracy of the action. This stream of interaction is used in a twofold way: on the one hand, to add knowledge to the system aiming to enrich the user experience, and on the other hand, to inform retailers on the overall consumer experience, the engagement with certain products, the user's level of interaction and finally the path from the notification to the success (or not) of the purchase.

The most significant contribution of this study is the classification of physical environments and existing observation techniques. Initially, they establish a taxonomy of spaces: retail, home, institutional, workplace, entertainment and travel. Then, they capture 14 observation techniques, as listed below:

- Atmospheric Observation
- Motion Tracking
- Video Analytics
- BLE Beacon Tracking
- Wi-Fi 'sniffing' or tracking
- Geomagnetic field mapping
- Geofencing
- Geolocation tracking
- Social data analysis
- Large Interactive Displays
- Digital Activity Logging
- Augmented/Virtual Reality
- NFC Payments
- RFID tagging

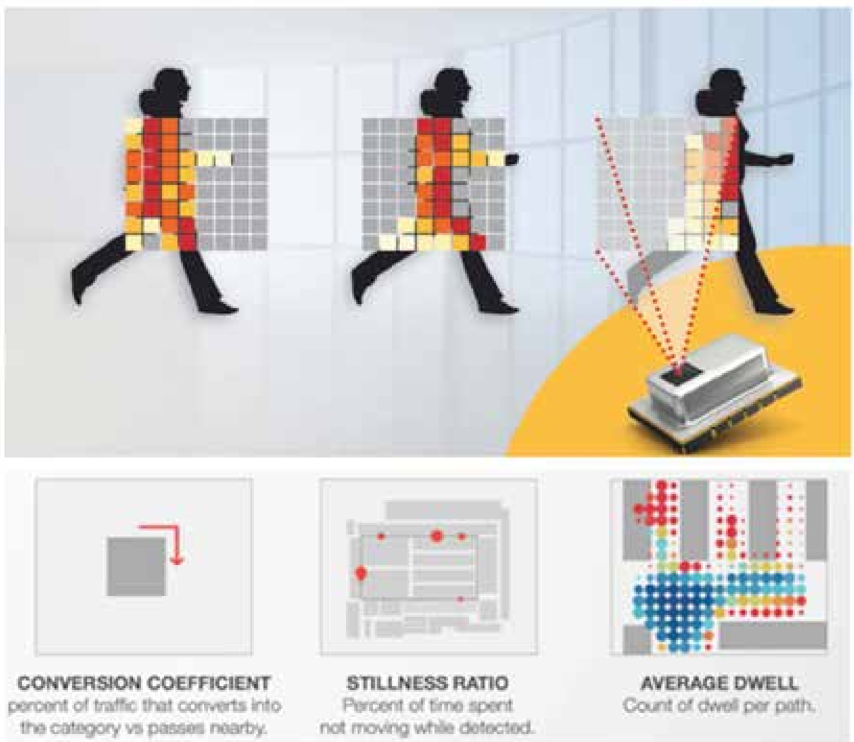


Figure 33
indoor Positioning Mapping Process (Hansen and McLeish, 2015)

The final part of this study focuses on a short experiment of a user leaving his work to visit a coffeeshop. The combined application of the aforementioned observation techniques, enables the authors to measure user engagement and introduce engagement indicators extrapolated both my metrics (head orientation, moving patterns etc.) but also through empirical observation.

There are two significant parallel outcomes of this study. First of all, the fact that the observation techniques produce an enormous amount of data. ‘Even a 23-minute walk to a local coffee shop generates several million data points’ (Hansen, McLeish, 2015). This fact alone demonstrates the huge potential of interactive environments for rethinking architectural design. Secondly, throughout this study, it becomes evident that while the notion of User Experience is somehow refined through this research, further clarification is needed for the architectural design of connected environments. ‘Although the concept of user experience is widely used in the field of Human-Computer Interaction, there is generally no accepted definition of user experience yet’ (Achten, 2019). However, throughout this study, the research makes a major contribution on architectural design process by integrating UX principles in it.

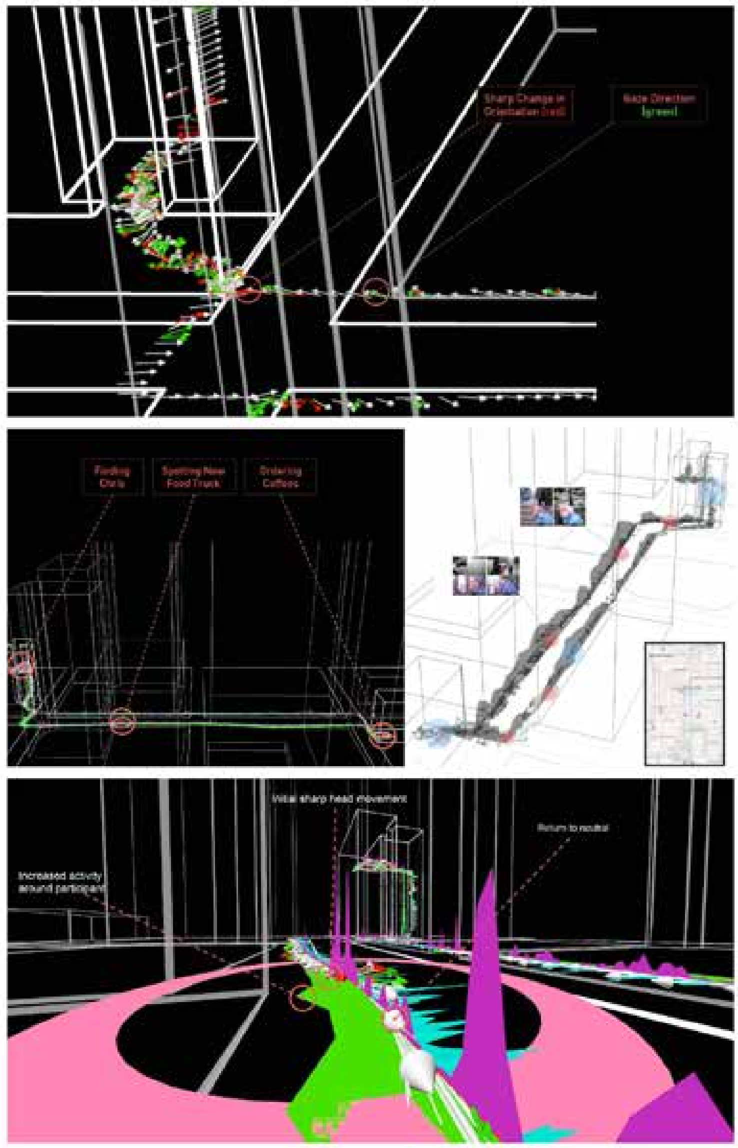


Figure 34
Orientation, movement and moments of engagement (Hansen and McLeish, 2015)

Design Approach II: Designing through Metaphors

What

The second design approach leverages the notion of metaphors to explore the novel kinds of interaction between user and environment. Specifically, Kim and Maher (2020) intends to understand embodied interaction of smart environments through the use of metaphorical references, aiming at identifying 'new design spaces' for smart environments. The conceptual metaphors used consist in depicting the smart environment as a device, a robot and a friend.

Why

According to the authors (Kim, J., Maher, M.L. et al., 2020), digital technologies can enhance interactivity and intelligence. However, there is a research gap in understanding and designing the design space of interactive designs in the built environment. This gap is filled through the use of metaphors, borrowed by Human-Computer Interaction 'as a vehicle for representing and developing designs' (ibid.) Using metaphors involves the exploration and expression of an idea that is integral to design generation and innovation (Brady, cited in Kim & Maher, 2020). Following that premise, metaphorical concepts can unlock new - yet unexplored – design spaces of interactive environments.

How

The authors (2020) use two conceptual tools as a vehicle to reach the design approach. The metaphor constitutes the first conceptual tool, adopted by the HCI. 'A metaphor is a mapping process from a familiar object to an unfamiliar object, and it provides the framework to familiarize an unknown concept through a mapping process' (Kim and Maher, 2020). Embodied Interaction serves as the second conceptual tool of this study. According to Dourish (cited in Kim and Maher, 2020) embodied interaction is about 'how we understand the world, ourselves, and interaction comes from our location in a physical and social world of embodied factors'. Then, the authors combine the two conceptual tools into one: the embodied metaphor, defined by them as 'a mapping process between a source domain of embodied experiences and a target domain of an abstract concept' (ibid.) There are several examples proving the constant relationship between spatial features and user expressions, as well as between user actions and specific system actions. Therefore, the embodiment, as a link between the volatility of user behavior and the responsiveness of system behavior consists in an important medium for the design of physical environments. The user and the system when performing a task are considered as important components and play a key role in identifying the different perspectives of embodied interaction for the three established conceptual metaphors: device, robot and friend. Specifically, when the user has direct control of the system with an embodied interaction, the smart environment acts as a device. When the system actively performs tasks, analyzing data and external conditions, without human control, the smart environment behaves as a robot, emphasizing building automation and automation controls. Finally, when the system 'intervenes in certain activities done by the users' (ibid.) in a human-like manner, the environment behaves as a friend.

How can we categorize space according to these three metaphors? The authors embrace three distinct components: interaction type, interface type and affordance.

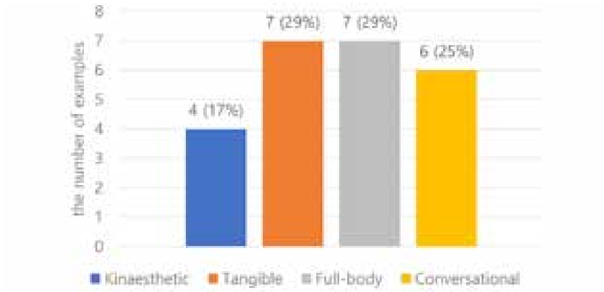
Here, these three components, their definitions and their variations are presented:

Interaction type: the ways by which a person interacts with a product or application (i.e. instructing, conversing, manipulating, exploring and sensing).

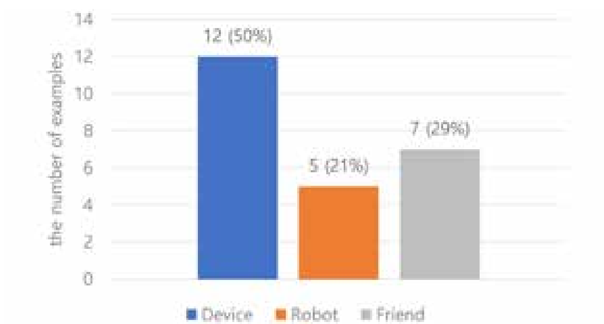
Interface type: technologies that enable and support the interaction (e.g. WIMP, GUI, touch, speech, wearable, tangible, AR and VR)

Affordance: the action possibilities of a user when the user interacts with a designed artifact (e.g. pressing a button or turning a knob).

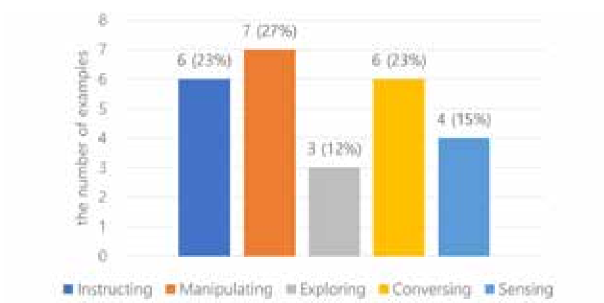
Then, the authors analyze 24 existing embodied interaction designs in terms of the three components (interface type, interaction type and affordance) and intend to assign them to each metaphorical concept. The outcome of this process is a table containing each metaphorical concept matched with the components that mainly characterize them. Specifically, the device metaphor is linked with the interactions of instructing, manipulating and exploring. In this case, the smart environment is imagined as a conceptual extension of the smartphone at a larger scale.



Kinaesthetic	Device: E1, E3, E4 Robot: E2
Tangible	Device: E5, E6, E7, E8, E9, E10, E11
Full-body	Device: E12, E13 Robot: E14, E15, E16, E17 Friend: E18
Conversational	Friend: E19, E20, E21, E22, E23, E24



Device	E1, E3, E4, E5, E6, E7, E8, E9, E10, E11, E12, E13
Robot	E2, E14, E15, E16, E17
Friend	E18, E19, E20, E21, E22, E23, E24



Instructing	Device: E1, E3, E4, E12 Robot: E17 Friend: E20
Manipulating	Device: E5, E6, E7, E8, E9, E10, E11
Exploring	Device: E13 Robot: E17 Friend: E18
Conversing	Friend: E19, E20, E21, E22, E23, E24
Sensing	Robot: E2, E14, E15, E16

Figure 31
The viewpoints of user expectations of intelligent environments (Kaasinen et al., 2013)

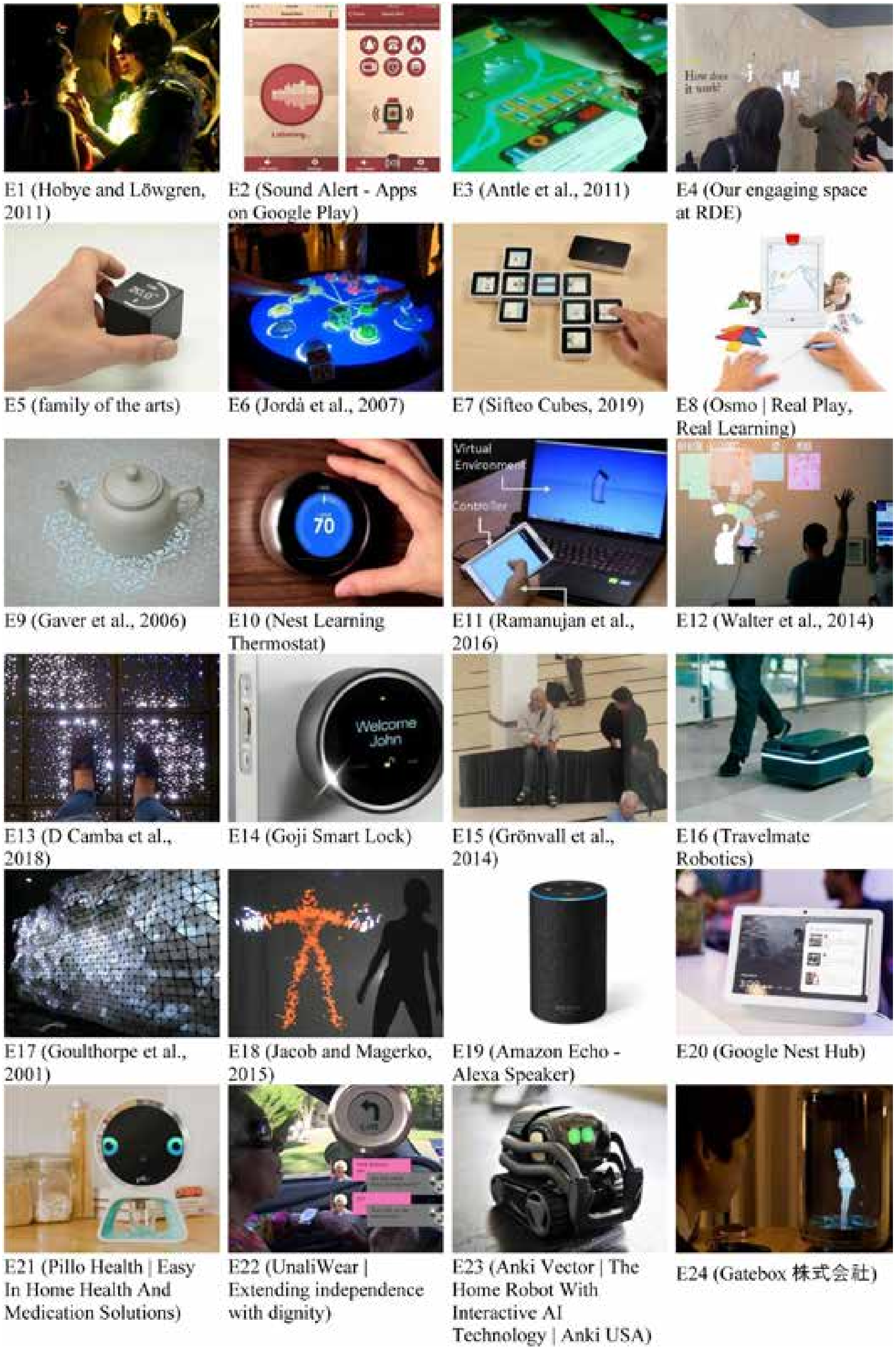


Figure 31
The viewpoints of user expectations of intelligent environments (Kaasinen et al., 2013)

As an interface, the most typical is a GUI (Graphical User Interface) and the affordances are both physical and digital. The robot metaphor is associated with learning and adapting interactions. The interface has a robot type and the affordances are physical. The Friend metaphor relates to advising and supporting users and triggering 'meandering interaction' (ibid.). Speech and multimodal interface types are used, while the affordances produced relate to speech, facial expressions and the actions of a virtual assistant.

The last part of this study investigates the user's adoption of the metaphors as a mental model, by establishing educational scenarios and engaging students, as well as the methods used by designers to apply the metaphors and produce their conceptual designs. As far as user perception is concerned, three concepts emerged: signifier and affordance, interaction modality and purpose of design. This process depicted 'the effect of the conceptual metaphors on recognizing affordances in smart environments and on designing new smart environments' (ibid.). As a result, the metaphorical concept can serve both as a design tool and as an educational tool for designing smart environments.

Design Approach III: Designing through Interaction Narratives

What

The third design approach, stated by Maria Lehman (cited in Achten, 2019) and further elaborated by Henri Achten (2019) refers to the integration of narratives, as a means to dynamically connect user, building and interaction types. According to Achten, ‘a narrative is a coherent story of the inhabitant, which needs to be supported by activities of the building’ (ibid.).

Why

Narratives as a tool is by default closely related to the qualitative nature of architectural design, steering away from the technical objectives associated with the technological components. In that sense, ‘the concept of narrative enforces a consistent unfolding of events between the user and the building’ (Achten, 2019). By analyzing the narrative of a user or a cluster of users within a specific spatial context firstly, and then linking it with an interaction type allows us to clearly identify the decision mechanism of switching from one interaction type to the other. In other words, narratives directly connect the user with the building, and further add up a spatiotemporal framework on this relationship.

How

Narratives as a tool for interactive design are experimented in the case of rethinking the public library, as envisioned by Lehman (2018). The scope of this study is to enhance the library concept and advance the library as an institutional system through architectural

Figure 36
Idea activation spectrum (Lehman, 2018)

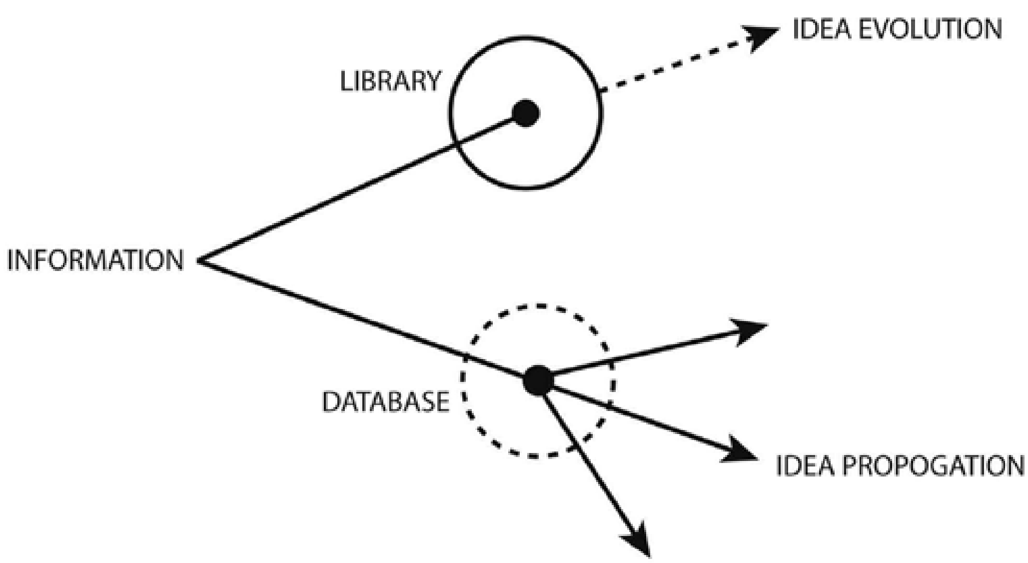


Figure 35
The library as idea anchor
Lehman L. M. (2018) Future-proofing the public library, Public LibraryQuarterly, 37:4, p.410)

Combine? When?‘ is suggested.

In the Concept Generation, an abstract but comprehensive solution to the design problem stated in the Analysis phase is synthesized. The techniques of this step are presented in Table x. The authors elaborate the technique of framing the design drivers that combine a feature of the design with some aspect of the environment of that design and act as generative forces in the design process if they are embedded in a design question. (Achten and Kopriva, 2010). In most cases, the equilibrated combination of design drivers generates valid design concepts.

The third step consists in the simulation of the concept, varying ‘from a digital simulation in a computer program up to a full-scale realization’ and constitutes a significant part of the design process due to the ‘strong temporal component’ of the interactive systems. As presented in table xx, four simulation techniques are pointed out: Animation, Physics-based Simulation, Performance simulation, and Prototype-based simulation. The authors shed light on the Prototype-based simulation and specifically the Wizard-of-Oz technique. This prototype ‘fakes’ technology, adding a fast track channel in the whole design process, in the sense that replaces a part of technology by a human act. As defined by the authors ‘a wizard-of-oz experiment is a working prototype of an interactive system, building or environment in which part of the technology is performed by a human or some kind of prop’ (ibid.).

In the final step, the Assessment, the kind of behavior of the design is tested. Three techniques are listed: Requirements comparison, User-Client assessment and Persona-based Evaluation. Concentrating on the last technique, the authors suggest two distinct strategies: profile checklist and role-playing. The persona-based evaluation enables an objective perspective of the design outcome, by establishing a correlation between the desires, demands and habits of the persona and their corresponding design features.

While the structure of the process is a synthesis of numerous techniques suitable for the execudesign and new technologies. The first step of the study identifies current discrepancies of the public library in light of the constant flow of data that confuses people, and highlights the potentialities of the public library despite the phenomenon of extreme digitization nowadays. The second step is the elaboration of the librarian narrative. Both at a social and an operational level, librarians are the pillars of the public library and, according to Lehman (2018), their role has to be redefined and enriched. This creative redefinition can reshape their role from being 'gatekeepers' of data, to becoming 'sensemakers'. Sensemaking includes two distinct goals: pattern detection – exposing, exploring and harnessing trends in data/information, and need prediction – probabilistic need for a particular piece of information (ibid.)

The third step is the narrative of ideation within the spatial context of a library. In that sense, the flowing information can be stored and processed physically and digitally in order to promote ideation. The library as a physical repository of information can lead to idea evolution; the library database as a digital repository can lead to idea propagation. In this context, the narrative of ideation focuses on the ways that people engage with ideas within the library. As such, five types of engagement are identified: celebration, learning, sharing, growing/evolving, creating. Through this process, users of the library can become idea activators. Towards this end, personalization and gamification become key tools.
The fourth step includes the connection of the five types of engagement with new spatial functions that can support the ideation narrative and the anthropocentric focus of the future library.

Virtual/Augmented Rooms can contribute to a full virtual experience towards the goal of celebrating ideas. Interconnected Gaming Rooms can connect library users globally and promote the learning of ideas. A Decentralized Library Space imagined as an extension of the library can possibly initiate a virtual book discussion and work towards evolving ideas. Interactive Book Rooms that 'evoke the essence of a book for a book discussion' promotes idea sharing. Finally, a new typology of the creator's room can create the perfect background for a user to brainstorm and create ideas.

The intriguing part of this study is the juxtaposition of new technologies with new architectural spaces that are twofold: on the one hand, they focus on the narrative of users and librarians interacting with the ideation process; on the other hand, they promote innovation at a design / spatial level in the sense that they bridge the gap between technological advances and their spatial implications.

Design Approach IV: Designing based on the User Experience brief and persona

What

The fourth design approach does not limit the study to the concept generation or the interaction type, but frames holistically a methodological framework that includes the whole process from the analysis and the investigation of the design problem up to the assessment of the design.

Why

This approach intends to reverse the long tradition of architecture, imposing that certain behavior of people in the built environment is taken for granted by the architects. By transferring the user experience brief and persona methods from the field of User Experience Research, the authors (2010) sought to answer the question: ‘how do we design a building that behaves in relation to each type of user?’

How

The authors identify four distinct steps that constitute the methodological framework: Analysis, Concept Generation, Simulation and Assessment. In each step, the present a set of available methods, initially describing, the issues, reasons and work approach of the method. Following this point, they define the method and its practical milestones; finally, they elaborate a specific example and share notes on things that should be considered.

Specifically, the design problem is investigated during the Analysis phase, encompassing five distinct techniques: User-based Analysis, Time-based Analysis, Function-based Analysis, Object-based Analysis and Cost-based Analysis. Focusing on the Object-based analysis, they introduce the REMASC technological analysis checklist, which actually requires a deep investigation of the existing technological components. REMASC stands for Respond, Enable, Materialize, Actuate, Support and Control and it is evident that it requires a good understanding of the existing technological developments. A series of follow-up questions such as ‘How? What else? Sufficient?

Analysis techniques (A)	
A1. User-based analysis	User needs (A1.1), user-system interaction (A1.2), user activity schedules (A1.3), user change patterns (A1.4), user-response schemas (A1.5), single versus group users (A1.6), user group dynamics (A1.7), user contingency planning (A1.8), user comfort requirements (A1.9), user experience brief (A1.10), and the persona (A1.11).
A2. Time-based analysis	Cyclic analysis (A2.1), time functional depiction (A2.2), time cumulative depiction (A2.3), spider diagrams (A2.4), circle diagrams (A2.5), speed of change (A2.6), frequency analysis (A2.7)
A3. Function-based analysis	Function change analysis (A3.1), fitness for function change (A3.2), emergent functions analysis (A3.3), UML use case diagrams (A3.4).
A4. Object-based analysis	REMASC technological analysis checklist (A4.1), sensors and actuators (A4.2), change logic and controllers (A4.3), SPA (A4.4), obedience versus conflict (A4.5).
A5. Cost-based analysis	Cost of change (A5.1), profitability of interactivity (A5.2), assessment boundary (A5.3).

Table 6 Analysis techniques
(Achten and Kopriva, 2010)

REMASC technology analysis checklist	Example question: "Can I use this technology to…"
Respond	...respond to changes, demands, factors, people, events, and so on in the environment or context of a system?
Enable	...make possible or enable that change, adaptation, movement, and so on can occur?
Materialise	...physically create components of an interactive system?
Actuate	...actuate or realize movement, rotation, scale, temperature, transparency, and so on?
Support	...support the realisation of an interactive system, not the interactivity itself, but the conditions to make it possible?
Control	...control the behaviour or dynamic aspects of an interactive system?

Table 7 REMASC Technology Analysis checklist
(Achten and Kopriva, 2010)

Follow up questions	Example question
How?	How can I use this technology, how does it work?
What else?	What else do I need for this technology to work?
Sufficient?	Is this technology sufficient to achieve what I need?
Combine?	How can this technology be combined with other parts of the system or technologies?
When?	When is this technology used in an interactive system, building or environment?

Table 8 Follow up questions
(Achten and Kopriva, 2010)

Simulation techniques (C)	
C1. Animation	Animation and interactive structure animation
C2. Physics-based simulation	Lighting and energy simulation. Environmental simulation.
C3. Performance simulation	Performance of the building; effectiveness.
C4. Prototype-based simulation	Wizard of Oz, wireframing.

Table 9 Simulation techniques
(Achten and Kopriva, 2010)

Concept generation techniques (B)	
B1. Identify design drivers	Identify major themes that can structure important parts of the design.
B2. Frame design drivers	Set a design question in which the design driver can operate.
B3. System view	Describe the whole of the building as a system.
B4. Design for emergence	Design a system bottom-up, not top-down. Allow for components to react to each other, so that they take profit from each other.
B5. Design by component	Focus on a key technological component from which to develop part of the design.
B6. Technology framing	Given a particular technology, set the technology in a particular context in which it will be used.
B7. Performative design	Set parameters of the building design, and link these parameters to one or more performance criteria.
B8. Design principles	Check how the design meets Norman's design principles: visibility, feedback, constraints, consistency, and affordances.
B9. User experience	Take the persona and related user experiences as a guideline for designing concepts.

Table 10 Concept Generation techniques
(Achten and Kopriva, 2010)

Assessment techniques (D)	
D1. Requirements comparison	Comparison of building performance with requirements
D2. User-client assessment	Determine whether there is convergence in the assessment for the user and assessment for the client.
D3. Persona-based evaluation	Determine to which degree the performance meets the requirements of the relevant personas.

Table 11 Assessment Techniques
(Achten and Kopriva, 2010)

tion of interactive design, the authors argue that ‘the architect has to avoid the ‘death by method’, meaning that he or she should not become completely absorbed by the method, only to forget that the goal of using a method is to create a design’ (Achten and Kopriva, 2010).

III.5 Conclusions

In this chapter, four distinct approaches have been analyzed to integrate interaction into architectural design. These four approaches propose divergent methodologies for studying and implementing interaction, but imply different things. The approach deriving from the UX Research focuses on the technological aspect, expanding further the input-output process and leveraging as much as possible the existing technological tools. In this approach, the overall outcome is less design-oriented and almost 100% technologically driven. The outcome also depends on the scale, the program and typology, as well as the goal of the design. For example, the UX research design approach seems more adequate in cases where it is important to add commercial value or produce user engagement insights for the manager or the owner.

In contrast, the fourth approach, also based on the User Experience brief and persona, but is evidently better structured in terms of the design process and overall it is better conceptually framed. Moreover, it encompasses the step of Concept Generation, which proves to be indispensable for an optimal design process.

The second approach examines three different metaphors and demonstrates that the same set of interactions in the same context can be translated through a different metaphor (device, robot or friend), thus being a subjective part of the design that depends on the personality of the designer – not only on the profile of the user. The narrative approach introduces a holistically reinvented typology that does not only revisit the user interaction in a certain context, but alters architectural space from the ground up.

Of course, this is not an exhaustive list of design approaches. There exist a lot more in the growing body of interaction design research, which currently is in the diapers. These four approached were chosen either because they provided a well-structured methodology from the

Design Approach	Typology	Status	Main design goal
UX Research	Retail	implemented	To add commercial value
Metaphors	Smart Home	theoretical	To create a framework for switching between interactions
Interaction Narratives	Public Library	theoretical	To reinvent the typology
UX Brief and Persona	N/A	theoretical	To provide a valid simulation and assessment tool

Table 12 Methods classification by typology, status and main design goal
(elaborated by the author)

Design Approach	Analysis	Concept Generation	Simulation	Assessment
UX Research	Time-based and Technological Analyses	Design by Component	Prototype-based	Persona-based evaluation
Metaphors	Technological Analyses	Frame Design Drivers	Prototype-based	To create a framework for switching between interactions
Interaction Narratives	User-based Analysis	Frame Design Drivers	N/A	To reinvent the typology
UX Brief and Persona	REMASC Technological Analysis	Frame Design Drivers	Prototype-based (Wizard-of-Oz)	To provide a valid simulation and assessment tool

Table 13 Methods classification by typology, status and main design goal (elaborated by the author)

beginning to the end of the design process, or because they invented a new way to think about design in relation to technology. For example, the Henri Achten (2014) introduces the Agent Perspective for Interaction Design, derived by the Multi-Agent Systems (MAS) Theory. In this approach, he inserts the notion of agency, where objects and people are equally considered as agents and responsiveness is perceived as their intrinsic property. However, it is about a method that is valuable for the abstraction but needs to be methodologically constructed in order to be useful in the concept generation'. As stated by the author (2014) 'the rather well-developed notion of multi-agent systems from Artificial Intelligence can provide this [theoretical] framework, but needs to be formulated in an accessible way for architects.'

Interestingly enough, all approaches demonstrate that Interactive Environments constitute digital design tools that enable architecture to embody fluidity, temporality, movement and change. However, it is clear that one-to-one relationships are not sufficient to represent user behaviors. Instead, there is a strong need to discover relationships, time relations and sequences of actions combined with their attached temporal and environmental actions.

It also becomes evident that not all methodologies can be generically translated into a design concept. They largely depend on a set of temporal and contextual parameters, such as the building typology, the status of built space (built-unbuilt) at the time of intervention and the goal of the design. Since concept formulation is neither an objective nor an automatic activity, a concentrated effort is required to develop an enhanced concept able to integrate interaction at a deeper level.

CHAPTER IV

Experimental Design Studies

Abstract

The fourth section presents a series of studies, conducted in four different building typologies: workplace, hotel, public building, home. The studies investigate one scale at the time, following a bottom-up, incremental approach, building, at the same time, the methodological framework of translating the technological analysis into new spatial design approaches. The first study, EcoMotivate, presents the analysis of human-system interaction within the building in the context of the b-a-a-s conceptual model. The design goal of the experiment is to design for social awareness for energy saving in workplace, thus acquiring a design approach based on UX analysis. In the second study taking place at a hotel in the old Venetian Port of Chania, the location analytics technology is tested at the scale of a building interior. The design goal is to rethink the hotel room through connectivity. The hotel room is redesigned to be transformed according to the scenario of the hotel room as a butler. The third study is conducted at the Municipal Market of Chania, Crete, evaluating user behavior on a population of 33 participants comparing their spatial experiences before and after the use of ICT. Through qualitative and quantitative methods, behavioral change and user experience is analyzed among users with and without access to Crete 3D, an online ICT-based innovative informative platform, aiming to establish a theoretical framework of understanding user interaction with built space. This process enables knowledge transfer in a twofold way: it shows how to use metrics to evaluate user-building interaction and how, users can quickly gain a deep understanding of the building in use. Using this knowledge in the interaction design process, the Agora is then rethought as a historical thinktank and as a commercial hub, using the approach of designing with narratives. The fourth study presents a case study in the historical center of Athens, outlining an alternative approach to smart home design thinking and addressing the complex

challenges of IoT integration in a more integrative, contextually relevant manner. Suggesting a more open, spatially conscious stance and a more collectively conceived IoT selection, the article advocates that when dealing with the complex challenges of everyday spaces for urban dwellers, a holistic approach to space design must be achieved.

Study I: Designing Social Awareness through UX Research

During last years, Europe has witnessed remarkable progress in the field of new technologies focused on reducing our carbon footprint. Big retrofit projects, low carbon emission automobiles, combined heat and power systems (CHP) have contributed to promote environment-improving practices at a large scale. In 2005, the EU Ecodesign initiative was developed to address the environmental impacts of the energy use of appliances and devices and to assess the efficiency of the proposed measures. Moreover, the EU has made major efforts in setting the minimum requirements on energy-using and energy-related products placed on the market. According to the 2012 EU Energy Efficiency Report, major energy savings will be realized through simple consumer behaviour shift, such as equipment usage and office lighting in the tertiary sector.

This project intends to create an innovative, multi-level, game-like system to increase eco-awareness and consumer engagement as well as to generate cost-effective, sustainable competitive advantages for energy conservation and increase in renewable energy use. The project's main scope is to design a smart-sensor network that evolves without human involvement as well as to establish an 'internet-of-everything' setting in energy-consumption related activities in the work sector, by adopting energy-efficiency and renewable energy technologies suitable for work applications. IoT becomes the tool to design novel spaces emerging through User Experience Research and Persona.

The study suggests a new, innovative platform for knowledge and exchange of ideas, to provide information, support and guidance to communities and to invent ways to disseminate and share the gained information to working communities that are more or less familiar to the sustainable way of life. This platform is also intended as an open source hub that intends to provide real-time information on the end-user behaviour, analyse and improve it through a peer-to-peer network focused on energy consumption. Sensor and network capabilities will contribute to the shaping of the “sustainable lifestyle” that work hubs are invited to share and promote. The project will project urban living as a “parameterized variation” of dynamic urban factors such as carbon footprint, energy waste, energy consumption, allowing the users of urban space to change these qualities by actively participating in it. Members of the work hub are treated as end-users that will be able to manage their personal data and take advantage of the IoT network to take back control of their energy consumption levels. A bottom-up approach will be identified to suggest sustainable strategies regarding consumer energy saving in terms of consumption during working hours. According to their energy-related behavior, workplace users are classified into three levels of social awareness.

The project suggests dynamic ways to alter this situation: bridge across users, companies and consultants in order to create multiple ways to alter the work habits by approaching different work members according to their education, gender, age and willingness to change their lifestyle. Users will be able to observe the relation between their habits and their energy consumption levels, while new sustainable technologies focusing on the quantification and evaluation of consumer behaviour will be developed.

Introduction

Workplaces are often contexts where potential impacts of individual behavior change are mediated by organizational and group issues. With the presence of user-controlled infrastructure systems such as air-conditioning, lighting and heating, staff is gaining control over decisions related to the working environment. Moreover, the majority of the working staff is not able to recognize the invisible link between disrupting a habit and the overall environmental impact of the specific action. Daily life is characterized by repetition, which associates form in memory with the practiced action and typical performance times (Wood et al., 2005). In that respect, changing long-established habits into a sustainable working lifestyle requires a multidisciplinary motivation system.

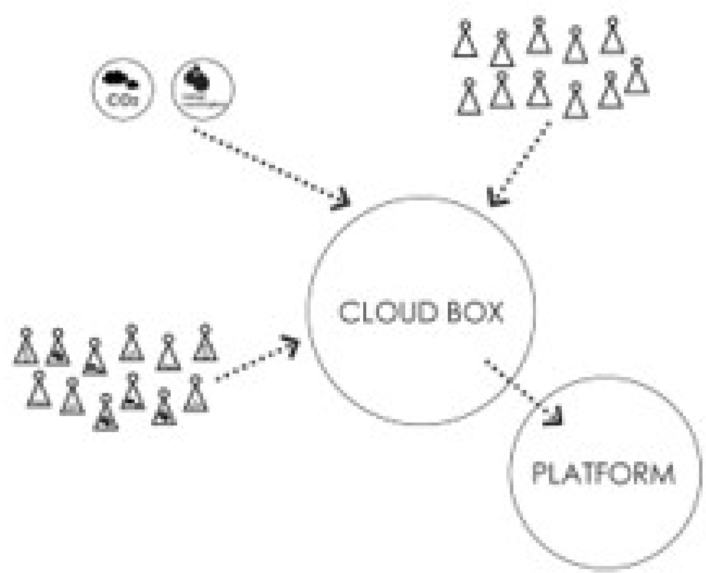


Figure 37
EcoMotivate

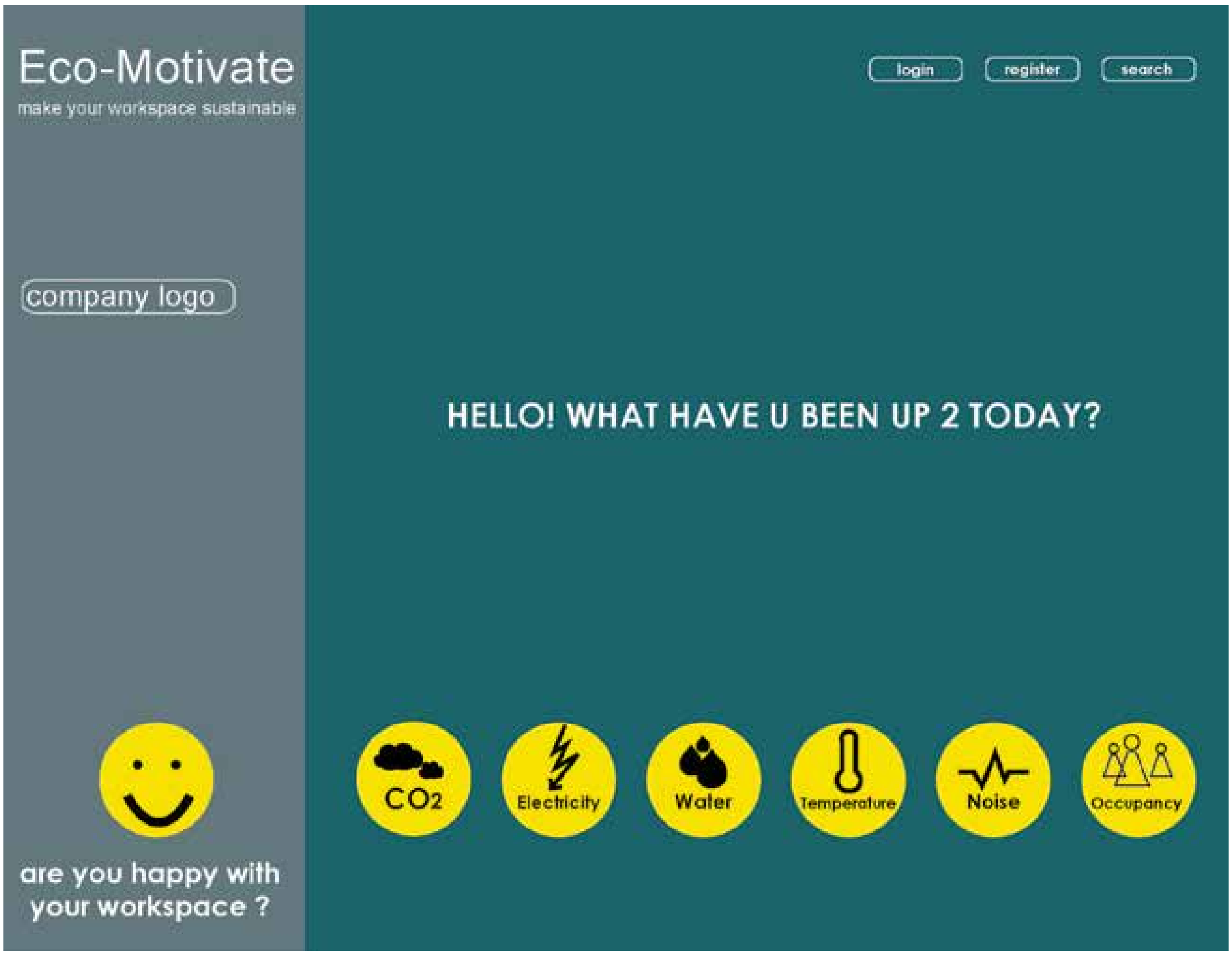


Figure 38
EcoMotivate

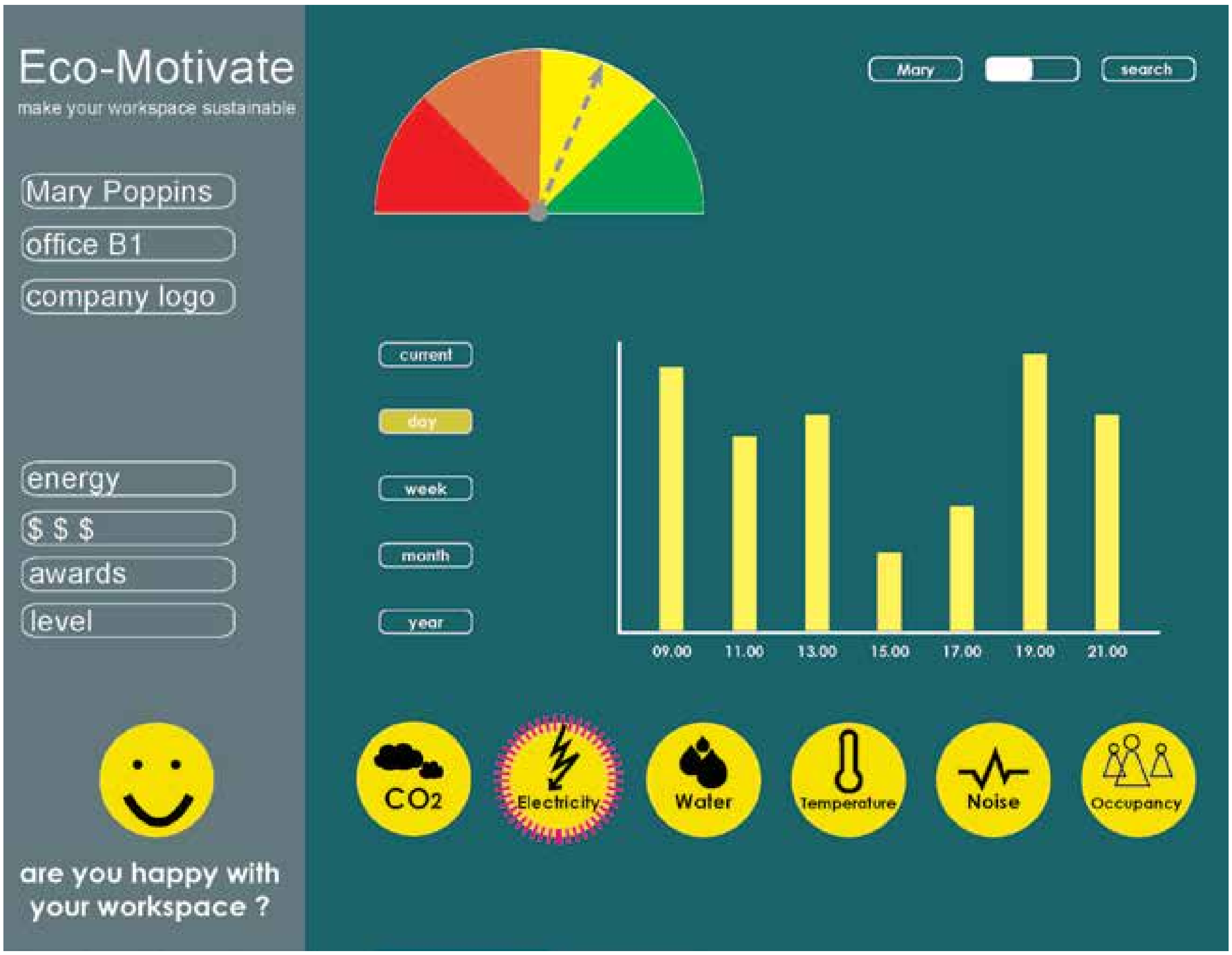


Figure 39
EcoMotivate

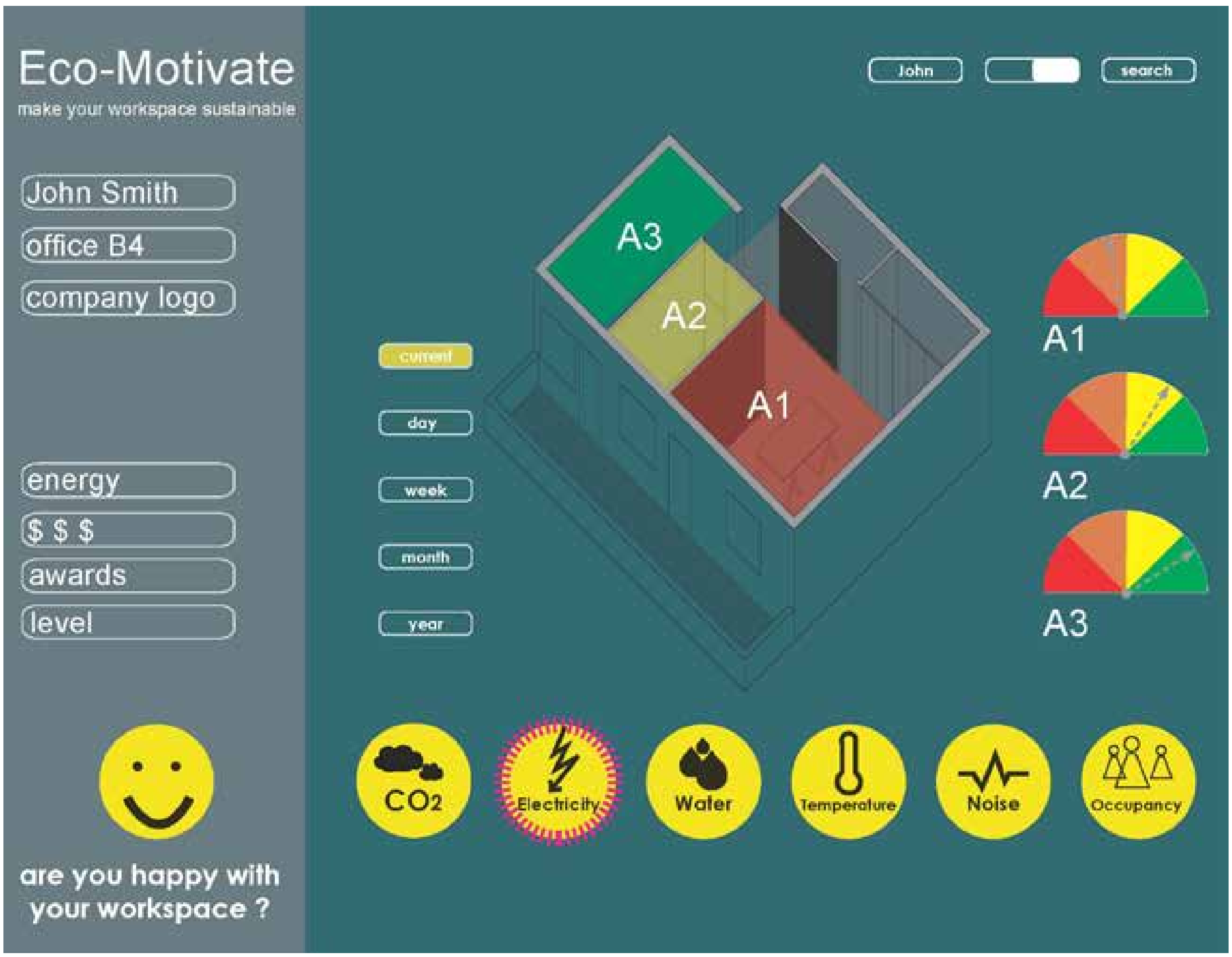


Figure 40
EcoMotivate

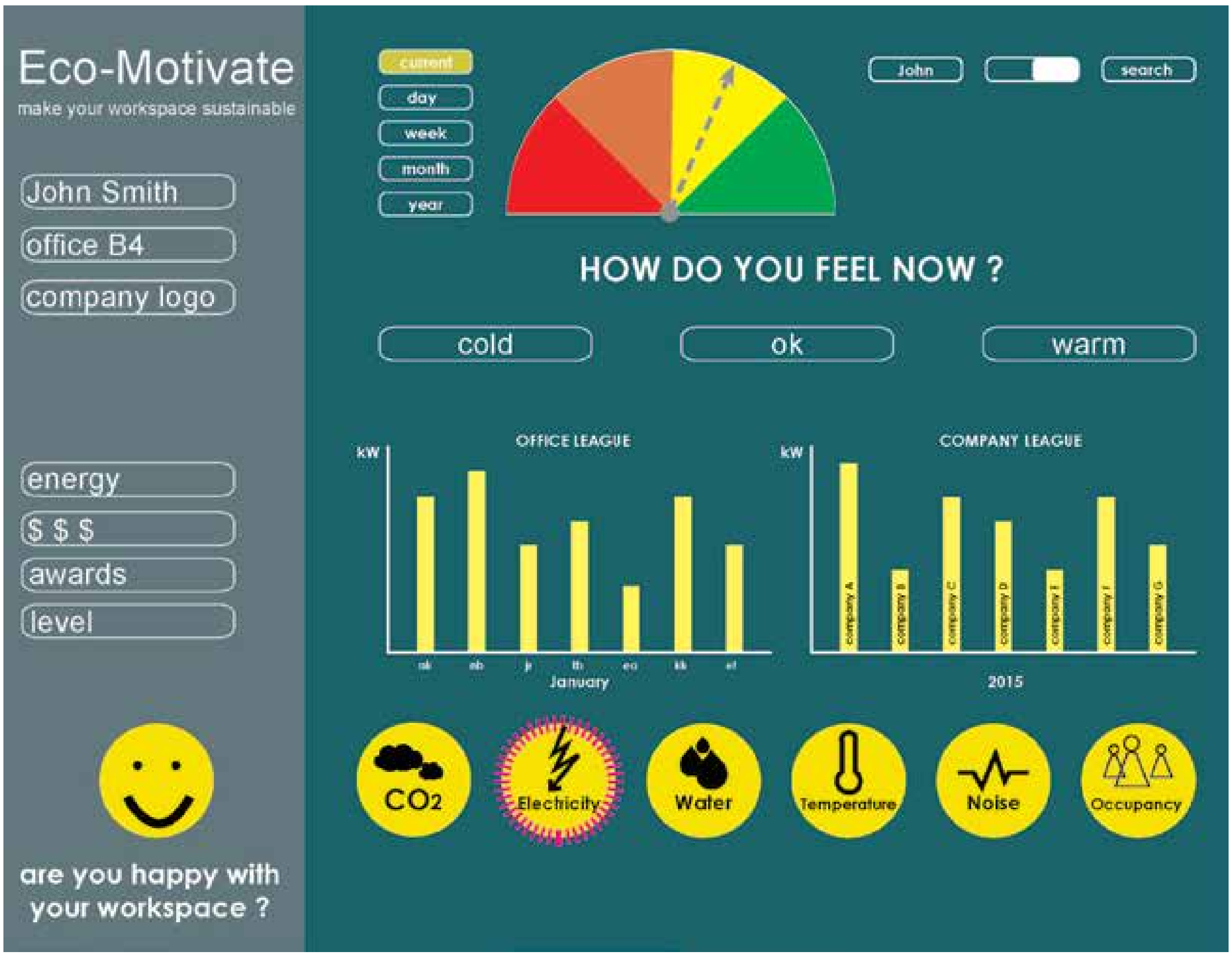


Figure 41
EcoMotivate

Project Background

This study is based on the notion that automated control of buildings, transport and other energy management processes are not sufficient to radically reduce energy consumption levels (Batey et al., 2015). On the one hand, new technologies have allowed for the emergence of virtual workspace, which is linked to the urban scale, while traditional workspace relates to the building scale. On the other hand, multi-tasking has allowed for a higher mobility rate nowadays (Laing, 2013). According to a Typical Work Space Utilization Survey [AECOM, 2013], internal mobility corresponds to a minimum of 20% of a typical working day. As a result, a major behavioural shift in the way users perceive and control space is necessary. A number of solutions have been sug-gest ed for the motivation of users to consume less energy through the shift of everyday habits. The usual aim is to model users and their decision-making, intending to promote a household sustainable behaviour. However, there is a major difference between the hours spent at home and the workplace. According to the ATUS (American Time Use Survey), on an average day in 2013, employed persons, ages 25 to 54, spent 8.7 hours in working and related activities, while 2.8 hours in household and other activities. Energy behaviour in the workplace has been analysed by the American Council for an Energy-Efficient Economy, aiming to employ communication tools, such as emails, websites and prompts as well as deploy engagement techniques, such as feed-back, rewards and competition mechanisms. In April 2009, a retrofit program was launched at the Empire State Building, aiming to reduce energy use by 38% and lead to annual energy savings values at $4.4 million (Empire State Building Case Study, 2009). The program studied the role of occupant comfort requirements, system design characteristics, changed operating schedules and incentives in building energy use. In Europe, myEcoNavigator was launched in 2013 with the aim to provide independent support by modern means of communication to help consumers find truly sustainable and efficient products.

Platform Implementation

Aims and Objectives

The platform aims to provide a real-time feedback system based on an open-source model of knowledge that is able to track, log and monitor energy-management issues and will engage users into disrupting their everyday habits, aiming to reduce energy consumption.

The idea is based on two layers: user engagement through energy visualization and productivity boost through the understanding and controlling workspace. On the one hand, visualization of the building's electricity and gas use with kWh, costs and CO2 data will demonstrate the links between the behavioural aspects of the employees and the overall impact of the company workspace. On the other hand, taking back control of their workspace will enable users to be more efficient and productive. In that framework, the suggested platform will act as a catalyst in minimizing the Sick Building Syndrome (SBS) effects, a worldwide problem of building occupants experiencing acute health and comfort effects that appear to be linked to time spent in a building (Molina et al, 1989).

Users will be encouraged to take advantage of natural lighting, use less air-conditioning, make sure that all equipment is turned off at the end of the day rather left on standby, telecommute, use the carpool system, use fans in the summer, turn the thermostat down slightly, limit car use, use the recycling facilities accordingly and change a huge pool of everyday habits that later the overall picture of a sustainable workplace.

Parameters

Field studies have shown that it is impossible to achieve thermal comfort for 100% of the occupants within a thermal environment, even if their clothing and level of activity are similar (Bakker, 2010). Although there is a large pool of parameters that alter thermal comfort and influence energy consumption, the platform provides data for the following parameters: CO_2 emissions, electricity and water consumption, temperature and noise levels, as well as workspace occupancy. It was also necessary to get an overall picture of the user's thermal comfort. In that respect, there is a 'user happiness' option, where the user can show if he feels comfortable in his workspace.

Processes

The platform is defined through a series of adaptive and event-driven processes. In order to achieve maximum user-engagement, the system goes through the following steps:

- Data Collection through Wireless Sensor Network. Each office will be connected to the platform through wi-fi sensors measuring each parameter of every workspace user separately. High-resolution data acquisition and ubiquitous computing are the powerful components to set up the platform.
- Data Verification and Analysis. The modeling of the system possesses extended capabilities of synchronizing, mining and parsing acquired data in order to process the stored information.
- Energy-to-Cost Conversion. One of the most demanding processes of the system is the cost calculation of the energy saved. How much energy has the user saved by switching off the air condition, or how much has he reduced his CO_2 emissions by using the carpool system to go to work?
- Data Visualization. Captured data will be available to users through graph APIs that will visualize the relevant information. Analyzed data will be projected on a daily, weekly or monthly basis.

Structure

The platform is defined by the following elements:

- User-friendly Interface. The interface follows a clear and simple layout. The sidebar on the left gives details regarding the company, office and user, as well as quick data regarding energy

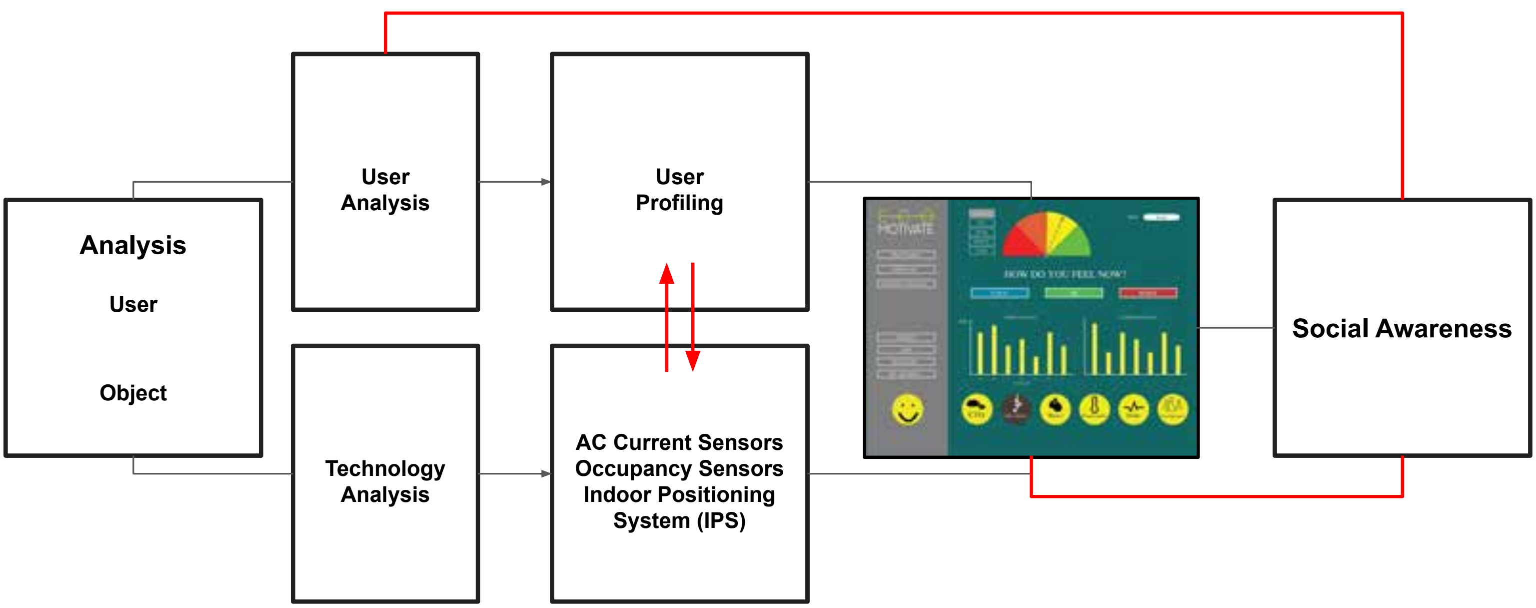


Figure 42
Designing Social Awareness through UX Research

cost, awards and levels. Through the top right buttons, the user can login, register and search data within the platform. By choosing the main parameter buttons, the user can be informed on the current, daily, weekly, monthly and yearly basis, while he can get quick information on the level achieved through the green attitude meter.

- Manager / Employee Environment. While the welcome screen is common both for the managers and employees, depending on the position of the user in the company, when he/she logs into the platform, the relative interface is loaded. The employee can track his/her energy data, cost conversion and awards, while the manager is able to switch between the employee and manager environment through the upper right buttons. In the manager environment, he/she can track and compare data among different employees of the company, as well among different companies of the platform League.
- Levels of green attitude. According to the data gathered for each parameter (CO2, Electricity, Water, Temperature and Noise), the user can track his/her level both for each separate component and the average level of the components. The green attitude meter informs the user in an intuitive and direct way and works as the synopsis of his environmental behavior.
- Badge system. The badge system works in accordance with the distinct levels. When the user evolves from one level to an upper one, he/she unlocks badges. This means that he/she is awarded a promotion by being able to track more data. For example, a red employee (lowest level) can only track his data and the other red employees data. When he/she jumps to the orange level, he/she can track both reds and oranges and so on. The same applies to the Manager (CSOs, FMs etc.) levels within the platform League, who can unlock badges as single users/employees or as company teams by improving the average employee energy use of their group of employees.
- Reward System. The reward system intends to become the commercial part of the platform and is inextricably linked to the badge system. The badge system works on the aggregate model basis. In that sense, employees can just add and not subtract credits from it. The accumulation of credits through the badges collection generates benefits that are interpretated into products and bonuses of the platform League companies.

Platform Calibration

During the design of the platform, a few problems had to be solved. The first issue pertained to the variability and volatility of the workspace under examination. The above-mentioned methodology is easily applied when workspace is distributed to rooms of one or two persons. The evolution of workspace within the context of mobility, client-focused work and working from home demands a more complex approach to data collection. Organizations reuse and transform the existing stock of workspaces, by creating Open Houses, Co-habited spaces and Co-working hubs. In that case, data will inevitably be captured through the combination of sensors and data loaded manually by the user. Moreover, due to the fact that the platform is a web event-driven mechanism, it was necessary to verify the events during the data analysis phase. Currently, the code goes through further analysis and development to integrate verification tests. For example, noise levels should change during the day in a meeting room, or water consumption should be limited during the weekend. Finally, the internal mobility, as previously mentioned, is a factor that cannot be measured. If a user has more meetings during one week but stays more at the office another week, the projected energy consumption reduction will be actually less than in reality.

Data as a definitive factor

The intersection of space with the ICT concept in the field of sustainability is not a new field. However, the spaces that have been investigated so far in this framework, are mostly residential or office buildings (Nguyen T., Aiello M., 2013). The prediction of user behavior in the field of hospitality is a field that has not been yet explored despite the fact that hotels intensely integrate many functions and activities of different people. Getting a big sample in less time is the most effective tool to predict human behavior and construct mobility patterns and behavioral models.

ICT offer to humans the ability to capture and transfer real time data towards different directions. Each human activity (work, living, leisure) is connected and measured through installed sensors, and the data cloud allows the possibility for this connection to be visualized and transferred towards both users but also hotel managers. To understand this connection we observe the existence of: a) visualized data, b) the space working as a layer where the users can extract and insert data, c) the space that hosts the required technologies. Important role in the juxtaposition of the three conditions is the existence of a user who on the one hand experiences the data set, and on the other projects his / hers story onto a data set. Therefore, the user becomes the core participant in that outcome. The team chose to work with electricity Wi-Fi sensors, as well as sensors that relate energy leak detectors. Among these also water leaks, electricity and temperature. The sensors have the ability to work in a 360 degrees of information extraction, both spatial but also focused on the user.

This means that at the core of this discourse is located the data itself. The data does not reveal the possibilities of interaction, and thus does not create new architectural stories without the permission of the participant. However, it allows the user to have access to a larger sea of information, than previously possible. They eliminate space in terms of square meters, but they enrich/facilitate social activities and services in existing space. In architectural terms they shift the attention from the form and shape of the design of spaces, to the strategy of how the cloud can be used more efficiently. In other words, traditional practices of design that used to place the user's needs at the center of the process are now focused on the access and use of the cloud. Hence data is becoming a central actor for architectural attention where the setting is the hotel and knowledge. This data has become knowledge and then shape the alternatives to users. Two are the highlights in this perspective. One reflects in a wider sense on how we can review the places of cooperation, and the second reflects on the mechanisms that make this trajectory work, which derive from the user practices that is at the foundation of this structure.

The outcome of the process demonstrated that the accuracy of the behavioral model and thus on the redefinition of space through data, depends entirely on the accuracy of the measurements. Data becomes the new 'metrics' of the building. Those data are strongly connected both to information related to the user but also to the performance of the space itself.

User Experience Research and Persona

Aiming to deduct realistic data regarding user behavior and investigate behavioral patterns, the integration of a real-time mechanism in the space under investigation is fundamental.
As a result, we suggest that the platform consists of three interdependent entities: The sensor network, which is placed on key areas of the building and transmits data wirelessly - the data cloud where data is stored, and finally the interface, which the end user will be interacting with.

The decoration along with the typology of the collective space becomes obsolete as a focus during this step. Conversely, people could be everywhere and communicate from everywhere as long as they have access to the network of Internet and apps. This transforms every space with a solid use (e.g. dining) to a multifunctional space (e.g. interaction room). The standards of being clean punctual and according to the hospitality rules would not be related anymore to the images of well-designed hotels, which will be a process of disembodiment. A new entity is born every time by the way users interact with the digital layer. This crossing of uses is not new, but what is new is the elimination of time and access to information that changes the spatial perspective.

The innovation of the application is based on two principle differences in comparison to existing applications and technologies. On the one hand, visualization in real time, a feature that will enable the end user to have a direct feedback on the relationship between the behavior and corresponding power consumption thus allowing to compare their consumption with the average of all people residing in the hotel unit under the same circumstances. On the other hand, it will give the possibility to measure the energy consumption on an individual level and motivate the end user through the platform by the means of a rewarding system, which is planned to be soon integrated into the platform based on the investigated behavioral patterns.

The platform incorporates the design of an experience that is personalized to each user's profile, preferences and sustainability behavior. By evolving social and digital intelligence tools, the platform could contribute to the improvement of sustainability performance through tips and advising on how to achieve a higher level. Personalized comments, RSS feeds, user tagging and subjective information can be used further to calibrate the application system and render it more efficient and easier to engage.

Conclusions

Although ICT is established within all areas of interest, its impact is fundamental since it totally transforms the perception of the places when the users are inserted in the data mining process. This catalytic presence of ICT and the way it sets a number of interrelated activities reveals the necessity of our field for parametrizing space, and offering spatial methodologies that facilitate the interaction between user and ICT. These include scale, context, method and the piecing together of different ideas and approaches both spatial and theoretical as to implement a spatial strategy able to fulfill the desirable linkage.

After a number of design documentation, we proceed in a flow, movement, geometrical diagram to reveal the latent connection between hard and soft infrastructure and energy consumption, elements that add to an energy reduction (physical light, shadowing, temperature, materials) and understood that the results of the documentation are exclusive and specific for each typology, and therefore require a narrowing down of the survey to each spatial module differently. This helped us create a methodology plan for the work with space once the sensors are installed.

Specifically, it is proved that local spatial form, local type, and social norms, define both performance limits but also positive modifiers for reduction of energy that outweigh the ability of technology to overcome. That became the first prerequisite for the establishment of the development approach.

Study II: Design Scenarios for the hotel room

Part of this study was published at the Proceedings of the International Conference on Cultural Heritage and New Technologies CHNT 23, Vienna under the title:
“Combining Indoor Positioning Systems (IPS) with Structure from Motion (SfM) 3D Point Clouds in Cultural Heritage”,

and as a poster at the International Conference DigitalHeritage 2018 New Realities: Authenticity & Automation in the Digital Age, San Francisco, under the title:
“Combining Indoor Positioning Systems (IPS) with Structure from Motion (SfM) Techniques in Cultural Heritage”.

Abstract

The second study intends to build design scenarios and integrate interaction in the architectural design through the use of metaphors. In fact, it proves that ICT can be an object for theoretical speculation in architecture and specifically in the hotel typology, when juxtaposing studies for the physical space, behavior patterns and real time data. The architect in this way becomes an intermediate to social, spatial and technological collaborations. By establishing a set of user-oriented methods and data-driven scenarios, it intends to reinvent the role of the architects in the field of user behavior. The selected monument under study is located at the seafront of the 700 years old Venetian harbor of Chania and used to be the private residence of Ambassador R. Krueger who built it on 1890.

Following this aim, the study is divided in three parts: the first part investigates how new sensor technologies and indoor positioning system can be applied in the hotel and specifically, which are the new possibilities that it offers at the scale of the hotel room; the second part combines the IoT technologies with an SfM (Structure for Motion) experiment, aiming to examine whether 2D data produced by IPS can be enhanced with 3D data from SfM in order to provide an enriched experience of navigation and personalized services customized to each user's needs; and in the third part, considering the above, the hotel room is rethought through the lens of technology and presented as a butler. The overall aim of this study is to design and assess synergies for smarter spaces, architecture and technologies, by constructing techniques for better space performance.

Introduction

One of the latest technological advancement in this goal is the creation of digital or spatial augmented reality technologies, able to reproduce in real time information and offer them to users. It has enabled the development of spatial data advanced digital tools, thus creating an evident benefit for the urban cultural heritage sites. 'In the ancient nuclei of many towns, these sites are like pieces of a puzzle that has become illegible; they pose serious problems of knowledge and documentation, in addition to problems related to monitoring their state of conservation' (Gabellone 2009). Among the many sectors where these concepts are used, hospitality has gained presence for the ability of these technologies to interconnect managerial objectives and visitors and allow corporations to formulate possible space configurations that can respond to low energy consumption. Beyond the field of sustainability, spatial virtual reality concept describes a rather multidisciplinary context. It celebrates the physical and material consistency of a place with its typological and aesthetic dimension, enhances this conflict between hard infrastructure and contemporary energy challenges and imposes an innovation of methods and tools for a better environmental behavior. It invokes users to recognition and interpretation of what constitutes a participation to a "higher objective" as if it is their own personal contribution to a better space.

The expected result of the analysis is to build a line of reasoning on how the study of the two interconnected layers (architecture and ICT), can be set as priority in the architectural design process and in the concept generation. Specifically, this analysis aims at opening up a typological discourse in the interaction between users and new technologies, allowing the fundamental role of architecture to emerge. It also highlights the role of the actor (ICT/data) as a determinant factor in the perception of the new spaces, specifying the role of the "active participant" (user) (Saskia Sassen, 2011) as a testing tool for the successful function of a project for reducing energy consumption in the hospitality sector. It brings in the table the way the smart city seems to offer a possibility of discussing about space and how the architect would offer and advanced ideas for sustainability and regeneration, bridging the gap among the social, economic, cultural, and physical understanding of ICT (Geropanta V, Cornelio Mari E.,2014).

In order to simultaneously conduct the two studies, two distinct research groups were formed: the first group explored the potential of Indoor Positioning System within the building while the second group created a 3D Point Cloud from SfM, while. The first part of the paper presents the analysis, results and limitations of the SfM 3D Point Cloud process. The second part explores the IPS technology within the monument. The last section of the paper focuses on the potential of combining the outcome of the experiments into the same digital environment, aiming to produce a model that 'can be used for the generation of a large amount of diverse information in both qualitative and quantitative formats' (Rodriguez – Moreno et al. 2016). The hotel room is redesigned as a butler, aiming at giving an additional level of information, while at the same time assisting the room guest.

For both fields the case introduces a series of issues of interest. On the one hand, it shows the spatial survey that new technologies require in diverse settings, and on the other hand, it hints at the changes in social behavior that the presence of ICT in these spaces would bring about. Latent under this integration of space and ICT, there are user - driven actions, and human interaction with artificial intelligence. The combination of these two factors, aim at highlighting the emergency in talking about the changing patterns of our field, the future involvement of architecture in the discourse about the smart city and introduce a new methodology on working with the environmental footprint in the hotel's sector.

Technological Analysis

Indoor Positioning System (IPS) Process

The first part of the research study presents the implementation process of an Indoor Positioning System (IPS) within the monument interior space, aiming to track user location within the building and record real-time visitor flows. The research team intended to create a digital building map providing the accurate location of each occupant who navigates into the building's interior space via smart mobile phone device.

In this framework, the team used the indoor positioning platform Indoor Atlas and its component mapping application, Indoor Atlas Map Creator 2, which operates on Android OS.

Implementation Process Overview

The implementation process consisted of the following three steps: 1) The team signed up and uploaded floor plan images aligned with geo-coordinates on the world map to the link: https://app.indooratlas.com (setup), 2) users downloaded and installed on their mobile phones the Indoor Atlas Map Creator 2 application. Then they logged into the account and generated signal maps from collected data while they physically moved in the space (mapping). 3) The Software Development Kit (SDK) was generated.

The research team accomplished the above-mentioned process using the mobile device 'Samsung S7 Edge'.

Implementation Analysis

'The indoor positioning system (IPS) is composed of two components. The first processes the raw data from the inertial measurement unit (IMU), which ends up in relative position coordinates, which are passed to the second component. The second component transforms the relative coordinates into global ones and brings them into the context of the building' (Bernoulli et al., 2010). IPS technologies collect data using the smart device sensors from the surrounding environment such as magnetic, beacon, Wi-Fi etc. with the help of the user's relative

Figure 43
Designing the hotel room as the perfect butler

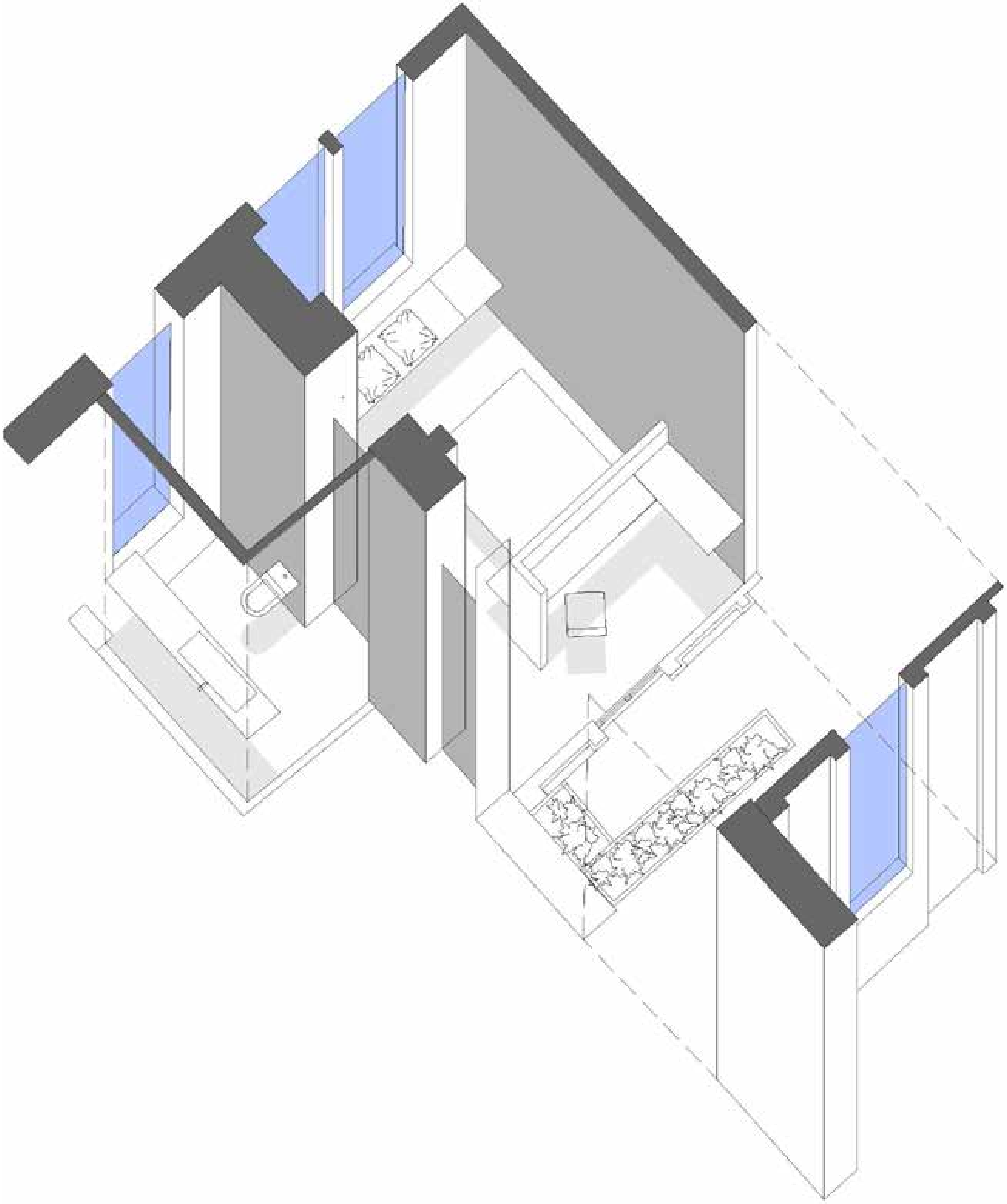


Figure 44
Hotel Room Isometric

movement while moving physically into the space. The selected data are then compared against digital maps, which have been produced by algorithms on Indoor Atlas cloud platform so as to obtain user's location. The best location accuracy can be achieved when more data have been observed (Indoor Atlas, 2019a). After several tests and detailed recording of the steps and the constraints presented during the implementation of the mapping application, the research group achieved the creation of a digital building map for two levels of the hotel accommodation. Below, these main constraints and therefore keypoints of attention are gradually presented.

1. Floor plan alignment with geo-coordinates

The main requirement of the setup step is the alignment of the building satellite image with the correspondent vector plan. However, the map provider isn't always able to show accurate photos of the case study building as in some geographic regions satellite images have low quality or insufficient details. If building's outlines are not clear, the floor plan alignment risks to be imported inaccurately and at a wrong scale (Indoor Atlas, 2019b). If the satellite view does not provide enough details to accurately align the image, the "Exact coordinates" alignment method can be used to achieve maximum superimposition of the two maps (Indoor Atlas, 2019b).
Another significant factor is the simultaneous uploading and alignment in case of multiple floor plans of the study space. In this case, floor plans must be meticulously uploaded with the same and correct alignment, paying particular attention to elevators, staircases and escalators, so as to achieve smooth and easy floor transitions. It is equally important to provide the "Floor Number" when the building has multiple levels as the correct floor number determines the exact superimposition of various levels.

Hardware requirements and settings

The devices' requirements for creating a digital map according to the official website are: a) Android software and OS version 5.0 or newer and b) Hardware sensors (accelerometer, magnetometer, gyroscope). The list of devices that are able to accomplish the mapping process is

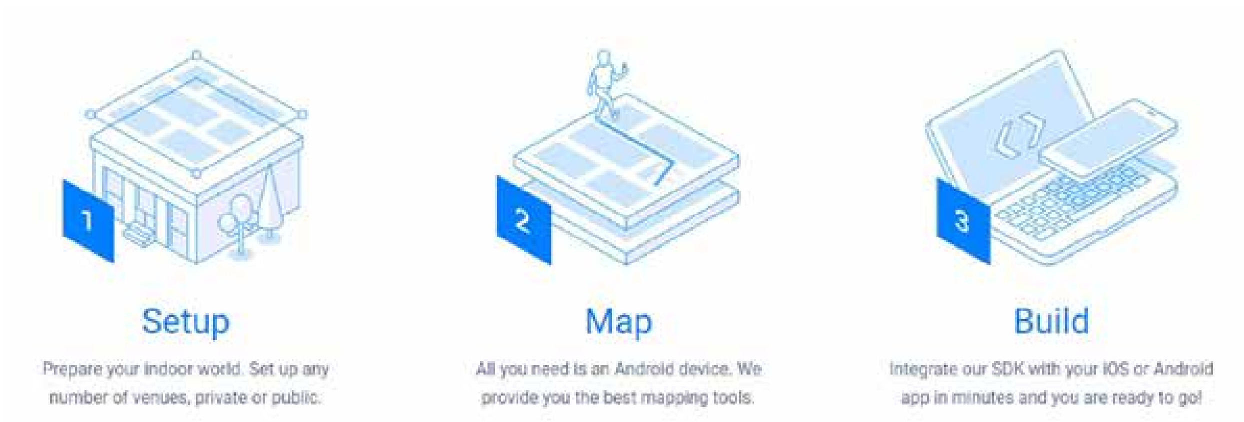


Figure 45
Indoor Positioning System Process

narrower than the one suitable for the positioning.
On the other hand, for the positioning mode, Indoor Atlas SDK can run on both android devices which support API level 21 (Lollipop) and on iPhone 4S or newer models. Indoor Atlas automatically uses all available sensors to provide the best possible positioning experience, but for the most accurate one, gyroscope and magnetometer are needed (Indoor Atlas 2019c).
Another crucial point is that the Wi-Fi scanning features in the device settings must be enabled and have a strong signal, otherwise the recorded paths are not optimal and the resulting map quality is affected.
Low Wi-Fi scanning quality or frequency, which varies across phone models (Indoor Atlas 2019d) lead to continuous MapCreator warnings pop-ups on the device's screen that hinder the mapping process and demand more time mapping on the same areas to achieve satisfying performance (Indoor Atlas 2019d). In order to ensure that the scaling was right, the distance between two waypoints was measured with the use of MapCreator2, during the Mapping Process.

Mapping Process

The mapping process requires the digital juxtaposition of the two-dimensional drawing with the global coordinates. The key points for this alignment are called waypoints and are identified by manually tapping on the digital map while standing at the physical space corresponding point. The most important part proved to be the correct alignment of the first waypoint. According to Eric Piehl 'After the first fix is computed, the heavy-duty algorithms kick in and very accurate positioning estimates are calculated using the geomagnetic and other methods' (Piehl, 2018).

During the mapping process, the following errors occurred: 1) some waypoints were placed at inaccessible physical spots. As a result, the user was not able to recognize them with accuracy when proceeding to checking in that points, or run out of time because there is a five-minute time limit while recording a path, 2) pop-ups appeared on the device's screen warning on the fact that the compass heading didn't match the path. Positioning the phone face up during the whole mapping process solved the issue. According to the software developers "if such a path is stored, the resulting map quality will be low and thus likely leads to red mapping analytics and inaccurate positioning." (Indoor Atlas 2019d) 3) it proved difficult to achieve an accurate location positioning of the user after the first mapping within the building. As recommended in official Indoor Atlas support solutions webpage (Indoor Atlas 2019d) an ideal Wi-Fi mapping coverage cannot be achieved with the recording of a single pass through a bigger space or even a corridor. Especially in wider spaces it is recommended parallel paths to be recorded in order to achieve the best geomagnetic coverage.

The building structure also played a key role in the mapping in terms of materiality. The material that has the ability to interact with the magnetic field of the earth and create a unique magnetic landscape is steel. However, the walls of the specific building are stone-built. The research team conducted an analysis of the structure prior to the experiment implementation to reassure that the mapping attempt would be successful. It was proved that during the building restoration and reuse as a hotel, metal beams covered by false ceilings were used for the reinforcement as shown in the image.

According to the study, important elements that contribute to the mapping process in the building are lifts. In addition to the metallic elements contained in the lift, another factor that can contribute is the barometric pressure resulting from the change of level. The barometer sensor of a smartphone can detect even the smallest changes in atmospheric pressure, which is modified whenever the user moves in a vertical direction (via a lift or a ladder).

SfM Experiment and Combination of the two methods

Initially, building pictures were captured from different perspectives - both ground level and aerial ones - and were inserted into the selected software for further processing. The same procedure was repeated using different hardware and software. Results were compared in terms of the process length, the number of steps required to achieve the optimal result and the quality of the results. Supplementary pictures were taken and processed in, aiming to manage the preferred outcome.

Experiment Process

The software used processes pictures and creates the 3D model by focusing on finding common points between pictures. Hence, the photos selected for import should be as focused as possible, and have at least 30% overlap with each other.

After the selection of the images and their insertion into the software, Agisoft PhotoScan Professional needs four steps for the creation of the 3D model. The first one is the command "Align", which aligns the points of the inserted pictures. The second one is the command "Build Dense Cloud", which creates the 3D Point Cloud. The third one is the command "Build Mesh", which creates triangles from the union of the point cloud and the last command is "Build Texture", which applies texture to the 3D model.

RealityCapture follows a similar process. The steps are the following: photos insertion, alignment, reconstruction (mesh creation), reconstruction result, coloring, coloring result, reconstruction region set, reconstruction region mesh creation, reconstruction region mesh result, reconstruction region coloring, reconstruction region coloring result, and finally control definition and component consolidation.

Recap Photo is similar to RealityCapture but offers additional editing options of the model (mesh editing, etc.), and further combination with other Autodesk software (Maya, 3ds Max). Unfortunately, the educational version of the software allowed the insertion of only 100 pictures per project. The software is cloud-based in all matters that regards the creation of the model, and operates with the charge of the user with credits, depending on the number of pictures each project includes. The 3D model is not created on the computer, but on the cloud server of Autodesk. After the model is created, it is available for downloading and further editing on the user's computer.

After seven attempts, the 3D model optimization technique was established to the following steps: 1) Usage of one high-resolution camera, with big sensor, good lens (prime, not zoom), and polarized filter (for the elimination of reflections from windows and glassy surfaces) , 2) picture overlapping at least 30%, 3) picture capturing of the whole building besides the more focused ones, 4) picture capturing on cloudy days in order to avoid shadows and reflections,

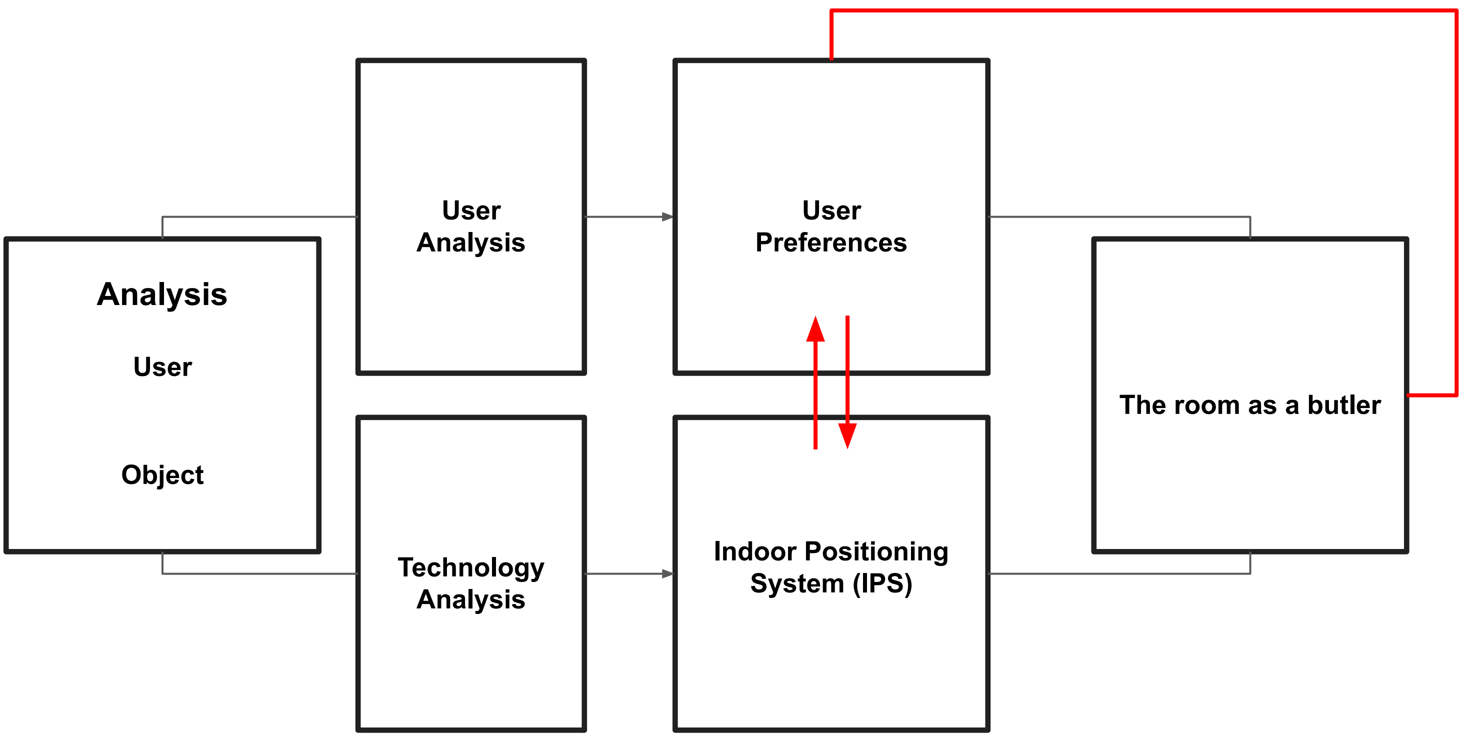


Figure 46
Designing the hotel room as the perfect butler

5) picture capturing in the minimum time possible on the same day, in order to avoid position change of movable objects and shadow differentiation on each facade and finally 6) in the case of use of drone, camera specs should be finetuned (i.e. resolution, stabilizing system), pictures should be taken from a low level and should include as much building view as possible.

Combination of the two methods

This case study was used to allow the establishment of a new spatial framework where the two methods will interrelate, influencing and feeding into each other. On the one hand, SfM is an already applied photogrammetry method producing imagery using low-cost metric cameras and aims at the sparse reconstruction of the building's point cloud model (Hopkins Nyimbili, 2016). On the other hand, the Indoor Positioning System is a new method, currently in beta version, that produces Human - Building Interaction quantitative data and tracks in real time the users' location within the building. SfM produces geometry through scanning, while IPS uses Internet of Things to extract informational data of the building. While both methods are developing technologies and none has reached its full potential, they remain completely different, both in terms of their operational process and the outcomes. Their only common point is that they both relate to the geometrical attributes of the building and extract information on it. We argue that the SfM produces form, while IPS deciphers the function of the building.

Which is the optimal way to combine these two methods into a common spatial framework? And how would this combination contribute to the establishment of the building-as-a-service model? The integration of the two methods into a novel three-dimensional space can be executed in a twofold way. First, as a means of integrating building function into form. In that framework, the relative user position and movement paths extracted by the multiple two-dimensional IPS layers can be geo-referenced with the 3D point cloud model created by the SfM method. What is necessary, here, is the development of new BIM libraries in order to take into consideration the level of detail required and the simpli□cation of the models. 'The BIM offers a distinctive factor, which does not exist in any other field: a multi-layered spatial character in the third or even fourth dimension, when historic phases of the building are considered. These 3D models must allow a continuous transition in scale between the survey of the whole architectural complex and its individual elements.' (Rodríguez-Moreno et al., 2016). Secondly, as a means of enhancing the user experience within the building, through the combination of the two methods with VR applications. Given that user location is trackable through the use of smartphones, IPS applications are able to calculate the building occupancy, densities and flows real-time. At the same time, the geometry of user flows can be referenced within the same axis system of the SfM model.

Envisioning a new hybrid hotel typology: the room as a perfect butler

Combining the above, we could envision the hotel to be converted in a smart environment, where the mapping process and the SfM contribute to a very precise perception of the interior space and the real-time information on the exact position of the guest acts as the agent for reshaping the room experience. In fact, the strategy of this specific design followed the premise that the room, instead of being static and monotonous, can acquire a subtle layer of technology enabling the attitude of a butler. How can this be achieved? There are two ways in which the butler explicitly yields multi-layered effects on the hotel room space. First, by reducing complexity and secondly, by defining, delimiting and protecting the boundaries of personal, private space.

The first butler service intends to disentangle the complexity of information and data that a guest is subject to during his visit. Hotel environments often create informational overload. The threshold of success is when IoT decodes the high complex environment. In that respect, the butler is designed to eliminate information according to user preferences. The butler interface will be projected through the hotel room TV and the interaction type will be instructing and exploring. The second service relates to the use of technology to create an intelligent tool that creates a clear zone of private space. In the era of ubiquitous computing, the boundaries between public and private space become unclear. This phenomenon is often seen in the hotel typology. Through the butler, users provide real-time information on their schedule, preferences and needs and communicate with the reception without physical presence. Both services promise the articulation of a simple, clearly defined private space enhancing user experience.

Conclusions

The concept of bringing architecture in the core of the discussion for the project of reducing energy on a user-based data mining has set the background of this interdisciplinary research. Under this spectrum, a set of conclusions opened up a discourse that can have repercussions at the practical and theoretical level.

In this study, the role of the architect can be defined as acquiring the following values:
1) Applying ICT and expecting users to interact requires a definition in scale, and material limitations, that can be highlighted by the architect for creating the survey part;
2) the space of the network, the space between the user and the devices, the new collective space born by the interaction of the user with ICT, the projection of data on the traditional spaces are part of the parametrical organization of the architect.
3) The space in the smart ecosystem is also a reactive environment where the user interacts with the sensors and with the network as an actor embodying artificial intelligence.

Here, an approach to experiment and combine SfM and IPS methods in the current state-of-the-art architectural technologies is demonstrated on the monument of Ambassador's Residence in Chania, Crete. The usefulness and limitations of the methods are presented in the two experiments. The contribution of the current study consists in overpassing the operational application limits of the existing technologies and trying to juxtapose a 'relative, image-space coordinate system' into a 'real-world, object-space coordinate system'. However, the two technologies have significant limitations, such as the need for multiple cameras in the case of SfM, or the use of specific Android Smartphones for the building mapping in the case of IPS.

Study III: Data, information and urban layers as drivers of design

Part of this study was published at the ICO'19 Conference under the title:

"Smart homes: Methodology of IoT integration in the Architectural and Interior Design Process – A case study in the historical center of Athens"

Abstract

This study presents a methodology to transform a traditional home to a smart home. Along these lines, two observations are highlighted: first, that there is an obvious need for new concepts of "enhanced architectural design" that are driven by, and appropriate for, smart homes; and second, that it is fundamental to reconsider the role of user motivation to bridge the gap between the functionalities offered by smart services and user's needs. Using a case study in the historical center of Athens, the article outlines an alternative approach to smart home design thinking that addresses the complex challenges of IoT integration in a more integrative, contextually relevant manner. Suggesting a more open, spatially conscious stance (through design) and a more collectively conceived IoT selection, the article advocates that when dealing with the complex challenges of everyday spaces for urban dwellers, a holistic approach to space design must be achieved.

Introduction

When observing how institutions approach the smart city inside their home country, the aspect of the design mechanism of the integration of such initiatives in existing space has been overlooked or discarded by the over-ambitious targets for prosperity and welfare. Researchers devote only passing attention to the creation of design rules that these strategies introduced to reach the users and maximize human and building interaction (Hook and Jonas, 2012). These rules are seen as factors that change little – and add little – to the spatial experience of the new smart homes. For instance, when specialists discuss how they can deploy information technologies to ameliorate a buildings' management and function, they devote plenty of attention to discuss how the new users accept/reject/use the IoT (sociological research) and whether financially these initiatives reinforce capitalism (Kaasinen, 2013). On the opposite, they barely notice if the integration process of IoT in existing space caused spatial transformations to the original place and therefore had an impact on user behavior that would provoke human – building interaction (Deloitte, 2019).

In the field of smart homes, this phenomenon is even more evident. Smart strategies are more shaped around a quantitative model (CO2 emissions, density calculations, etc) remaining in this way far from reaching the everyday user (Paone and Bacher, 2018). Even though statistics show that people remain home much more in relation to the past (Americans stayed at home 7.8 days more in 2012 compared with 2003), and although the technology is highly integrated in the housing market, somehow these two phenomena lead neither to a better human - building interaction nor to a better home design (Sekar, 2018). Therefore, this study frames analysis of an existing case study and examines the processes of integrated design-technology thinking. Here, I argue that the integration process is as a technical as immaterial and encompasses a complex series of procedures carried out by architects.

My intention is to contribute to the field of smart homes by focusing on two aspects: a) the architectural implications of the integration process of IoT and b) the ways user behaviors change after the application of IoT. To allow the two different approaches to cooperate, they analyze the project of the refurbishment of an apartment in the historical center of Athens and its transformation to a smart home. The expected result of the analysis is to build a line of reasoning on how the study of three interconnected layers (IoT, user behavior and architectural space), can be a departure point to define the traits of the smart space and how this allows the rise of an "enhanced architectural design technique". The study moves beyond the traditional way, which consists of 'designing, installing and operating each [building] system separately' (Sinopoli, 2010). It rather intends to unify building systems and maximize the interaction between the occupant and the space by creating an online tool that will function in a twofold way: on the one hand, it will bridge up the occupant with his living space, and on the other hand, it will extract user behavior data and living patterns.

Methodology

This study combines a textual analysis and an empirical methodology. Specifically, I try to establish state-of-the-art IoT technologies and design thinking that together has the potential of creating a unified adaptive ecosystem, able to interact with the user and adapt to his needs.

Firstly, before the design process, I created some exercises such as guided interviews targeted to the property owners on a dual perspective: to establish the design questions and the kind of smart services the property owners would like their home to have. I then proceeded in thorough research of the technological innovations currently available in the smart home market to identify which IoT devices would be more adequate for the specific context. As a third step, I inserted in the design phase the subjective data as collected by the interviews and our research on preliminary smart home prototypes. In the end, the juxtaposition of the findings led to a layer of 'new technologies' that will be applied to the design of the specific space.

While experimenting with the smart home prototypes in the field of Human-Building Interaction (HBI), three distinct layers of possible communication between building and user were established: the data, the information, and connection layer. The data layer concerns the control of basic building systems and energy consumption tracking. The information layer encompasses the process of turning data into visual information for the occupants. The connection layer aims to bridge up to the space user with the urban tissue and potentially the smart grid, thus establishing 'new cognitive hierarchies similar to those exhibited in the operations of human minds' (Mitchell, 2007). It is suggested as the last step that the three technology layers are integrated into one unified interface, accessible through smartphones and portable devices.

Once the technological setup was concretized, a knowledge database was created in collaboration with the property owners to describe and prioritize user needs and preferences. During this phase, all subjective data acquired through the interviews were analyzed, to deeply understand how the user perceives new technology functions and how user preferences and needs are ranked. Having completed the two previous steps, the research focused on the creation of the new technologies' layer, which was derived from the juxtaposition of available functions supported by the selected technologies and user preferences regarding their interaction with the space under study.

Case study: N apartment and the design strategy of a Smart Home

The N apartment is located on the fourth floor of a typical housing block, the 'polykatoikia' (Rampley, 2012) in the center of Athens at Plaka neighborhood. The historically and culturally significant buildings of the surrounding area inspired the property owners during the design process. The apartment is 95 m2 and is exposed to the west through large openings that connect the interior with a 20 sq. m. open terrace facing Nikis st. The apartment is the only property on the fourth floor and connects with the building public staircase at the northeast part of the building. Even though the building was designed to face the street only from the west, the back (east) side also gives views to Skoufou Street, due to the low height of the adjacent building.

In the framework of these criteria, the first step of the architectural design consisted of shaping the basic layout according to the users' needs and the main building regulations. The structural elements that are freestanding in the middle of the space, as well as the facade composed by large openings that cannot be altered due to the Greek Building Regulation, were the basic spatial limitation (Greek Building Regulation (Greek version, 2012). In terms of infrastructure, the fact that the sewage and water pipes are located at the northeast side next to the public staircase led the positioning of bathrooms and kitchen at this side, leaving the southwest part of the space for the living space, office and two bedrooms. Therefore, the architects chose to situate the living space and kitchen centrally, thus creating an open space that will be connected with the office through sliding panels that unify or separate the living - working space. This layout also enhances the notion of privacy, since it separates the living space (north) and the night space (south) vertically.

The owners, people of higher education engaged with culture and music, intended to create an innovative, in terms of user experience, residential space for short term or long-term lease. They desired that tenants would constantly interact with it while staying at home. Specifically, several guided interviews with the owners and their elaboration led to the establishment of the following desired characteristics:

1. Tenants will be able to monitor and control the outer shell and the electrical/mechanical systems of their space.
2. Tenants will create building scenarios based on certain automation rules. For example, the system will know that every day, at a specific time, the roller shutters will open, or by informing the system that the tenant leaves the house, lights will be switched off and the shutters will close.
3. Tenants will learn about the way energy is consumed within the space and how with their actions they can respect better the environment.
4. Social connection and interaction should be achieved between tenants and the rest of the city.

These characteristics require the extraction of data related to the user behavior and control of systems. Given that the scope of this study relates to user behavior understanding and not technological innovations as such, it was crucial to identify the most accurate and easy-to-install system. To model the data layer, we consider the physical space as a network and based on the best performance of connectivity the team chose Legrand Smart Home because it offers a wide range

of Connected plugs, Connected switches and Connected devices (Valena Life Technical Specifications, 2018).
Although IoT is installed within traditional locations, such as walls, kitchen and bathrooms its impact is fundamental since it transforms the perception of these places (Virilio, 1999). The IoT integration strategy was designed into three main sequences that depict all the transformations following the order of a pyramid: slowly expanding from the relation data - user to the user - building and then user - city. This means that it starts from the micro-scale of the interior design, to pass to the building scale and then to the connection with the public space. The correct documentation of the materiality reveals the aesthetics of the architectural design process.

New forms of design stages emerged - The interaction design and the formation of smart space

Once the basic layout was specified, the design team investigated the strategy to apply the technological innovation features. On the one hand, the architectural design by definition uses the architectural scale (1:100 or 1:50) and then further investigates scales with an increased level of detail (1:20, 1:10 or 1:1). On the other hand, in the field of electrical engineering, the design of interactive features is conducted at micro scales or even nanoscales. To bridge the two worlds, the authors worked at the interconnecting 1:1 scale.
Firstly, certain points of the space were picked up, the so-called 'interaction points', where we could better understand the design. At these specific points, the design of took place at multiple scales: a) the architectural design that provokes human interaction with the architectural space in terms of function and form, b) the moment of interaction of the building with the technology and c) the design of human-building interaction (HBI) in terms of the infrastructure (electrical - mechanical system) and shell.
The interaction points were selected through empirical analysis of the architectural space in the process of shaping. The medium used to allocate and identify the points was the three-dimensional model of the space. In this context, 'the model is not just a three-dimensional picture of geometry, but a rich representation of the building that contains all kinds of interesting and useful data'

Figure 47
Smart Home Design - Interaction Points

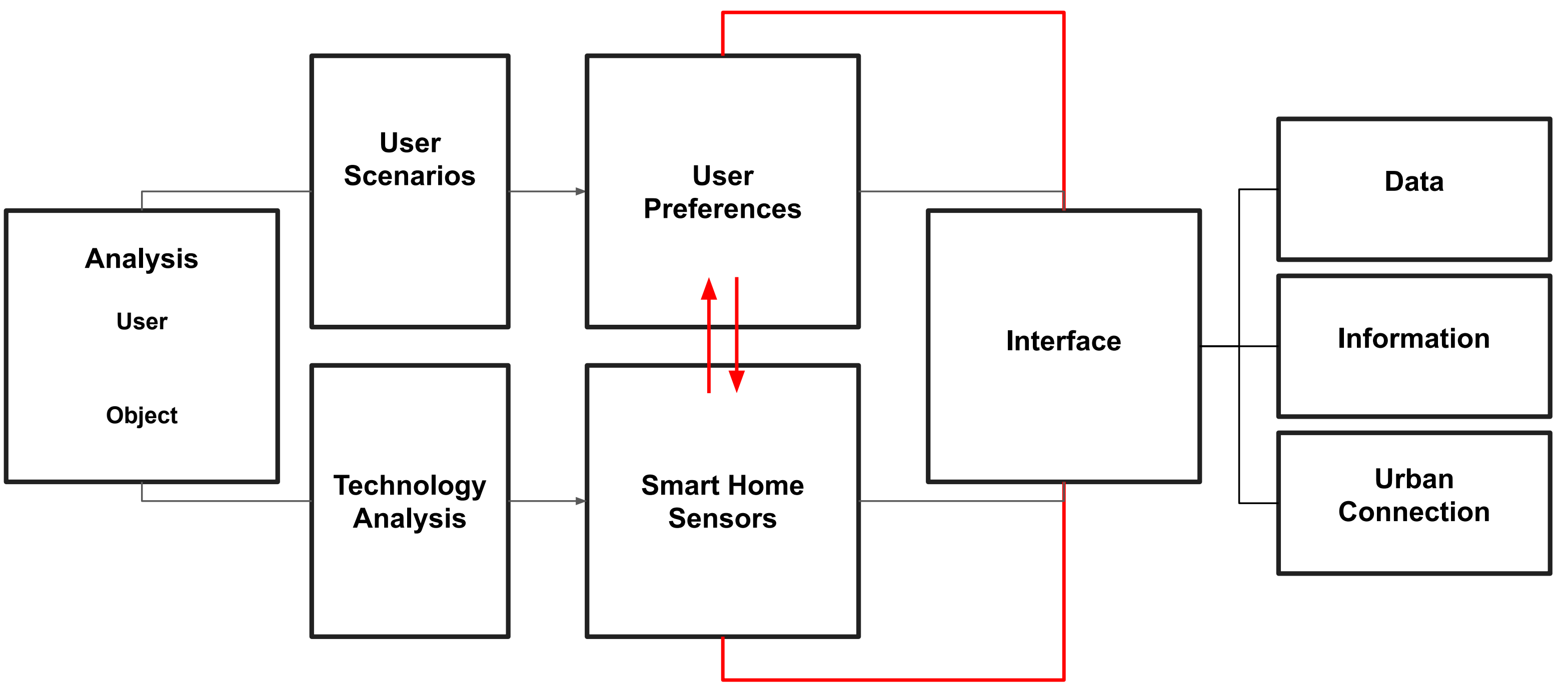


Figure 48
Data, information and urban layers as drivers of design.

(Pittman and Kolarevic, 2003). The group of interaction points created an interactive network. The activation and deactivation of certain network points will serve as the basis for the scenarios built by users.

Moggridge and Verplank coined the term "interaction design" in the late 1980s to define this intersection between user and device (Steenson and Scharmen, 2018). In technical terms, to extract data, three components are essential: sensors (hardware), interface (software) and end-user device. In our case, the sensory system was wireless electrical components, such as plugs, switches, and doorbell, while the selected end-user device was the Smartphone.

Following the interaction design principle, the authors established three layers of interaction to respond to the owners' requirements:

1. The data layer, transmitting real-time information on the space energy flows, that represents how users can access, store, transmit, and manipulate information.

More specifically, the implementation consists of establishing the main node that connects the electrical subsystem (plugs, switches, shutters, etc.) with the wireless internet network and the end-user device. Commands are either voice-activated or executed through the physical switch or the smartphone. The central node also connects with supplementary attributes, such as connected lamps or the wireless intercom. It is the nexus of the user with the automation scenarios, that can be set up through the smartphone (Legrand Home Automation, 2018).

2. The information layer activated through QR code scanning and functioning as the 'sustainable voice' of the space by releasing practical information on how to reduce energy consumption. This requires a collection of data in the "cloud" and how this data is then transferred to all different devices and each user. This process enables architects to envision traditional spaces as knowledge tanks and learning resources, something that alters the processes of the conception of space.

The implementation of the information layer followed two steps: the identification of the strongest design points in terms of sustainability, such as the double-glazed energy-saving windows and the natural gas A-class underfloor heating system and the translation of the real-time data acquired by the central node of the data layer into visual information through charts and diagrams.

3. The urban connection layer, that will connect the user with the cultural aspect of the city,

focusing on any ‘smart’ initiative. This process enables architects to envision homes as transit spaces with the outside and IoT becomes the agent of connectivity in this case.

The urban connection layer uses the end-user device to connect with urban activities. By identifying the user preferences and habits at home, this third layer will be customized to satisfy user needs.

These three layers of interaction gave rise to novel uses of physical space because of the installation of IoT and the integration of telecommunications (telephone lines and wireless signals), necessary enterprise software, middleware, storage, and audio-visual systems.

The first new space is the immaterial network where all information related both to the user’s life and also to the buildings’ materiality is gathered as data and is offered in the service of the other users. For this to happen, it is necessary the use of diverse apps and the permission of the users. This new novel space confirms the social interaction between users and city and explains the process of building - user interaction as well. The second space is the one created outside of smart devices, the space between the user and the device. This new space is not subject to any specific measurements, but it is flexible enough, depending on the user´s task and the device. It regards the 3D projections with the relevant information that one takes as a result of the user- IoT - building interaction. It looks like a 3D hologram with the ability to interact and respond to human movement. This new in-between space strikes attention in terms not of it is physical and geometrical configuration but in terms of how it is offering information about the existing space.

‘Enhanced’ architectural design emerging from the integration of IoT in the interior design process

Here, I argue that when interrelating the three components of the smart space (space, IoT and skilled users) (Komninos, 2014), in the design process of the specific case study, then the tacit process that follows the architectural design is enriched, “enhanced” and might bring bigger human – building interaction.

Traditionally, the architectural design process appears because of the dialogue between users and architects, considering contemporary tools (Norouzi et al. 2015). The emotional liaison created by habituating the space, the various social norms and the economic and political situations were certainly protagonists in the cognitive process of the design establishment of both parts. In the establishment of the smart home afterwards, however, the possible connection and communication between users, buildings, and technologies raise as being the most important feature.In this new kind of space, sensors constitute both a newly-inserted technical object and a new form of communication that alters the way that space is perceived by the user. According to Paul Virilio, 'when a technical object is invented, say the elevator, the staircase is lost...There is no technological gain without loss on the level of living, the vital" (Virilio, 1999). Similarly, through the emergence of interactivity between user and space, some of the static attributes of space, especially the time-related ones, are lost.

In this case, the existence of a new intelligence layer was observed, creating direct connections between the systems and its users redefining the alleged 'smart space'. According to William Mitchell, this new intelligence layer is conceived as a living organism that consists of four components: the brains [ubiquitously embedded intelligence], the nerves [effective communication of digital telecommunication networks], the sensory organs [sensors and tags] as well as the knowledge and cognitive competence [software] (Mitchell, 2007). The distinguishing feature of this new living organism is that can be implemented only through human interaction with the above components. In other cases, I observed the intelligent ways of inserting sensors in the building cells leading to a building scanning and data collection for the building maintenance and life circle (Marrone and Gentile, 2016). This would allow cities to receive more local information and allow for a technological restructuring in the offered services.

Here, the architectural design process required three more considerations: the interaction points of IoT - building, materiality, and performance of the selected IoT and the way IoT allows for maximum interaction between user and the built environment. This triplet of thoughts advance architectural thinking and lead to a new, enhanced method that requires collaboration between different actors and interests (architects, property owners, actual users, companies of technology).

Conclusion

In this study, I venture the idea that architectural design might bridge the two above-mentioned realities bringing maximum interaction among all participants (space, users, and IoT). It seems inevitable that the focus will shift away from the technological innovations and that the main concern will be the education and participation of users with the new digital tissue. This evolutionary educational process predicts that architects would face a challenge in design to conform to the complex, connection and maximum interaction achieving process that the smart homes would require. As a result, it is evident that to create a liaison between the human and its surrounding space, an “enhanced” architectural design is required that bring together the three components. In the specific case they achieved this goal by using existing technologies such as smart home sensor systems and QR code applications [data layer], creating an extra level of knowledge on top of the used technologies [information layer] and integrating the above with the ubiquitously embedded intelligence of the smart city [connection layer]. This activity gave rise to several “smart spaces” that can be defined according to the number of interaction users might have with the building and the IoT.

Study IV: Reinventing the Municipal Agora of Chania

Part of this study was published at the eCAADe + SIGraDi 2019 Conference ‘Architecture in the Age of the 4th Industrial Revolution’, Porto under the title:
“Exploring the ICT potential to maximize
user - built space interaction in monumental spaces: The case of the Municipal Agora in Chania, Crete”,

and as a Chapter of the book ‘Research Advancements in Smart Technology, Optimization, and Renewable Energy, IGI Global’ under the title:
“Enhancing user experience
in public spaces by measuring passengers’ flow and perception through ICT”.

Abstract

The fourth study investigates user spatial experience transformations that occur in hyper connected public spaces and transform them to hybrid spaces (Geropanta, V., & Cornelio-Marí, E. M., 2014). Following this target, an experiment is conducted at the Municipal Market of Chania, Crete, evaluating user behavior on a population of 33 participants comparing their spatial experiences before and after the use of ICT. Through qualitative and quantitative methods (the use of the technology Indoor Atlas as well as questionnaires) behavioral change is analyzed among users with and without access to Crete 3D, an online ICT-based innovative informative platform, aiming to establish a theoretical framework of understanding user interaction with built space. This process enables knowledge transfer in a twofold way: it shows how to use metrics to evaluate user-building interaction and how, users can quickly gain a deep understanding of the building in use. Using this knowledge in the interaction design process, the Agora is then rethought as a historical thinktank and as a commercial hub, using the approach of designing with narratives. Interaction is intertwined with architectural design, aiming at highlighting its unique capability of combining historical value with the commercial typology.

Introduction

According to Nikos Komninos, intelligent cities are encountered at the intersection of innovation and collaborative digital spaces. “For us, a digital city is a collaborative digital space used to facilitate and augment the activities and functions taking place within the physical space of the city” (Komninos, 2008 p.247). In digital spaces, information acquisition is facilitated by sensors, digital networking and other technologies. But how can we evaluate user experience and user-building interaction in a physical space where digital technologies are not already embedded? The issue of combining wireless ICT with IoT technologies and immersively integrating them into the user environment are the crux of the problem. In this specific case, the objective is to decipher user experience within the public space of the Municipal Market of Chania, by establishing a temporary digital environment within the bustling physical space. Following this objective, the paper has been divided in seven sections. The first chapter analyzes empirically types of visitors and their interaction with the building’s physical space. The second and third chapter, focus on how ICT and IoT technologies contribute to the decoding of user behavior in this specific case, while the fourth chapter describes the in-situ experiment. Then, qualitative and quantitative data sets extracted by the alleged technology and traditional users prior to their visit are analyzed and compared. The sixth chapter draws upon the entire thesis, tying up the empirical and metric strands, aiming to provide a comprehensive model of user behavior in the framework of new digital technologies. Finally, the conclusion highlights areas for further research.

Background

The use of ICT in evaluating user experience is not a new phenomenon (Skarlatidou et al., 2019). It has received considerable attention in the field of Human-Computer Interaction (HCI). Specifically, the areas of product, software and web services rely extensively on user feedback. At the same time, the current advances in UX research have led to an increased interest in evaluating user experience within spatial contexts, both in the light of sustainable design (Jeong Kim), (Janda), in Post-Occupancy Building performance (Motsatsi, 2015), and finally in the context of smart buildings design (Jia & Srinivasan, 2015). In that context, researchers have shown an increased interest in developing ICT tools dedicated to user education. These new educational tools have led to the emergence of new learning techniques that transform user into a skilled person, able to be relevant at the fourth industrial revolution (Harrari, 2015).

The juxtaposition of the learning process through ICT within the urban tissue constitute the fundamental pillars of a smart city project (Komninos, 2014) and the identification of a smart / hybrid space (Geropanta V., Cornelio Mari E, 2014). As a matter of fact, from a theoretical point of view, there are three components for a smart city: urban space, ICT and skilled users (Komninos, 2014). These altogether frame the hypothesis that once ICT is applied at urban space, then the predicted flows and behaviors of the traditional setting alter in a more educative and holistic way. This marks the beginning of the passage from the spontaneous way of wandering in the daily social practices to a cognitive layer of information that subtly accompanies the user during the monument visit. This layer of information is continuous and invisible, able to achieve the state of 'calm technology' as defined by Weiser (1995).

Methodology

The methodological approach taken in this study is a mixed methodology based on empirical analysis as well as qualitative and quantitative data acquisition and comparison. During the first part of the study, the research team visited the building and conducted an empirical documentation of its morphological entities, aiming to extract patterns of flows within the site and highlight the points of maximum interaction between users and built space. As built space, we define: a) the interior space of the building and b) the interstitial spaces that connect the built space of the monument and the urban tissue.

During the second part of the study, the research team enga ged a group of 33 users, formed by young people that visited the building on a summer day. Two subgroups were formed: the users of the first subgroup entered the building and were asked to circulate freely, while the users of the second subgroup launched the visit after navigating into the Crete3D platform. Crete3D is an online WebGL platform, where the users can find replicated morphologies of the main archaeological Cretan monuments presented through a conceptual 3D model. Through the platform, users are able to navigate around the monuments and speculate them at different levels of spatial and contextual detail. The platform allows for switching between seven historical periods and offers a comparative study of their evolution in time. The platform's innovative feature was the potential 'to manage such a large amount of information over the internet, in a transparent, light and simple way for the end user, in addition to offering the ability to compare data over time, during the historical periods.' (Parthenios P. et al, p.1, 2012). Users' location was monitored real-time through the Indoor Atlas application that was previously installed on every user's smartphone. To facilitate the process, we will refer to the first group of users as 'traditional users' and to the second as 'tech users'.

After the visit, the team sent a link of the questionnaire in the form of a google survey to both traditional and tech users. The questionnaire consisted of 33 questions, grouped in three sections:

Level of Knowledge prior to the visit
Overall Experience Evaluation
Building Evaluation with emphasis to architectural elements

A total of 33 anonymized questionnaires were completed. The research team analyzed the subjective data, extracted from the questionnaires and juxtaposed them with the objective data, which consist in the real-time location tracking acquired through Indoor Atlas platform. Finally, subjective and objective data was compared among the users that browsed Crete3D application and those that entered without any additional knowledge on the monument.

The experience of the Municipal Market: a spatial approach

The experience of the Agora is presented in three progressive scales. The first one includes an area analysis, which means the public space of the Agora, before the experimentation with ICT. We argue here that the way the experience is transformed during the implementation of ICT affects the imaginary and perception of the area in its entirety. Then we examine the relation of the agora with its immediate surroundings, as well as the possible impact of the projections at the scale of the block. Finally, the analysis illuminates the way in which ICT can affect the overall user experience and bring about important insights for future consideration. The next two subsections present the two architectural scales and how they affect the flows, human interaction with the building and user density. The following two subsections exhibit the momentum of interaction between user, space and ICT as well as the user behavioral pattern key points, as affected by the new digital layer.

a) The scale of the building

The Municipal Market of Chania is commonly known as the "Agora". It was built between 1909 and 1913 on the site of the Venetian platform bastion, and materials from the fort were used to actually build it. The overall concept was based on the design of covered market of Marseilles, with references to the Byzantine design tradition and the construction drawings of the engineer Drandakis. It acted as a public space, always dedicated to commercial activities during its construction carrying the political effort of embellishing an area that was not in the least attractive for its residents at that time as it was the main rampart of the fortification during the Venetian period. Its urban landscape is greatly influenced by the memories of its first functions and their venetian past: ¼ as butchers' shop, ¼ as a fish market and the rest as vegetables and fruits markets, enriching today the collective memory of Cretan people. However, since the transfer of the fish market to Souda as well as the vegetable section outside of the city center, many of the shops became touristically oriented shops rendering much of its first heritage immaterial today.
Works of restoration of its old remaining parts didn't start before the 1960s and in 1980 it was designated by the Ministry of Culture as a monument. It is in these transformations that users perceive the evolution of a monumental space to a space firstly with touristic aim and then to a touristic product.

From an architectural point of view, the place initially extended in the 19th century limits of the city of Chania. Exactly in the point that united the old with the new city, the building's main entrance was oriented towards the newer city creating a dialectic relation between the new and past city boundaries. It measured in total 4,000 square meters in a surrounding area of 17,200 square metres. It is a cross shaped edifice with a gate on each wing of the cross (four in total). It is characterized by the existence of a large shaped corridor placed in the core of the building that leads in all four wings and extruded to that a second cross shaped space of attaching shops (figure 1, 2).

At the beginning, the eastern and western part accommodated the butcher shops, the western the fish market, while the rest were housed on the north and south wing. Today it houses in total 76 shops, such as grocery shops, bakeries, meat, fish, cheese stores while many of them sell the local Cretan herbs. There is also a pharmacy and some restaurants and cafes frequented by the locals during the day. In this way the two crosses, although parallel and attached, mix with people flows. Seating areas in different places as well as stop areas make this mixture smoother and enhance the perception of events (Tschumi B, 2005) to the user.

Furthermore, the building was mainly built by cement, brick, blended with steel construction on its cover. Its southern facade is made entirely of the carved pyrite while many materials from the old fortress were recycled. The facade design includes renaissance elements while the entrances and main openings are all of curved forms. The two different heights add more lighting in the interior of the building as the upper part is all made by steel and glass while the lower part consists of a series of windows all illuminating the interior of the space. Additional technical lighting illuminates each shop, showing the marketing tendencies of the local traders.

During the visit to the monument, different data were empirically observed: users are of three categories, locals that visit the market for commercial reasons, tourists and locals that use it more social reasons. The first category creates an intense flow in the main corridors of the building with additional stops in the facades of the local products. They are characterized by the velocity in their moves, and the familiarity with local buyers. This first category interacts with the building only to buy / trade products and therefore the architecture quality seems indifferent. The second category, tourists seem to have similar experience although their attention is focused on the touristic shops as well. They might document architectural elements of the building and create larger densities in the three main points of the building (entrance, main corridor and exit). The last category ignores the shops and is oriented to the social activity areas (coffees etc). These create bigger densities in the seating areas. In the first case, the materiality of the monument and its historical essence is highlighted by the commercial practices of the users. In the second case, these elements are part of a three-dimensional setting that uses the different depths of the building perspectives to line up with with its flows. In the third case, the overall atmosphere, smells and experience explain the reason for being there revealing the cultural importance of the building. These instances, all refer to a subconscious awareness of the physical and material consistency of the building, although there is no real material revival of the actual importance of the building. This phenomenon reveals the importance of creating a project / intervention that could transmit the real values of the building to the past and future.

b) the scale of the surroundings

Today the agora's connection with the surrounding compounds is also different compared to its past instances. While previously, it was constructed as an urban entity attached to others, creating a cluster dedicated to commerce, etc., today a visitor cannot easily perceive its continuity but rather its spatial differentiation.

In fact, in the past the demolition of boundaries with the fortress and the conciliation with the modern city was immediate. The streets connecting the new districts where the bourgeoisie mainly inhabited, such as the Courts, Halepa and Nea Chora, as well as the road from the Perivolia to the great metochia, all started and ended up in the Agora, something that is still obvious. At the time of its construction, the city council proceeded to a number of other projects such as internal tiling, construction of a shed, construction of reticulated cages in butchers and marble tables in fish farms as well as for construction of gutters. For this reason, the spaces around the Agora were formed appropriately so as to create adequate urban voids. The Market lately is tree-planted, a square and a parking spot is opened, the stables were set, the glass panes are painted with olive-colored white, so that the sun does not come in and spoil the products.

Today, the perimeter walls of the agora although they are remained in conserved conditions, and the additional projects of the exterior spaces create a friendlier environment, however, the non-permeable perimetrical walls and the less dense environment outside of these spots reveal the tendency of the architect to guide the accessibility areas. In these specific parts, all cars

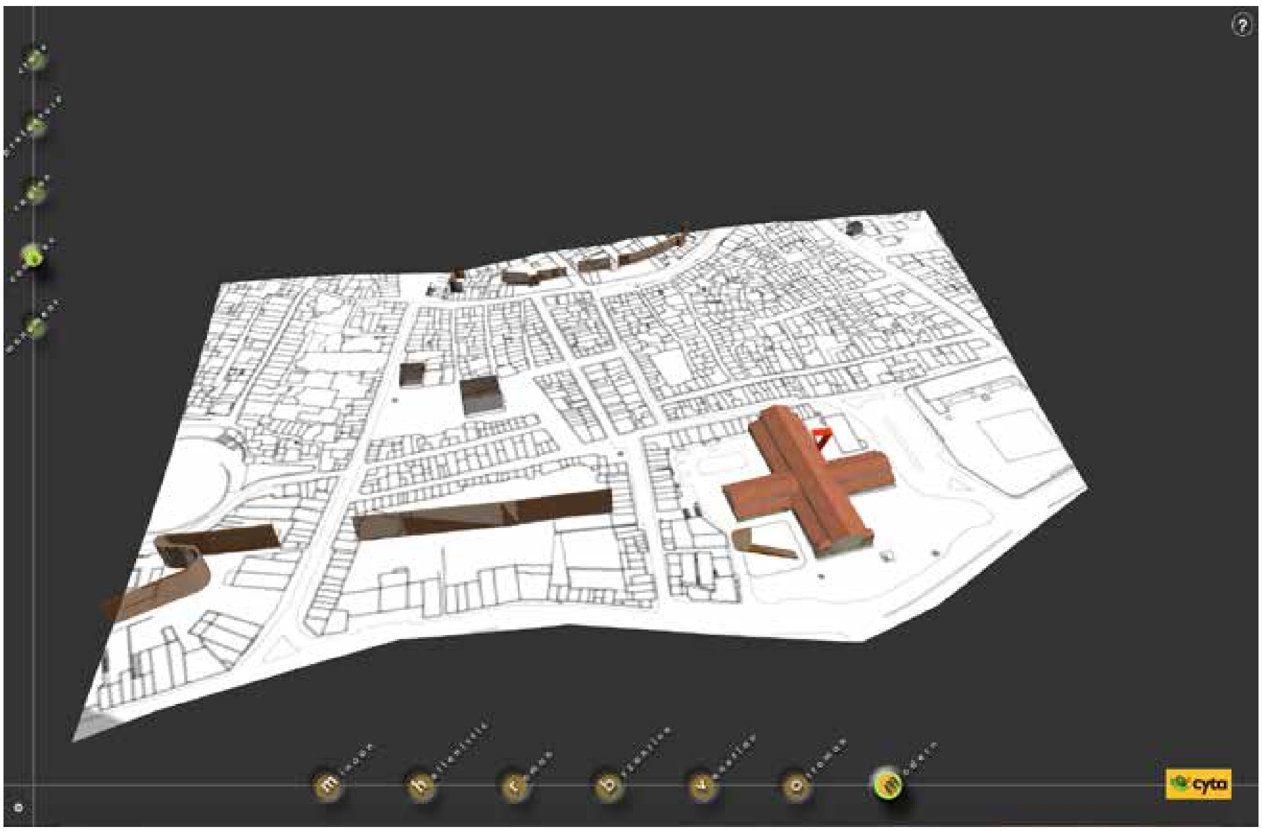


Figure 49
Crete3D: Scale of Complex

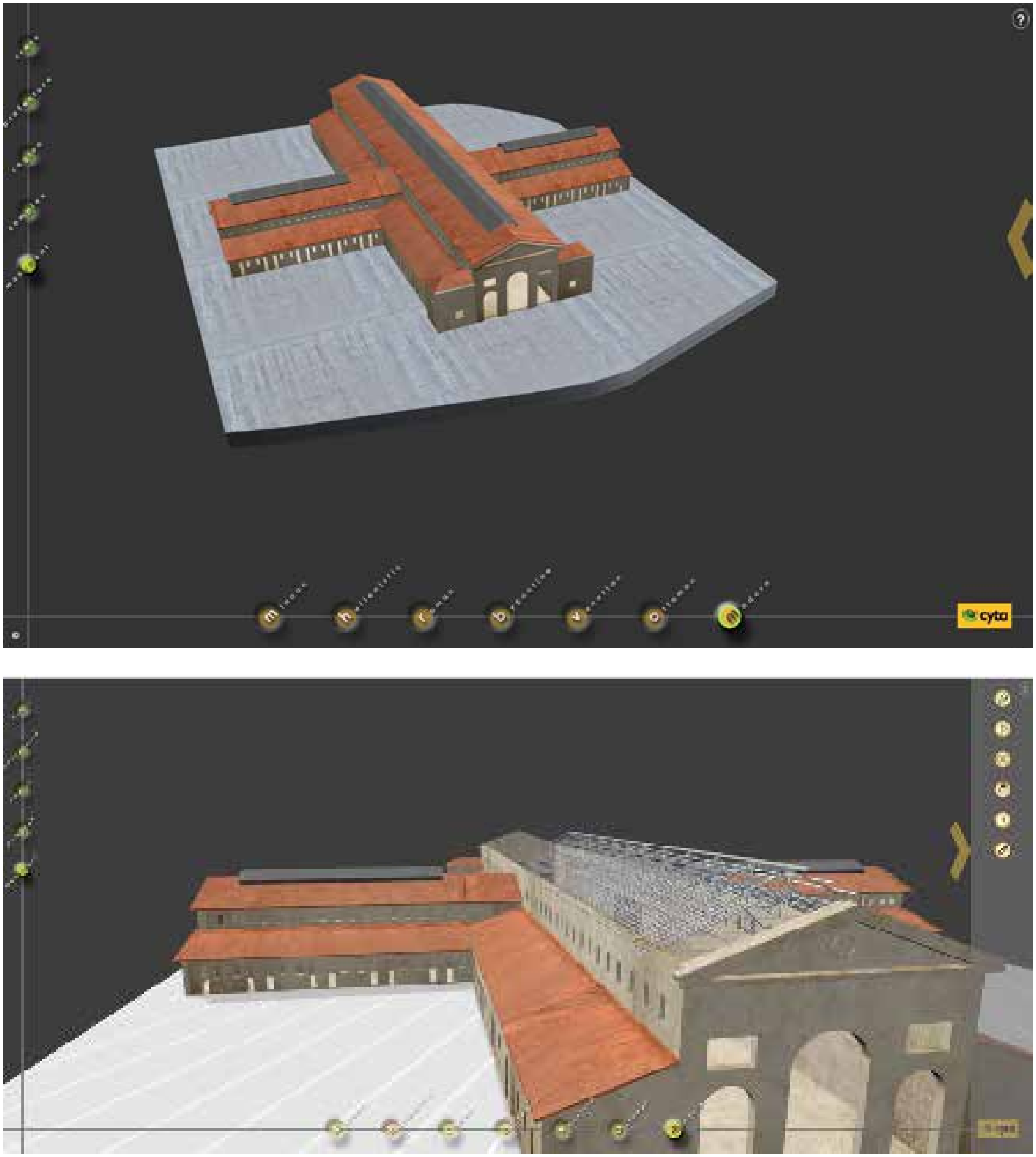


Figure 50
Crete3D: Scale of Monument / Level of Detail

are parked while in the main entrance all social life is gathered. The multiplication of the ground designed through the various staircases offer to the visitor an idea of monumentality as they augment the overall height. This allows to the user to identify the actual dimension of the building, the boundaries and the scale. Some of the previous functions in relation to the rest of the perimeter walls are left to their biggest part to the users' imagination. A new portico is created in the north entrance creating a covered pre- entrance meeting place and reinforcing the building.

Generally speaking, user experience is regarded as a comprehensive concept describing the subjective experience resulting from the interaction of visitors with the monument as a building. It depends on the different types of users (regular or occasional) and what they expect as well as on the relation between the users and contextual factors such as the physical elements and the architectural and cultural value of the building. As a multifarious concept, is based on distinct human factors and consists of different users' expectations and behavioral reactions. Although they have great research interest as they undertake the notion of user experience from a more human-centric aspect and a very subjective perspective, here the user experience is observed and classified based on user expectations as well as on physical elements of the building, before the experimentation with ICT.In this specific case, there are two types of users, the regular users or locals (locals who want to shop, locals who wander around the city, locals who socialize,) and the occasional users or visitors (tourists who are unfamiliar with the building). Based on the types of users, their movements and expectations the following categories of user experience classifications were identified:

Practical / efficient: The first type of users, locals, expect to perform everyday commercial activities within this building and accomplish practical and quick movement between the two sides of the city while the building is situated just above the new and past city boundaries. This category is characterized by the velocity in their moves, creates either an intense flow in the main corridors of the building or smaller flows with specific stops in certain facades of commercial shops. These users shape a more practical and efficient user experience.

Social: Locals also choose this building as a place to meet other locals, to socially interact and communicate, developing a more social user experience. Apart from the gathering of collectivities, small taverns or coffee shops can serve as spots for privacy, thus large user densities can be observed besides with specific spots of isolation.

Informational: For the second type of users, tourists, a more informative user experience is also shaped. Info points about the history of the building, central tourist kiosk with information about traditional recipes as well as tourist shops with local products provide tourists with all the necessary information and result to a relatively medium flow with large densities around the above points of interests.

At a second level of analysis, user experience is classified based on contextual factors such as the physical elements and the architectural and cultural value of the building.

Emotional: For all user categories, both locals and tourists, the building itself creates a feeling of positive surprise. The dynamic presence of people walking inside the building as well as the architectural elements of the building such as the internal building height, the presence of low intensity light and the limited openings create a unique atmosphere, surpassing tourists' expectations on the one hand reviving memories for the locals on the other. These feelings result in not specific and intense flows, with lots of intermediates stops, and in a more emotional user experience.

Sensory: The specific architectural structure of the monument creates feelings of continuity of space with the surrounding environment and a sense of flowing of activities. Large densities of people, both locals and tourists, are noticed around the 4 wings of the cross where the great openings and the intensity of light give the feeling of an external urban place, connected with the immediate environment.

Motivational: Some spots inside the building serve as info points for the city. The center of the building where the 4 wings intersect has information about the city as well as information about Cretan products while also in another spot old photos of the city and the historical monuments are being exhibited. All these encourage and motivate users to broaden their knowledge about the city and expand their experience by visiting other monuments and relate with the city.

ICT as a space mapping and knowledge generator tool

User experience is presented within all traditional locations in the public space of the municipal market and although ICT is only partially used throughout the experiment, its impact is fundamental since it totally transforms the perception of these places. This catalytic presence of ICT provides a vision of a smart city in concordance with the definition of a smart city theory (Geropanta V., Cornelio Mari E., 2014). Therefore, a deep comprehension of the physical dimension of the ICT here is essential for the desired generation of the enhanced user experience. Here, I argue that this analysis will lead them to identify the framework under which experienced is enhanced and becomes the instrument for new education resources.

ICT as a knowledge platform: Crete3D

To evaluate user experience and user interaction with the building, the group of tech users were introduced to the online platform Crete3D (www.crete3d.gr), an innovative tool that was designed by architects and archaeologists at the Digital Media Lab, Technical University of Crete. The key idea of Crete3D platform was to provide necessary information of the selected monuments, presented in five levels of detail (Crete, Prefecture, Region, Complex, Monument) and throughout seven different historical periods (Minoan, Classical, Hellenistic, Roman, Byzantine, Venetian, Ottoman, Modern). The platform implemented in WebGL visualises each cultural monument in five spatial levels of detail representing initially Crete as a whole, then by prefecture, region, complex of monuments and finally focusing on the actual monument (Parthenios P. et al. 2014). Unlike most monument-related visualization methods, the platform is based on the creation of conceptual models instead of providing descriptive details of the monuments. A model is usually constructed in order to discard details from the subject under study and retain only what is essential for some stated purpose (Henderson – Sellers and Gonzalez-Perez, 2010).

The platform depicts 148 monuments in Crete and analyzes fifteen of them in detail. The Municipal Agora of Chania appears in the Region of Chania, at the third level of detail, under the Prefecture of Chania. The abstract three-dimensional model of the monument appears when visiting the Modern Period at the x-axis and the Region on the y-axis. At the scale of the region, during the Modern Period, users are able to see the building location within the Venetian walls of the city. At the same scale, during the Venetian and Ottoman Periods, the Venetian Walls frame the current location of the monument. The user can enter deeper into detail when clicking on the pin of the

Monument. At that moment, a more detailed model appears within a part of the Old City of Chania.

The last level of detail appears at the scale of the monument. At that point the information is released in a twofold way. On the one hand, the user can gain knowledge regarding the geometry and details of the monument, by navigating into the building or by clicking on the roof and wall, which become animated on mouse-over. On the other hand, the user can acquire condensed knowledge regarding the monument's history, images, videos, hours of operation, link to google maps and other useful links, by selecting the pop-up menu at the right of the screen.

The fact that the material described above is available online gave the research team the opportunity to transfer condensed knowledge quickly and through a user-friendly way, a few minutes before the actual visit to the monument. Crete3D does not intend to promote a strictly architecture-base limited image of Crete's past, but a dynamic understanding of its hybrid cultural identity (Parthenios P. et al. 2014).

ICT for Space Mapping – Indoor Atlas

To measure the human building interaction, the authors used specific ICT and IoT that are based on location tracking data. This technology, is an indoor Positioning System (IPS), a system of network connected devices which is used for wireless locationing of objects and people inside buildings and partly covered areas (Lemmens, 2013). This system, which can be smartphones, tablets or mobile services, uses multiple signals from location devices, as well as sensors etc, calculating accurately the exact location of the device and its specific coordinates (latitude, longitude, and height / number of floors) (Keluža, Marin & Vukelic, Bernard, 2017). These coordinates, co related with the context (Senion,2016) allow to know when the user is located near a certain point, or being able to determine the position of the user regardless of their location in the building. The first refers to a system based on proximity (PS8) and the other is the IPS system (Senion, 2016).

The information obtained by IPS might be essential in the case of a real time analysis where the desired outcome is the identification of user's movement in the building, which zones of the building are more frequently visited, or for more time, and vice versa calculate the quantity of users visiting a particular area at a particular time, determining points of interest and therefore enabling the analysis of user behaviour.

In the market there are many IPS products. Some of them namely are the Here Indoor Radio Mapping, the Proximi.io, Anyplace Indoor Service and finally IndoorAtlas MapCreator 2. Briefly, the difference among those stands in the way that users depict their geographical location. For instance, in the case of Here Indoor Radio Mapping, users can produce a map by adding buildings and including floor plans and contours to set paths, while in the case of Proximi it is the platform that provides users with accurate location fixes. At Anyplace Indoor Service users can adding floor plans, images, POIs (points of interests), and use the campus mode to signify whether the building is part of a group. Finally, IndoorAtlas MapCreator 2 depends on an app through which the gyroscope and magnetometer on the phone record pathways. The authors chose to work with Indoor Atlas due to (a) prior experience with this app, (b)because it allows for free use plan and an unlimited number of venues with up to 1,000 unique users per account, (c) it requires very easy setup procedure.

Indooratlas depends on a sensor fusion technology that tracks the movement of the user using the built-in inertial sensors in the smartphone. With the integrated magnetic sensor (compass) and other sensor technologies in a smartphone, the software can accurately pinpoint and track the position of a person on the map using the magnetic field inside the building, creating a ‘’blue dot" on a map. The overall procedure consists of two steps, the setup and the mapping. The setup involves the signing up free at app.indooratlas.com which is the web portal of managing the IndoorAtlas floor plans, maps, API keys and applications. After this step, users upload a floor plan of the venue in the web portal and then make alignment aka Geo-Referenced Floor Plans over the base world map.Mapping (fingerprinting as well) is the method by which indoor positioning can be enabled. It involves collecting signal data from a target location with a mapping software (MapCreator 2) by physically walking through the venue. The research team used a suitable device for mapping (LG nexus 5X and Xiaomi note 5). MapCreator requires hardware magnetometer and gyroscope detectors with access to uncalibrated data. An assessment is made through testing the gyroscope and magnetometer calibrations using MapCreator in order to verify that the sensors function well. The simplest way to test live positioning after a map quality assessment is completed is by the positioning testing feature in MapCreator 2 (Android) or the positioning testing app Indoor Atlas Positioning app in App Store (iOS).

HBI Interaction, User Experience Measuring and Enhancement

The experiment begins with a visit to the Municipal Agora of Chania. Firstly, the team aligned the IPS coordinates with the GPS coordinates of the building, following the setup – map – positioning process as described in the previous section. The main requirement for the mapping and positioning is strong Wi-Fi or 4G signal. Since weak signal does not allow for accurate data, and inside the agora, the signal was not available at all building surface, the alignment process was repeated several times until being completed.

Afterwards, the research team engaged users and led them to the northern entrance of the building where the experiment would start. All participants were aged between 18 and 35. Their age was chosen on the basis of their familiarity with technology, as the experiment required users downloading Indooratlas API or a screen recording application to their smartphones. The time of the visit was deliberately arranged on a summer day that the Market fully functions and hosts tourist groups.

Initially, the entire user population was split into two groups (tech and traditional users). The group of traditional users entered immediately into the building. The only source of information received by these users consisted in bits of info that they heard from tourist leaders as well as an old-fashioned info point in the middle of the building. The group of tech users was given a laptop connected to the internet and were guided to the Crete3D platform. The majority of tech users went through all scales and details of the monument as well as the useful information provided through the pop-up menu, while a few of them clicked on other monuments, regions and complexes. After 15 minutes, the group of tech users entered the monument and made a tour in the interior of the monument. Both groups were advised to return to the same point at the northern entrance when their tour would end.

Despite the fact that Indoor Atlas provides unlimited sessions within the same user account, the research team encountered a sync problem when over ten active users were near the same building point. When this happened, the application was disconnected and the software's accuracy was lost, so the entire process had to be repeated from the beginning. The issue was solved by forming groups of three to five people who were connected to the application with the assistance of the research team.

Data analysis and Comparison

On completion of the visit to the building, a collection of subjective data through questionnaires was carried out. The research team worked simultaneously on the analysis of the videos of the two-dimensional user flow representation and data acquired through the questionnaires.

Questionnaires / Qualitative Data

The design of the questionnaires was based on a top-down approach of the users' knowledge level. The first group of questions investigated the level of general knowledge regarding the monument and tried to categorize the users in relation to the reason of their prior visit to the building. The second group consisted of evaluating the overall experience of the visit, while the third set of questions focused on the moments of interaction between user and space, aiming to provide a comparative analysis of the building perception between traditional and tech users. By the end of the survey period, data had been collected from 33 individuals, 23 of whom had no previous access to the Crete3D platform and are mentioned here as 'traditional users', while the other 10 had visited the knowledge platform without any time restriction and are called 'tech users'.

Regarding the level of general knowledge, all users had already visited at least once the building, while only one user of the group visited the building for the first time. The reason of their previous building visit was claimed to be: for 60% of tech users and 78,3% of traditional users for tourism while for 30% of tech users and 13% of traditional users for commercial activity. Of the 23 traditional users that responded to the question, only one indicated that his/her prior visit to the building was done for work reasons. Finally, 10% of the work users had used the building as a shortcut to shorten their walking path. In terms of their average previous level of knowledge, it was relatively higher among traditional users (80% of tech users vs. 87% of traditional users rated their level of knowledge between 4-8/10).

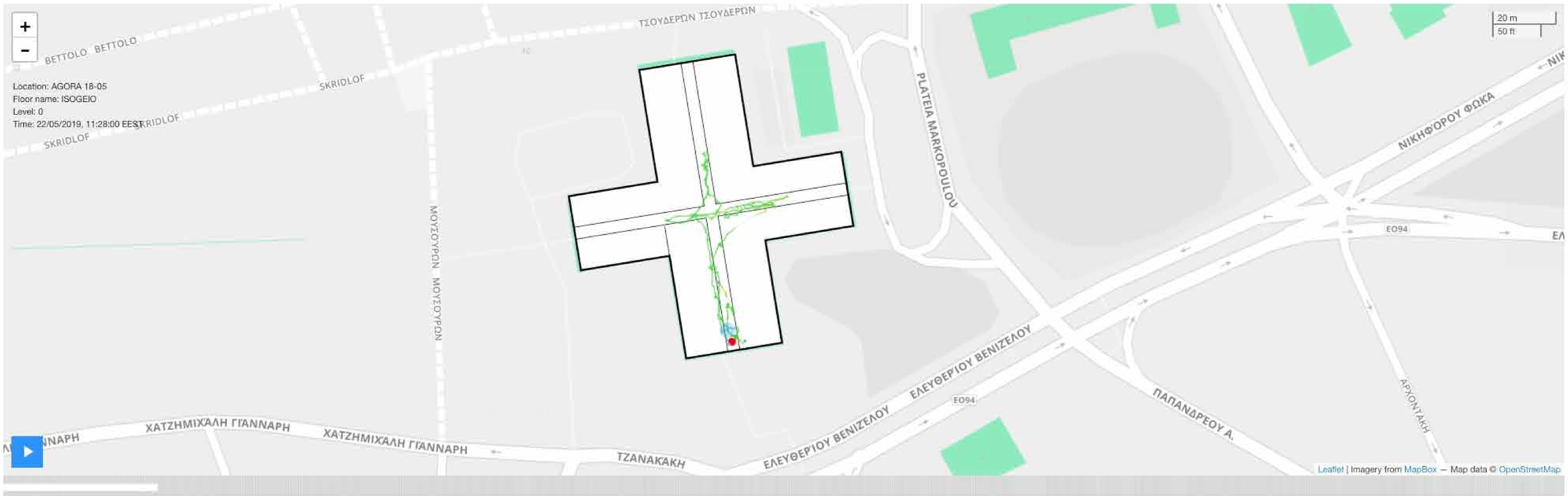
The second step consisted in evaluating the overall experience – building, senses, and spatial perception. This step followed the inverted pyramid structure with two set of questions – the first set requiring users to evaluate the visit asking also for their justifications and the second set asking users to give subjective data on the best and worst moments of the interaction with the space. The overall evaluation was very positive. Tech users recorded a significant increase of their evaluation rates compared to the traditional users. Specifically, the evaluation rate of 70% of the tech users was above 4 out of 5, while the correspondent percentage of traditional users was 47.8%. In response to the question: 'Please evaluate the visit (from 1 being Not pleasant to 5 being Very Pleasant)', a range of responses was elicited. Most of the positive responses of traditional users concerned the appreciation of this building as a monument and the flows of tourists that added livelihood to the space, while the negative ones consisted in the bad ventilation that led to bad odors and the lack of thermal comfort within the space. In terms of the tech users, the majority of their positive responses were related to the combination of architecture, tourism and technology as well as to the fact that they had the chance to reinvent the monument in a totally different way. Similar to the traditional users, their negative responses indicated the bad odor and ventilation and the crowded, almost suffocating space. The most surprising aspect of the data is that while some users gave the same justification for the experience evaluation, the users that belonged tech users rated higher their experience. For example, 10% of the tech users and 13% of the traditional ones claimed to having reinvented the space in a different way through this visit, but these tech users evaluated higher their visit.

Within the following set of questions in the second step, users were asked to highlight their best and worst experience during the building visit. Regarding the best experience, there was a significant difference between tech and traditional users. On the contrary, the answers describing the worst experience converge. Specifically, almost two-thirds of the tech users reported that their best moment within the building was when they stopped at the center, where they had the maximum visual contact, as well as the main entrance detail and main axis (north-south). A small minority did not mention any good moment in the building or highlighted the shop experience and communication with people as the best during the visit.

The last question of the second step asked users to choose among multiple choices, up to three spatial qualities that they would like to improve in the building. The question was based on findings from the empirical analysis conducted by the research team. It was considered that this

Timeline

Playback



kind of subjective data would usefully supplement and extend the spatial thinking of users. Participants had to choose among the four following features to be improved: ventilation, odors, lighting, materiality. The results were diverse. Tech users voted eight times for ventilation, seven for odors, three for lighting and three for materiality. Traditional users voted nine times for ventilation, eighteen for odors, eleven for lighting and four for materiality (image).

The third step of the questionnaire required users to give information on the pick of their interaction with the space and on their observations concerning architectural elements of the building. The first question in this set sought to determine the perception that tech users shaped for Crete3D. In response to the question 'What information did you obtain through navigating Crete3D?' four responses were given. Interestingly enough, the responses to this question were very diverse. Specifically, the majority of users reported that they learnt a lot on this building as a monument and its function. 20% of the users indicated that they gained information on the building's year of construction and current preservation status. Only one individual stated that this platform suggested a new way to explore monuments. On the contrary, 3 users claimed that they did not obtain any new information.

The second, third and fourth questions were dedicated to the identification of the human flows, as perceived by the users. When the participants were asked how many parts of the building they visited, almost all traditional users and 60% of the tech users indicated that they walked to all four parts of the building, while a very small percentage of traditional users and 30% of tech users claimed to have walked to the three parts. Only one tech user reported having walked to two parts. Respondents were asked to indicate how many times they passed through the center. The answers to these questions were similar among tech and traditional users: 60% of tech and 70% of traditional users passed through the center more than 4 times. 30% of tech users and 21% of traditional users passed 3 times, while 10% of tech and 9% of traditional users passes 2 times. Regarding the question 'Which was the main reason of your stops within the building?', there were differences in the ratios of tech and traditional users. 70% of tech users reported that they stopped to observe the architecture of the building, 20% that they stopped to shop or see the shops and 10% to orientate themselves. Interestingly, the ratios of traditional users were evenly distributed: 33% to watch the architecture, 33% to shop or see the shops and 33% to orientate themselves. In that sense, traditional users represent the three categories of the building users described in the first section of this study: the locals, tourists and locals with commercial activity.

The last question of the questionnaire was optional and sought to examine the level of understanding that users had achieved concerning the architectural elements of the building. Interestingly, all tech users answered the question, while 10% of traditional users did not respond. Among tech users, the results were the following:

1) two mentioned the entrance, commenting that ‘it gives you the impression that the building is significantly bigger than it actually is’,
2) five users highlighted the ceiling, due to its transparency and overall materiality,
3) two users indicated the wall due to the details and overall scale,
4) one user mentioned the overall layout and the scale of the building in relation to the urban tissue.

Regarding the traditional users, the answers were the following:

1) fourteen users mentioned the roof,
2) three users mentioned the central entrance,
3) two users highlighted the cruciform layout and
4) two users indicated the way that the building integrates into the urban tissue.

The most surprising data is that the majority of tech participants mentioned each architectural element ‘as described in Crete3D platform’ and gave a more detailed description of the element, such as ‘the ceiling, due to its transparency and overall materiality’, while traditional users responded with one-word answers.

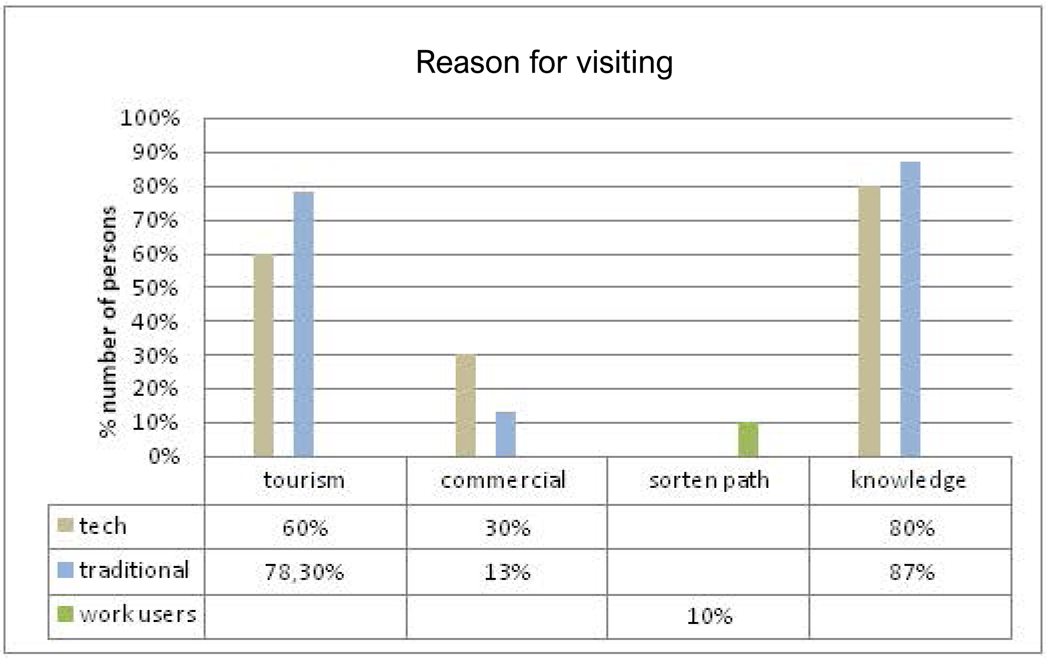


Table 14
Reason for visiting the Agora

Experience - traditional users		
traditional	positive	appreciation of Agora as a monument
		flow of the tourist that added livelihood into the space
	negative	bad ventilation
		bad odors
		lack of thermal comfort within the space

Experience - tech users		
tech	positive	combination of architecture, tourism, technology
		chance to reinvent the monument in a different way
	negative	bad ventilation
		bad odors
		crowded (suffocating space)

Table 15
Experience of tech and non-tech users

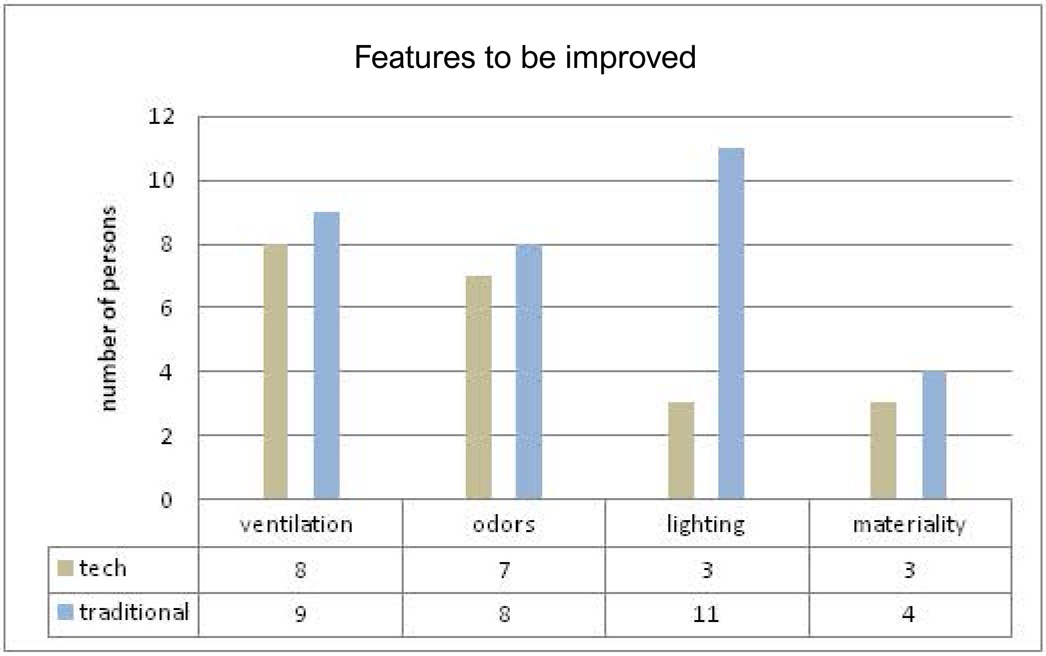
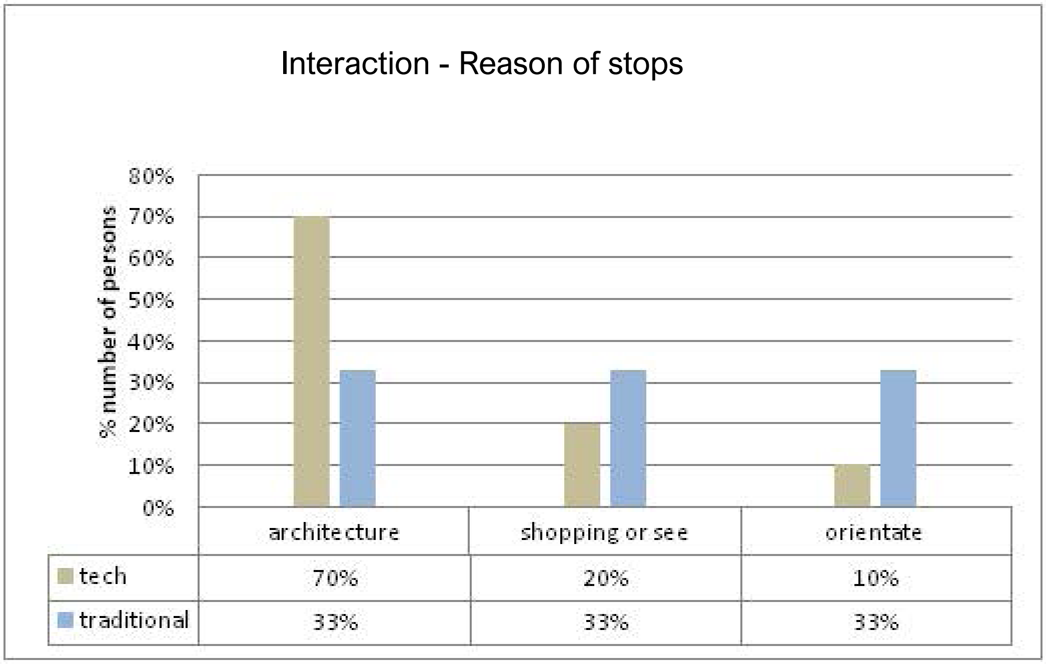


Table 16
Features to be improved and overall experience



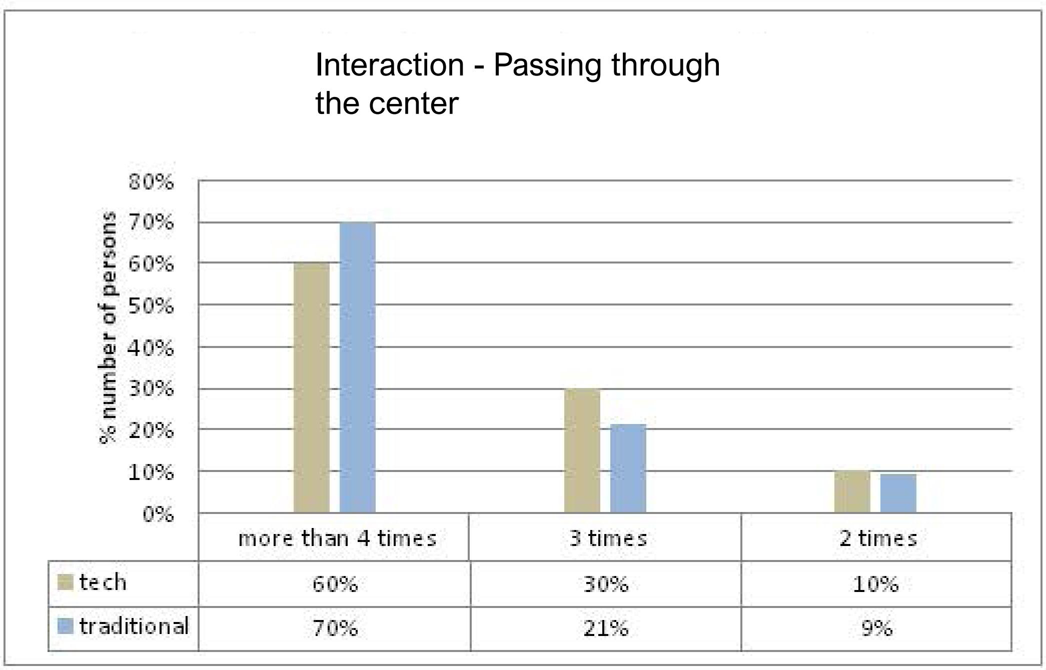


Table 17
Interaction keypoints

Video Analysis / Quantitative Data

The videos were extracted using two ways: screen recording and the indooratlas location tracking analytics tool. The first way was implemented to participants that used an iPhone, due to technical limitations of the software. Users opened the app interface showing real-time their location into the building and recorded their screen at the same time. The videos produced by the recording were then sent to the research team. The second way consisted in using the Indooratlas API, where each user logged in during the building visit and a unique Session ID Number was generated. The Session ID number was also sent to the research team by each participant. In both types of videos, user flow is indicated with a color-coded line, where color is associated with signal accuracy: green for good, yellow for moderate, and red for poor signal. Almost 10% of the overall video duration had poor or no signal and therefore was eliminated from and not considered for data analysis. The only difference between the two extraction techniques was the fact that in screen recording, the periods of time with poor or no signal were manually identified and taken out, while the Indooratlas API provided an automated histogram depicting the time in Y axis and the accuracy on the X axis.

The research team defined a series of parameters in order to gain a quantitative understanding of the user flows and stops within the building. The parameters consisted in the direction that the user followed after the first passing through the center, time spent in each of the building's wings, user stops in each wing as well as number of stops and corresponding time spent in the center of the Agora. Other parameters included in the analysis were the inaccurate tracing percentage, the overall user path duration and supplementary comments that varied per case. The results presented here are determined through the quantitative analysis, as well as through the observation of the final video, where tech user flows and traditional user flows are grouped and then were juxtaposed on a common canvas.

Interestingly, there were enough similarities as well as differences in the paths that that the two groups followed. The first parameter consisted in the direction of users after first passing through the center, In this case, the majority of both tech and traditional users turned left to the west wing of the building when they arrived at the center of the building at the first place. Specifically, contrary to expectations, 50% of tech users and 43,75 % of traditional users turned left when first met the central node of the building, despite the fact that at this wing, on the one hand two shops were closed and dark and on the other hand, there were two fisheries and two butcher shops in full function diffusing unpleasant odors. The rest of users moved as follows: 30% of tech users and 25% of traditional users moved straight ahead towards the north and 20% of tech users as well as 31,25 of traditional users turned right. None of the users returned to the north wing after the first passing through the center.

Regarding the overall time spent in each wing, both traditional and tech users spent most of their time in the northern and southern wings. In fact, traditional users stayed longer in the first wing. This correlates with two findings from the overall analysis: first of all, the fact that traditional users claimed that they lacked orientation within the building, resulting in staying longer in the first and more 'secure' wing of the building. Secondly, the fact that Crete3D represents details of the roof on the north-south axis as well as details of the north façade (main entrance), which led the tech group to this specific axis. We argue here that even if users spent more time in the same building section, this happened for different reasons.

Regarding the stops at each part of the building, data was acquired both from the video observation and analysis. Regarding the video observation, it is obvious that tech users traced a longer path and reached all end points of the building. On the contrary, most of the traditional users turned back at the middle of each wing and spent more time in the center. Data analysis shows that tech and traditional users executed the same amount of stops within each wing. What differs is the ratio of the time spent to the number of stops on average of each group. Tech users passed more times through the center, making 5.2 stops on average, while traditional users stayed longer in the center. This might happen due to the fact that traditional users had no knowledge input and tried to gain information through the screen located in the center of the building. In their case, it was the only medium through which they could find history facts and concentrated knowledge regarding the building.

Issues, Controversies, Problems

There are many issues and controversies framing this research. Issues and limitations arise at a macro and microscale. At the macroscale, the existence of a continuous cognitive layer alters the spontaneity of user movement within space. Once informed of being tracked, users no longer feel free to circulate anywhere in the building. The research team observed that most users felt stressed to absorb as much information as possible from the space. They impulsively entered into a state of competing their fellow users. The observed lack of spontaneity was further intensified by the fact that the group of users were young Architecture students, already possessing a level of knowledge on the monument.

At a microscale, the issues emerged were related to the signal inaccuracy, the ICT interface and the sync process. Signal inaccuracy was a constant issue during the experiment and formed a complicating factor at the analysis phase. Moreover, Crete3D is only available on desktop version, rendering the navigation at an open space extremely difficult. Users had to share a laptop prior to the visit, which in many cases interrupted the informational attribute of the visit. Finally, the lack of strong signal and the accumulation of people using the IndoorAtlas API caused sync issues. Specifically, the group of users had to be further distributed into smaller user groups to avoid signal congestion during the experiment.

Solutions and Recommendations

To overcome the issues mentioned above, the research team invented solutions at both macro and micro levels, aiming to extract accurate data. At the macro-level, in order for the users to feel that they participated in a collaborative, open process, they were guided by a group of their colleagues. They 'were advised by the research team to feel as flâneurs' (Karagianni et al., p. 605) and get the maximum out of this experience, without trying to memorize any information acquired through the ICT platform.

At the micro-level, the most intriguing part at the analysis phase was the calculation of

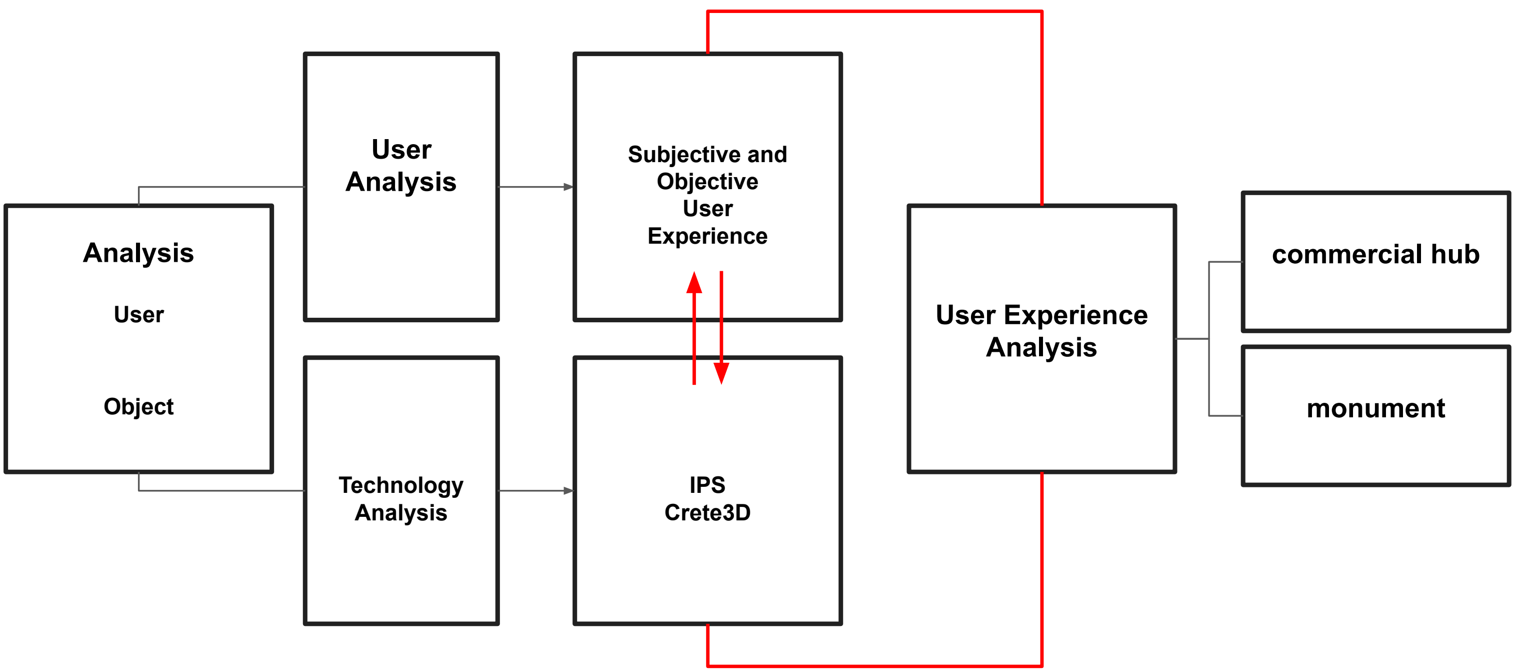


Figure 51
Reinventing the Municipal Agora of Chania.

stops compared to the moments that the signal was lost. This condition was calibrated by an observation: within the Indoor Atlas Session, when user signal was lost, after a couple of seconds it re-appeared at another point of the building, apparently due to the fact that once the end-device connects to the cloud, the system immediately tries to re-connect, depicting user position at the new point. This was crucial for the analysis of user movement and calculation of stops. Finally, regarding the signal congestion issue, the research team firstly reassured the optimal juxtaposition of the IPs to the GPS by conducting the alignment process three times before starting the user visit; secondly, the users formed 5 groups instead of 3 that was initially anticipated, in order to gain control of any signal issues that would arise.

Reinventing the Agora through the narrative of the historical tank

In this study, two analyses are presented: the technological and user- experience related. Both analyses, quantitative data and questionnaires depict a fundamental issue in the overall building experience: the Agora is mostly perceived as commercial center, while the monumental character of the building is not evident. The comparison between tech and non tech users proves that this fact is intensified among users that did not interact with the Crete3D platform. How can we rethink the Agora as a historical thinktank? Which is the optimal way to redesign the experience in the Agora, so that users perceive its great historical value?

The Agora mainly functions as a commercial hub. As such, the experience is largely influenced by the functions of small shops, the voices, the odors and the lack of lighting. The strategy suggested here is to calibrate the monumental character of the building by providing stimuli through technology to visitors. Specifically, the narrative representation will be based on the combination of the Indoor Positioning System with QR Codes that will act as agents for an augmented reality application. The scope of the application is to provide a 3d space of the building as if there were no shops and restaurants. Through the augmented layer, the visitors that are interested in the history can acquire valuable information on the monumental character of the building, while the commercial character of the Agora remains untouched and the habits of the locals and guests are not impeded.

Conclusions

In the current study, comparing users with and without ICT - knowledge input during their visit to the Municipal Agora of Chania, showed that ICT triggers an indisputable shift in the user's perception of space. In the empirical analysis, we identified three distinct categories: locals that use the space for commercial reasons, tourists and locals that use it for social reasons. It is interesting to note that when users were asked to point out the main reason that they stopped within the building, traditional users seemed to follow exactly this classification, while tech users followed a distinct path, thus shaping a new typology of people that reinvent the space through technology.

Another important finding was the fact that tech users evaluated higher their visit and identified more architectural and historical elements, although they reported to have lower previous knowledge of the building and its history. However, one unanticipated finding was the fact that traditional users spent a considerable amount of time at the center of the building, where the info point with the screen was located. This further supports the idea that people seek for spatial cognition, not only in terms of understanding the geometry of the space, but also to gain knowledge of the cultural aspects of it. "Building" is a construction of physical elements that creates and protects a space, while each of these two aspects - the physical and the spatial - carry a social value' (Alavi, 2017). It is also known that 'a person's activity space – the set of paths, places, and regions traveled on a regular basis – is an important example of spatial experience that influences people's knowledge of space and place, no matter what their age is' (Montello, 2015). What is crucial to understand is which is the optimal way to gain knowledge in novel spaces of enhanced cultural value.

Together these findings provide important insights into the way that user experience has been transformed by new technologies. This study acts as a knowledge container of spatial analysis, thus creating intermediate-level knowledge, as defined by Kristina Hook and Jonas Lowgreen (2012), knowledge that emerged from interaction design research and lays between general theories and specific instances. It is, in fact, obvious that, through the superimposition of the physical, digital, human and interaction layer, new strong concepts will be identified, articulated and discussed in the field of Human-Centered Design.

Future Research Directions

The work we present here is based on user analysis and research in spatial smart contexts as an ongoing conversation - a process of creating new educational tools and building new spatial knowledge. The relation between user experience, as studied in the field of Human-Computer Interaction is embodied in the Human-Building Interaction approach presented in this study. What seems to be missing, is the articulation of a new language that would integrate the diverse theories and constructs into a new theoretical investigation of User Experience in Smart Environments.

CHAPTER V
Results, Conclusions and Future Work

Results

This dissertation examined the interactions and synergies between users and technology on the one hand, and concept generation in architectural design from a human-centric point of view, and established connections between them. Having studied a large body of literature, it seems that these interactions, established by user research, and solidified by the field of Human–Computer Interaction, had to be investigated from the user aspect. Given the technological capabilities of our era, users contribute to data collection and analysis, being active or passive in a smart environment, as demonstrated in the second chapter. Moreover, the juxtaposition of toolsets provided by the UX Research stream and IoT hardware creates a dynamic stream of collecting data and feeding into the analysis stage of the design process. The notion of user is well established in architectural design, primarily because users use the space and in designed space, if users are overlooked users are unhappy in the spaces, and consequently they may be underutilized.

The principle theoretical implication of this study is that the advancements of technology enable the creation of an 'intelligence layer' in space. This intelligence layer can either follow the technological capabilities, thus rendering space 'intelligent by default' (i.e. add two smart gadgets in space to create some sort of automation) or be a product of the design, thus transforming space into 'intelligent by design'. In order to have an 'intelligent by design' effect, the interaction process between the designers and users must be integrated into the design process of the physical space at the earliest stage possible-concept generation.

After analyzing the process of the evolution of interactions between users and technology during the second half of the 20th century, as discussed in the first chapter it became clear that interactions between user, system and space, suggested and designed by architects or, in many cases, programmers and executed by researchers in the form of prototypes (until the emergence of IoT), has strong correlation with Computer Science. As such, it follows a scientific / engineering discovery process, and is thus a linear process. User–technology interaction research is mostly about the quantification of user experience and the extraction of usability metrics. In contrast, architecture is defined by empathy of the architect for the user; the architectural design follows a creative iterative, often messy and illogical path. The architectural design process aims to integrate the needs of a user or a group of users, often using empirical methods and rule-of-thumb processes in the design process, constituting a human-centered field per se.

Returning to the main research question, *How can we integrate technological interaction into the concept-generation phase of the design process?* this study extrapolated the principles established in the ‘Design Methodological Framework for Interactive Architecture’, developed by Achten and Kopriva (2011). In the first step of this thesis, four design approaches were analyzed under this framework. These design approaches were classified under the Achten – Korpiva model and were analyzed in terms of their typology, technology used and the design goal. This analysis aims to demonstrate that the technological interaction design forms part of the overall architectural design process, as it contributes to the spatial transformation and the user living patterns and scenarios of use. Then, four experimental studies in different typological and social contexts were carried out in that direction and from a user-centered approach. These studies were conducted at four distinct building typologies: workplace, hotel, residence, Municipal Agora. In each experiment, the design goal acted as a driver of user-technology interaction. In the workplace framework, the design goal was to increase social and environmental awareness of the building users. In the case of the hotel, the design goal is to rethink the hotel room as a ‘butler’ that assists hotel guests. The design goal of the smart home was to connect users with three scales, the micro-living scale, the neighborhood and the city. Finally, the design goal of the experiment the Municipal Agora was to be revisited as a monument and rethought in a way that would emphasize its historical value.

Towards a new human-centric design methodological framework

The study has found that the best strategy to use in a human-centric methodological framework is to break-down the design-build framework developed by Achten and Kopriva by dismantling it into its basic components and then testing which ones strictly align with the notion of user. To help unpack this, I frame the conclusions in groups of interdependencies, further explained below, depicting the synergies between people, architecture and technology. Each set of interdependencies are independently analyzed, and aimed at shaping a new theoretical framework of the big picture of integrating user interaction into the concept generation as part of architectural design.

Technology, IoT and data

The first interdependency is related to the technological analysis and hardware selection and the data extracted by this hardware. This step is fundamental in the design process and starts with the questions: What information do I need? How am I going to gather this information? Different streams of data, either qualitative or quantitative are extrapolated by each IoT component. Selecting the accurate system is a data-driven, bottom-up process, influencing the type of interaction.

Study	Typology	Technological Analysis	Quantitative Data	Qualitative Data
I	workplace	sensors / IoT	energy consumption data	user patterns / experiential metrics
II	hotel	location mapping / IoT analysis	real-time user location energy consumption data	experiential metrics
III	public building	ICT platform / location maaping	real-time user location	experiential metrics
IV	residential	IoT analysis	energy consumption data	user patterns

Table 18 Synthesis of Experiment Results
Technolgical Analysis and Data

Users, Interaction and New Experiences

Exposing users to new media and applications reveals new experiential loci firmly linked to the interaction type established in each case. In all cases, the interaction is primarily designed as exploring, instructing, passive instrumental and passive informative interactions, in that it gave feedback and informed users, respectively. The correlation of new experiences and interaction types is evident. What kind of experience do I want to create? Which type of interaction corresponds to that experience? Remarkably, all new experiences in the four experimental studies are organized by a social layer, which is the added value of focusing on the user aspect. Accordingly, in the four studies, the target users are active tenants, engaged citizens and empowered people.

Study	Typology	Target users	Interaction Type	New experiences
I	workplace	employees managers	manipulating passive instrumental passive informative	become socially aware increase productivity
II	hotel	employees guests	passive instrumental passive informative	become socially aware - feel protected
III	public building	guests	exploring instructing passive informative	reinvent the agora
IV	residential	tenants	instructing conversing passive instrumental passive informative	promote engaged citizens

Table 19 Synthesis of Experiment Results
Interaction Type and new Experiences

Design Approach, Typology and Design Goal

Architectural thinking can serve as a testbed for interaction design, expanding the human–computer interaction to human–smart space interaction. To articulate this transition from static to dynamic and from space to smart space, architects can think about how to design interactions by relating the technologies with architectural space. This is doable only if technologies — the system, the interface and the medium — function within the architectural design process as architectural elements. Likewise, the smart ecosystem becomes a new playground for architectural creativity and the 'by default' intelligence is replaced by the 'by design' intelligence. The design approach is based on the analysis of typology and in relationship with the design goal.

Study	Typology	Design Approach	Main Design Goal
I	workplace	through UX research	To raise social awareness
II	hotel	through meta-phors	To assist guests
III	public building	with narratives	To promote the twofold character of the building, emphasizing its historical value
IV	residential	data informa-tion and urban layers as design drivers	To connect the user with three scales

Table 20 Synthesis of Experiment Results
Design Approach and Goal

Users, Prototype and Novel Design Spaces

The last interdependency is related to the design methodology, its relationship with the prototype and the novel design spaces that users experience through this technology-oriented process. It presents ways for architects and designers to delve into user perception, and to acquire and analyze subjective and objective data. This kind of knowledge acts in two ways: first, it builds a dynamic relationship between the user and the space, rendering users active agents in the data feedback loop; second, the user-based knowledge generated feeds into the system, enriching its data output. The data feedback loop is enabled by one or more prototypes; some of which are tools available to users, such as the Crete3D platform in the case of Agora experimental study, or the user interface in the case of the EcoMotivate platform. As such, the prototype is intrinsically linked to the user-related methodology and also triggers the creation of novel design spaces.

These spaces are hybrid, enabled by their digital component and experienced by users in their physical space. From an architectural viewpoint, their spatiality can be visualized by users by adding the components of time and interaction. From an interaction-design perspective, the experiential element is a combination of user needs, available interaction types, and target experiences.

Study Title	**User-related Methodology**	**Prototype**	**Novel Design Spaces**
EcoMotivate	User Profiling User Scenarios	User Interface	space between UI and physical space
Ambassador's Residence	1:1 Interviews User Scenarios User real-time location tracking	Video	space between UI and physical space
Smart Home	1:1 Interviews	Drawings	Digital Space and UI
Smart Agora	Questionnaires User real-time location tracking	Video	Multi-scalar connecting tissue Scenario-based QR Code Application

Table 21 Synthesis of Experiment Results
User-related methodology and Novel Design Spaces

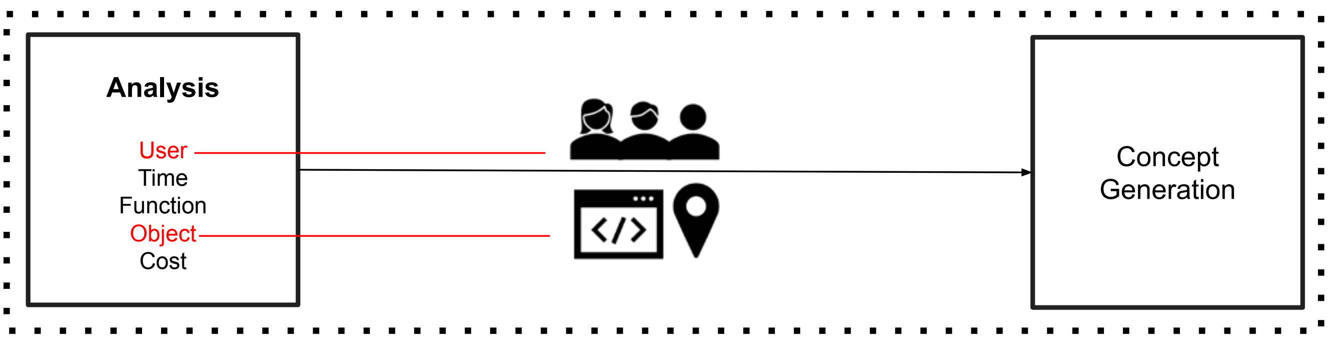


Figure 53
Focusing on the first two steps of the Achten - Kopriva methodology.

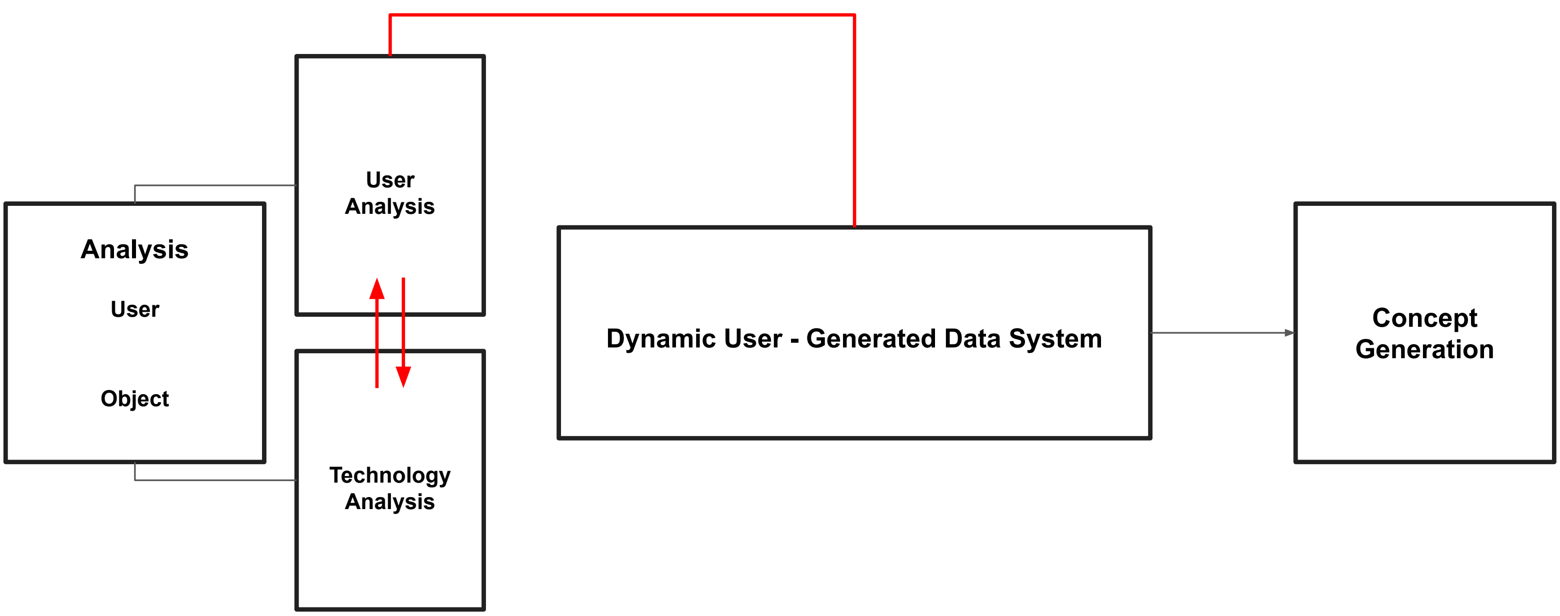


Figure 54
From Analysis to Concept Generation

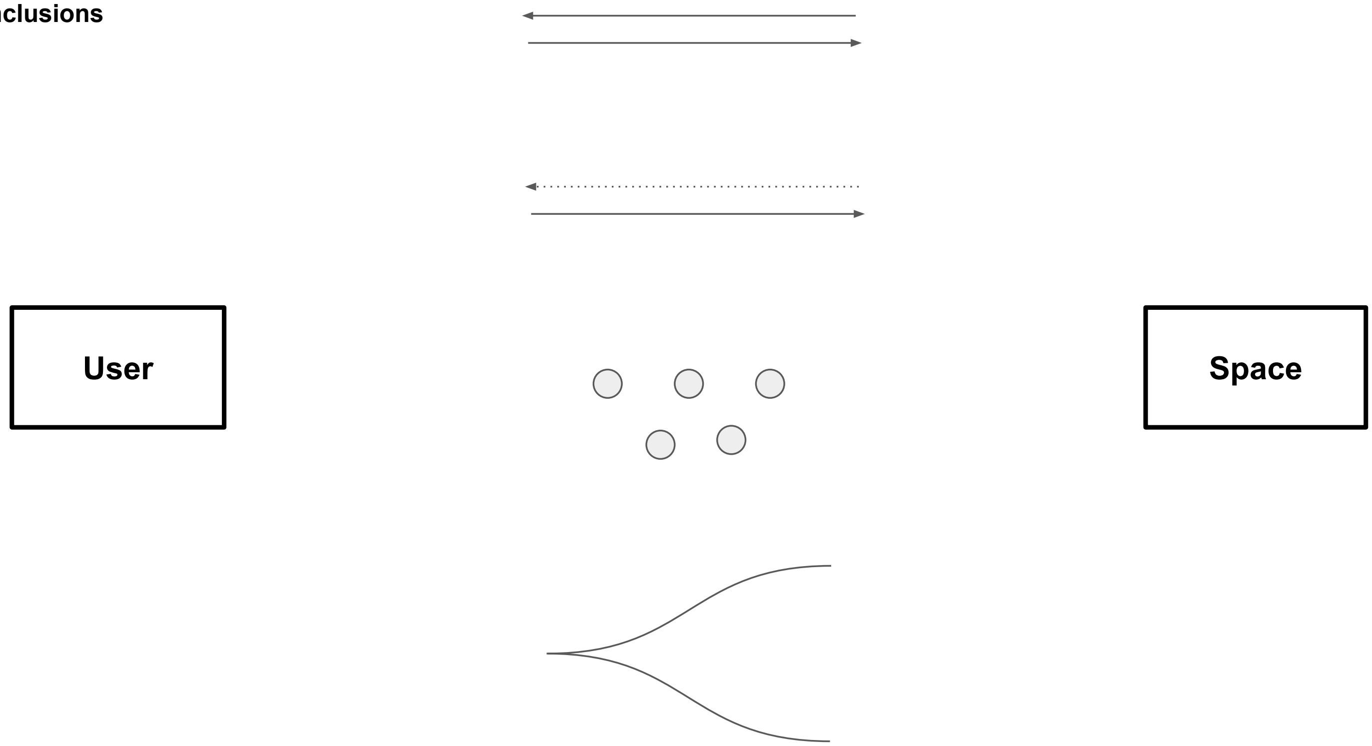


Figure 55
Identifying four communication channels between user and space.

Conclusions

This thesis has provided insights into the emerging synergies found at the intersection of user–technology interaction and the concept-generation phase of the architectural design. In fact, to my knowledge, it is the first methodological framework that emphasizes the strong connection between concept, architectural design, and user innovation. In order to provide a solid theoretical framework for architects and designers that are interested in integrating interaction and IoT into the design process, it builds a set of interdependencies of significant factors of the process. As such, users, user-related methods, the building typology, the design goal and the interaction type become the interdependent factors that the architect-designer can use in order to integrate the new technological capabilities in the concept generation process. The interdependencies model, confirmed that interaction and architectural design are not stand-alone processes; they work in parallel and act complementarily. As Christensen (2019) states, “You can’t solve part of the problem if you’re not prepared to answer the whole problem”. The interdependencies between user, design process and technology prove that all parameters defined by Achten and Kopriva in their methodological framework are interrelated, and thus should be examined as such. Although up until now, in most cases their components have formed independent work streams, their convergence offers a new quality to the whole design process, upgrading both the interaction and the architectural design. By producing simplified data-driven, user-generated knowledge at the preliminary design phase, novel spaces are encountered, unlocking new levels of creativity and new strategies to be used, reshaped, and tested in the design process.

Moreover, the human-centric methodological approaches identified in this study— assist us in understanding the role of user in the entire design process and extend our knowledge of technology-based, human-centric approaches. This process is long and complex. As such, it requires the synthesis of a series of user roles —guest, visitor, tenant, and tourist, architect, designer and computer scientist. I had to examine, merge, and after this, empirically observe these roles in order to provide a valid user-centered framework. In the end, the entire design process was reimagined through the eyes of the user, enabling the human needs, desires, aesthetics and perspectives to be incorporated into the initial design framework.

By establishing the ‘intelligence by default’ versus the ‘intelligence by design’ comparison, I demonstrated how interactive built space expands beyond simply installed sensors and actuators enabling interaction. As such, this study investigated the synergies emerging from the new relationships between user, technology and space, both as architectural phenomena and as new social circumstances. Moreover, the process of collecting data results in twofold benefits: 1) it establishes a new dynamic feedback loop between user and system, which collects user spatial and experience data and renders people a key feature of the whole process; 2) it creates a knowledge base that evolves and grows through interaction and over time.

This study is one of the first attempts to formulate a human-centered theoretical framework in an accessible way for architects and designers and users. By deconstructing and recomposing the parameters of the aforementioned methodological framework, it moves beyond the fundamentals of user experience research and incorporates user empathy encountered in the process of architectural design. For example, in the case of the Agora, the dynamic system of user location tracking demonstrated that users experienced lack of orientation at the center of the building. The design process intends to solve this issue and redesign the interaction route to enable better space orientation. This study also showcases the advantage of the human-centered, architectural design process via user interaction and supports a new spatiality, and also empowers users.

Does such a user-centric process disruption empower users by enhancing their experience? This study shows how the smart ecosystem can unlock endless potentialities of space. On the one hand, technology becomes a tool for architectural designers to analyze spatial interaction and simultaneously, the space being designed serves as the testbed for technological applications and experimental user approaches. New knowledge is acquired from the behavioral patterns of users, the specific knowledge of users' experience in designed space, the conflicts between the intelligent layer (the digital part) and the physical space, and even the reinvention and revisiting of major architectural elements, such as building typology. By incorporating users into the design process and exploring this need, this holistic hybrid model provides architects with valuable data on the human aspect of the smart ecosystem and reveals innovative ways to create novel (smart) spaces within the design process—spaces that can expand, improve and promote new experiential phenomena.

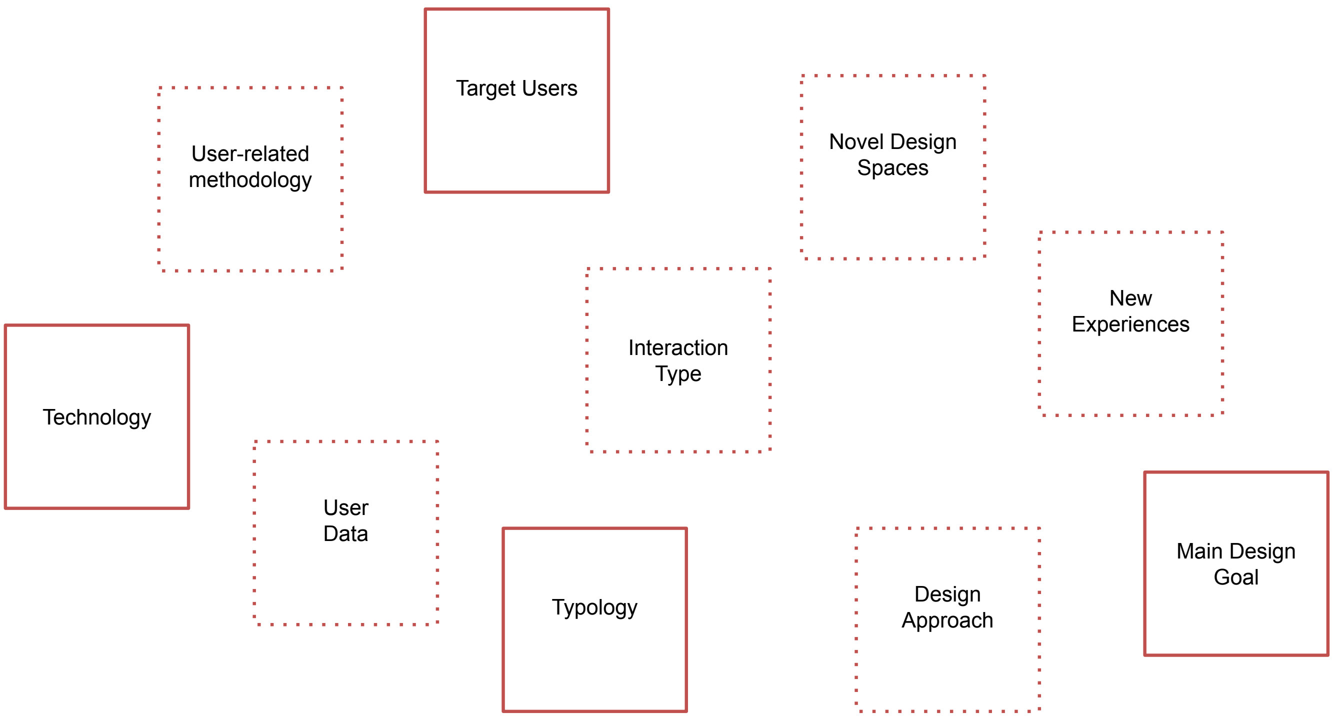


Figure 55
Establishing the interdependencies model.

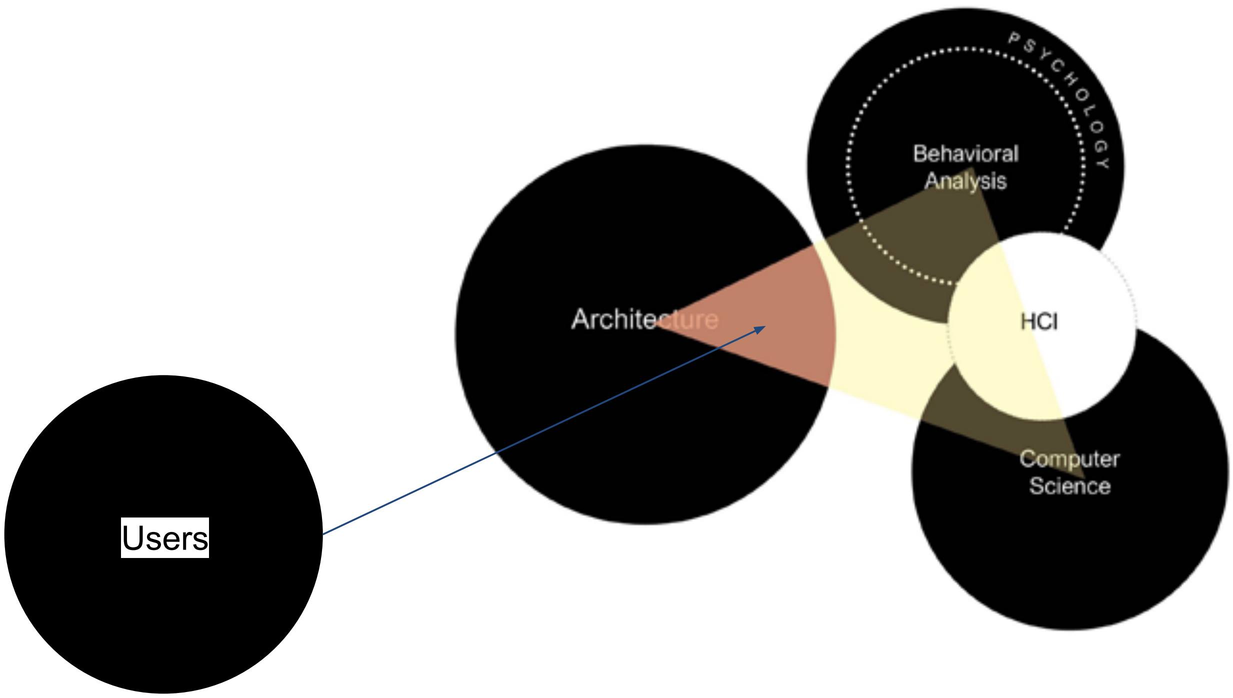


Figure 56
Revisiting the intelligence layer.

Discussion and Future Work

The question arises, could this synergy of user interaction and architectural design operate in a non-human-centric way? (e.g. measure the building performance or create a direct interaction between space and technology, skipping user). The relevance of user input is clearly supported by the current findings. This new understanding should help to promote human-centric approaches in the design of smart spaces, rendering intelligence an architecturally designed attribute of the new spatiality.

The number of devices connected to the internet will radically increase in the near future, making the interaction between the material and immaterial, human and non-human parts of the smart ecosystem even more complex. An increasing number of devices will be able to provide all types of interaction, passive and active, instrumental and informative. Communication will be further simplified and the aggregation of many devices and their enhancements to design and a numerous other process will be facilitated. If the debate over IoT and new methods of communication and interaction is to be moved forward, a better understanding of the human-centric approach must be developed.

The results of this study are based on the technological analysis of existing, tested and approved technologies. From a technological viewpoint, would it be possible to integrate a new technology and simultaneously produce technological and design innovation? While this approach would be extremely innovative and would allow for a fast-track technological experimentation and evaluation within the spatial context, the interdependencies framework should be restructured to allow multiple iterations between user and technology, until the solidification of the technological prototype. Similar to this approach is Mueller and Thoring's (2012) model that disassembles the operational path of Lean Innovation and Design Thinking and then merges elements of the two into a new combined framework called 'Lean Design Thinking'.

The methodology employed in this study offers guidance on the interaction of users and new technologies with architects and designers. Two points must be considered here: firstly, that the idea of interdependencies creates a layer of flexibility in the design, thus facilitating the innovation process; secondly, as Achten mentions (2011) the architect has to avoid "death by method", in the sense that the added value of a methodology in the architectural design process is to help designers to solve issues without losing their inspiration. It provides guidance but, unlike other disciplines, it does not require protocols and formal expression of every step.

Another issue that emerges through this study is the integration, representation and implementation of interaction at later phases of the design process, such as in the preliminary and executive design process. Whilst this study substantiates the usefulness of human-centric approaches as part of conceptual design, it does not confirm the ability of integrating user-technology interaction at later phases of the design process. Although it is relatively easy to think about conceptual design, the process of executive design still seems a stand-alone process in an early phase. What kind of representational techniques would an architect use to accurately represent the interaction design in later phases, such as the design execution or even construction phase?

What's Next?

Future work can focus on the implementation of a complete prototype of interaction design at the Municipal Agora of Chania. Expanding further the Design Approach of Narratives, where the Agora was rethought as a commercial hub, and also as a historical thinktank, the goal is to produce a three- dimensional model on a real-time development platform and experiment with different types of interaction, as well as various representation techniques. In that framework, a series of concepts on the new spatiality will be examined: the notion of proximity, connectedness and distinctiveness and their correlation with interaction types. Going even further, parallel to the experimentation and design of novel spaces, it aims to identify new or disrupted types of interaction, expanding beyond the interaction types, as presented by Preece, Rogers and Sharp (2002) and investigate novel interaction types that relate to the new spatiality and reinforce the human-centric aspects of the smart ecosystem.

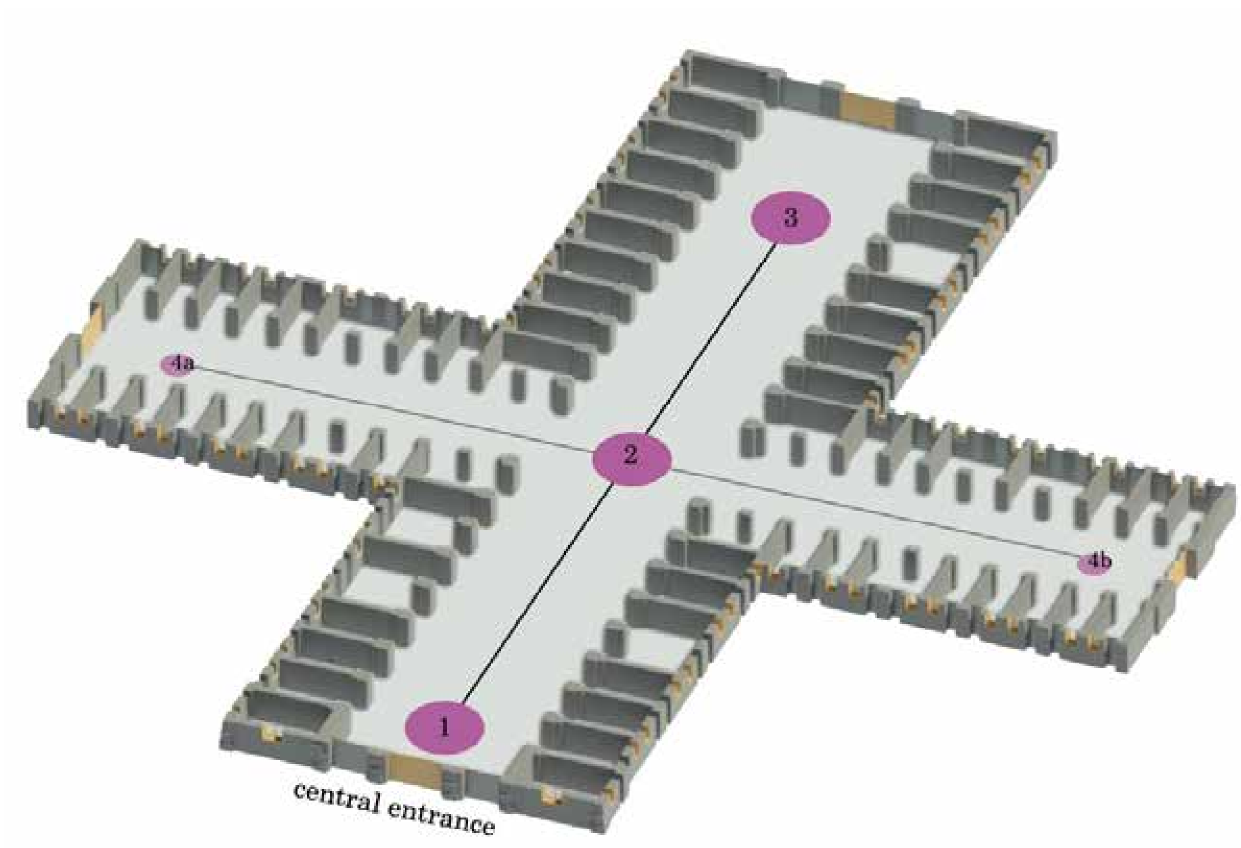


Figure 57
Suggested route of Interaction

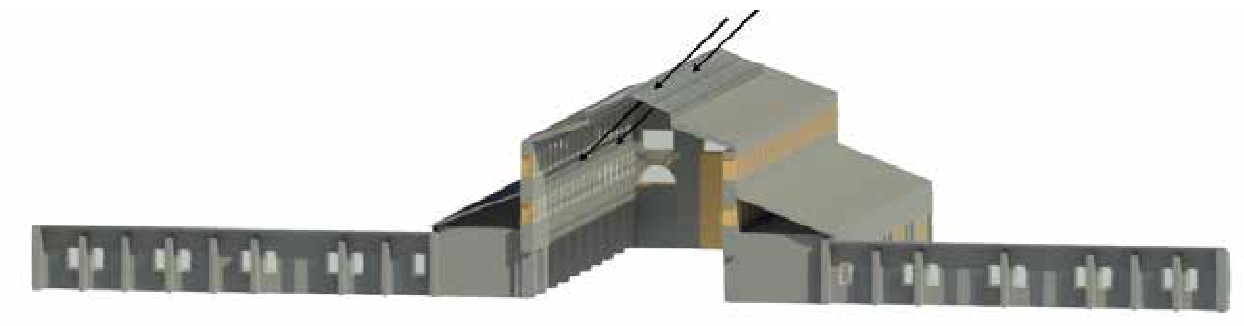


Figure 58
Augmenting the light from above

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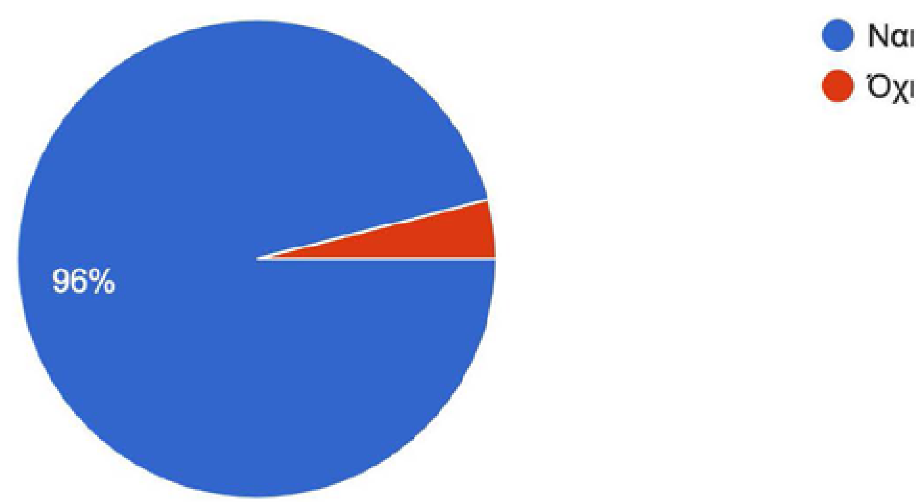
Appendix A
Questionnaire Synopsis

Section I

Είχατε επισκεφθεί στο παρελθόν τη Δημοτική Αγορά Χανίων;

25 responses

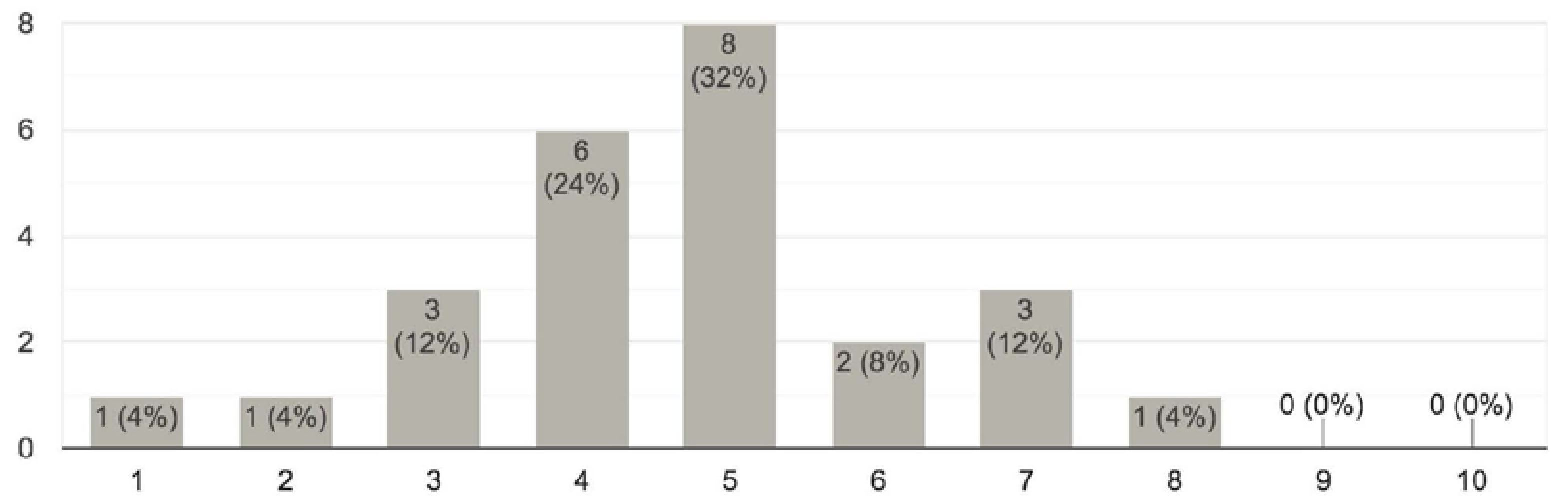


Αν την είχατε ξαναεπισκεφθεί, ποιος ήταν ο λόγος της επίσκεψής σας;

25 responses

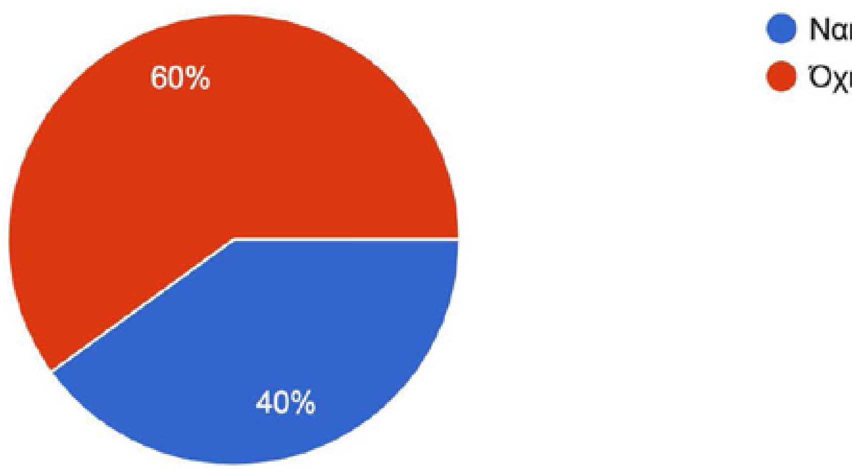
Πριν την επίσκεψη της 22ης Μαΐου, από το 1 μέχρι το 10, πώς θα βαθμολογούσατε το επίπεδο των γνώσε...ας σχετικά με το κτήριο / μνημείο;

25 responses



Κατά την παραμονή σας εκτός της Δημοτικής Αγοράς, περιηγηθήκατε ηλεκτρονικά στην πλατφόρμα CRETE3D;

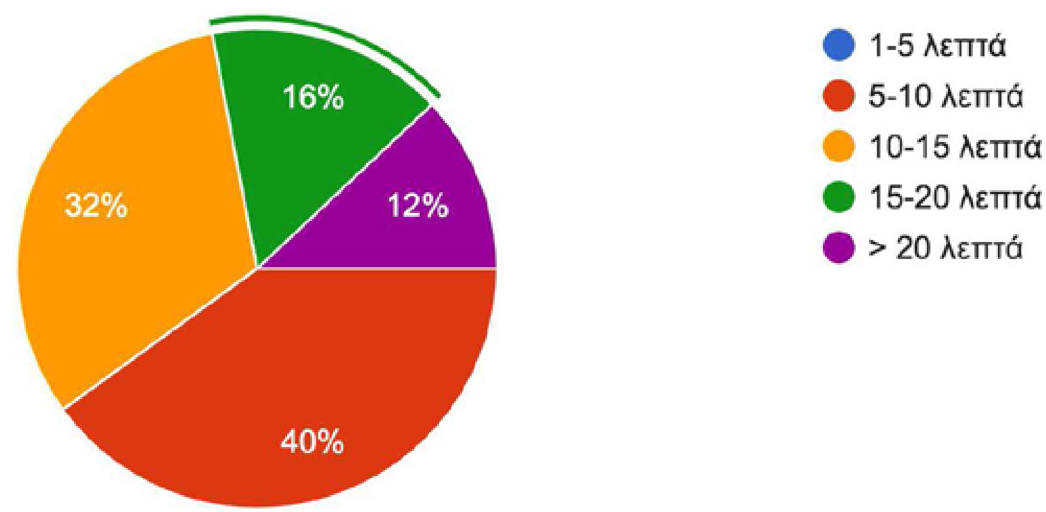
25 responses



Section II

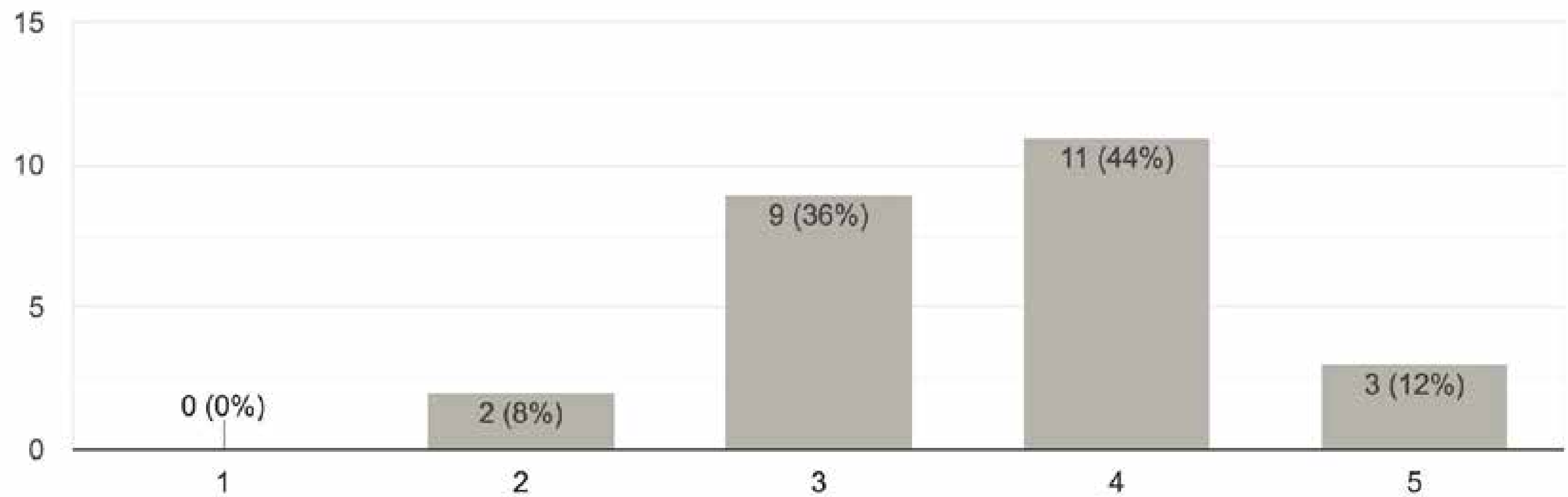
Πόσην ώρα παραμείνατε εντός της Δημοτικής Αγοράς;

25 responses



Πώς θα χαρακτηρίζατε την επίσκεψη;

25 responses



Γιατί;

Κόσμος
Μια αγορα ητανε.Και οι τιμες δεν ηταν και τοσο οικονομικες.
Ζεστη και οσμες
ήταν μία ευχάριστη περιπλάνηση
ωραιο κλιμα
μυρίζει άσχημα,με εκνεύρισε και ένας ρατσιστης καταστηματάρχης
διότι περιηγήθηκα στον χώρο με διαφορετικό τρόπο και παρατήρησα πράγματα που δεν είχα προσέξει άλλες φορές.
Πολυπολιτισμικό σημείο συνάντησης και τριβής.
Λόγω της παράδοσης
Γιατί είχε πολλή ζέστη
ωραίο κλίμα που συνδυάζει αρχιτεκτονικη, τουρισμό και αρχαιολογία...
Είχε πολλά πράγματα αλλά με ενοχλούσε η μυρωδιά
διοτι περιπλανηθηκα παρατηρωντας τον εσωτερικο χωρο της αγορας
Η αγορά ήταν γεμάτη από κόσμο που της έδινε ζωή και έτσι ως επισκέπτης βίωσα την αγορά του σήμερα και μεταφέρθηκα στην αγορά του χθες.
Παρατήρησα περισσότερο τα μαγαζιά που είχε
Μπήκαμε σε καταστήματα και μιλούσαμε με τους υπεύθυνους
άσχημες οσμές, κακώς αερισμός
Δοκιμάσαμε μια νέα εφαρμογή για για τους περισσότερους απο εμάς,η οποία αποτελεί έναυσμα για την εξερεύνηση νέων τεχνολογιών σχετικών με την επιστήμη της αρχιτεκτονικής.
Γιατι ενιωθα πως ημασταν μια μεγαλη ομαδα
Υπήρχε συνωστισμός
Μάθαμε και καινούργια πράγματα
Μάθαμε καινούργια πράγματα
Δεν υπήρχαν σημεία ενδιαφέροντος
Παρατηρησαμε το μνημειο με προσοχη και συναναστραφηκαμε με τους εργαζομενους της αγορας

Ποιό σημείο σας έκανε ιδιαίτερα θετική εντύπωση και γιατί;

Κόσμος - κίνηση

Κανενα

το κεντρο, για τις πληροφορίες που ειχε

το μαγαζι που πουλουσε μπακλαβάδες

ο αριθμος των εμπορικων καταστηματων και ο τουρισμος

μου αρεσεθ η οροφή

Θετική εντύπωση μου κάνει η ζωντάνια και ο παραδοσιακός κρητικός χαρακτήρας που διατηρείται στην καρδιά της πόλης

Η ζωντάνια, οι μυρωδιές, η περιέργεια, η υποβόσκουσα χαλαρότητα μέσα στη διαφαινόμενη ένταση.

Οι παράγκες με τα τοπικά προϊόντα γιατί μέσα στην αγορά μπορεί ο ξένος αλλά και ο ντόπιος να βρει ό,τι ψάχνει.

η βοήθεια που μας προσέφεραν οι συμφοιτητές μας ο οποίοι φάνηκε να γνωρίζουν καλά το αντικείμενο της άσκησης

η οροφή με τα γυάλινα ανοίγματα

το κέντρο της αγοράς που έβλεπες όλες τις εξόδους και επέλεγες σε ποια κατεύθυνση να πας

Ιδιαίτερα θετική εντύπωση μου έκανε η δικτυωτή στέγη της αγοράς, αλλά και τα παραδοσιακά μαγαζιά, όπως τα κρεοπωλεία και τα μαγειρεία που διατηρούν ακόμη την παλιά τους ταυτότητα, αν και η αγορά έχει χάσει την παλιά της αίγλη .

Το κέντρο

βόλτα στα κρητικά παραδοσιακά μαγαζάκια

Το σημείο όπου "τέμνονται" οι άξονες κυκλοφορίας καθώς απο αυτό το σημείο είναι δυνατή η οπτική επαφή στο μεγαλύτερο μέρος του κτηρίου.

Το κεντρο γιατι μπορει να εχεις εποπτεια για το τι συμβαινει απο καθε εισοδο

ο κυριως αξπνας που συνδεει την πλατεια με τον πεζοδρομο απο πισω, καθως η οροφη σε εκεινο το σημειο ειναι ενιαια και σε παροτρυνει να προφωρησεις ευθεια

Τα μαγαζιά γιατί είχαν τα τοπικά προϊόντα

Τα μαγαζια γιατί είχαν τα τοπικά προϊόντα των Χανίων

Η στέγη εξαιτίας της δομής της

Ποιό σημείο σας έκανε ιδιαίτερα αρνητική εντύπωση και γιατί;

Κανενα

-

Μαγαζιά με φαγητά, δυσάρεστες μυρωδιές

τα σημεία με μαγαζια, οπως τα ιθχυοπωλεια, γιατι φαινόντουσαν απεριποίητα για ενα τοσο σημαντικό σημειο της πολης

η ψαραγορά διότι ήταν απεριποίητος χώρος

η κατασταση του κτιριου

η μυρωδιά και τα τουριστικά μαγαζιά

Η συντήρηση του κτηρίου και των καταστημάτων

Η κακή αισθητική της πλειοψηφίας των εμπορευμάτων.

Δεν είχαμε ολοκληρωμένη εικόνα της άσκησης και του σκοπού της

πολλά καταστήματα, όχι και τόσο καλά διατηρημένο μνημείο και καθαρό.

οι μυρωδιές από τα κρέατα και τα τυριά...

Δεν μου άρεσε το γεγονός πως υπήρχαν τόσα τουριστικά μαγαζιά, ενώ ως χαρακτηριστικό μνημείο της πόλης θα μπορούσε να αναδείκνυε καλύτερα το ιστορικό της παρελθόν.

Ισως θα ήθελα να είχε καλύτερη οσμή

έντονη άσχημη μυρωδιά, κρεοπωλείο απέναντι σε εστιατόριο, ελεύθερα περιστεράκια μέσα στο χώρο της αγοράς

Το σημείο πανω στον άξονα της κυκλοφορίας όπου βρίσκονται τα τραπέζια των εστιατορίων καθώς δυσχεραίνουν την κυκλοφορία.

η ανατολικη και η δυτικη πλευρά γιατι με θλίβει η εικόνα που αντικρίζεις κατα την έξοδο

το σημειο με τα ψαρικα γιατι μυριζαν

Ότι τα καταστήματα δεν ήταν σωστά ομαδοποιημένα

Δεν ήταν καθόλου ομαδοποιημένα τα καταστήματα

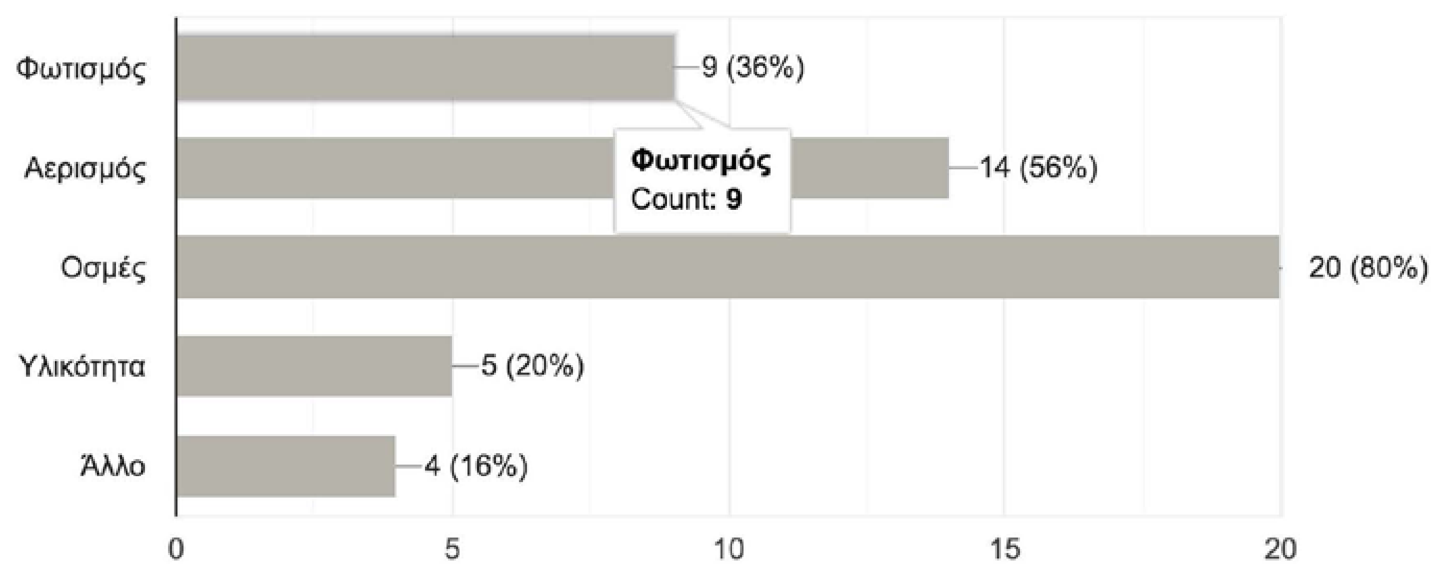
Η διάταξη των καταστημάτων

Τα αντιαισθητικα τουριστικα μαγαζια

κανένα

Αν μπορούσατε, ποιά χαρακτηριστικά του χώρου θα βελτιώνατε;

25 responses



Appendix A
Questionnaire Synopsis

Section III

Τι αποκομίσατε από την ψηφιακή σας περιήγηση στην πλατφόρμα Crete3D; (μόνο για όσους περιηγήθηκαν στην πλατφόρμα)

Πληροφορίες σχετικά με την αγορά

Κάποιες γενικές πληροφορίες για τον χώρο

έμαθα πιο πολλά για το μνημείο αλλά και για ολόκληρη την κρητη

Κάποιες πληροφορίες που δεν γνώριζα σχετικά με το έτος κατασκευής και το πότε είχε αναγνωριστεί ως διατηρητέο μνημείο.

Στο να διαπιστώσω πως θα μπορούσα σαν μαθητευόμενος αρχιτέκτονας όταν σχεδιάσω ένα κτίριο να μπορώ να προβλέψω κατά κάποιο τρόπο την διαδρομή των διερχόμενων σε μια πιο ελεύθερη και όχι τόσο αυστηρή κάτοψη στο να κάνει ο καθένας μια πιο ευχάριστη διαδρομή

Πληροφορίες σχετικά με το κτήριο όπου στεγάζεται η αγορά και την γνώση ενός νέυ τρόπου εξερεύνησης παρόμοιων κτηρίων και περιοχών.

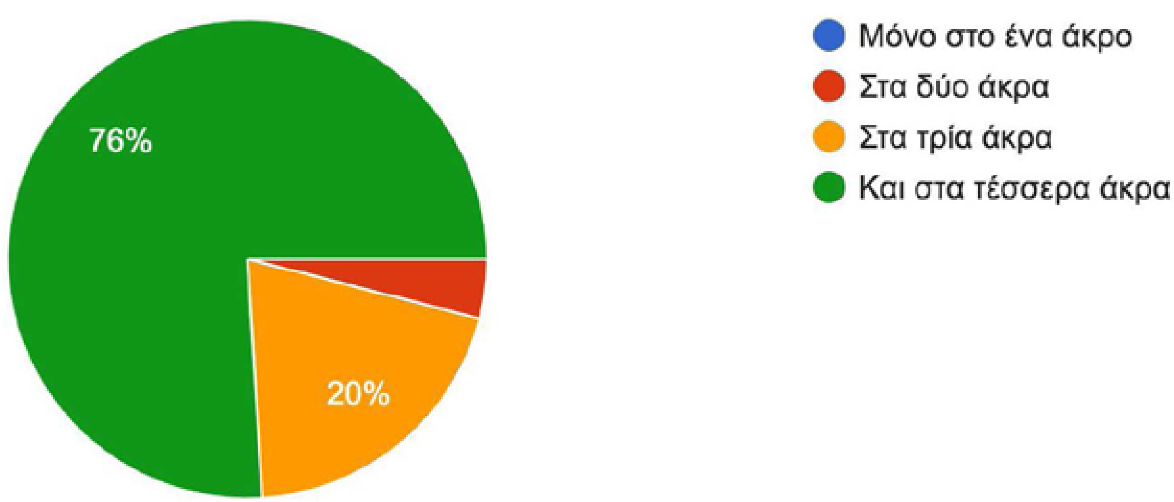
Μια ξεκαθαρη εικονα , ευκολα διαχειρισιμη και με γενικές πληροφορίες σαν περιγραφη ταινιας που τlς λεπτομερειες θα τις δεις βλέποντας την.

γενικες πληροφοριες οπως ετος κατασκευης

-

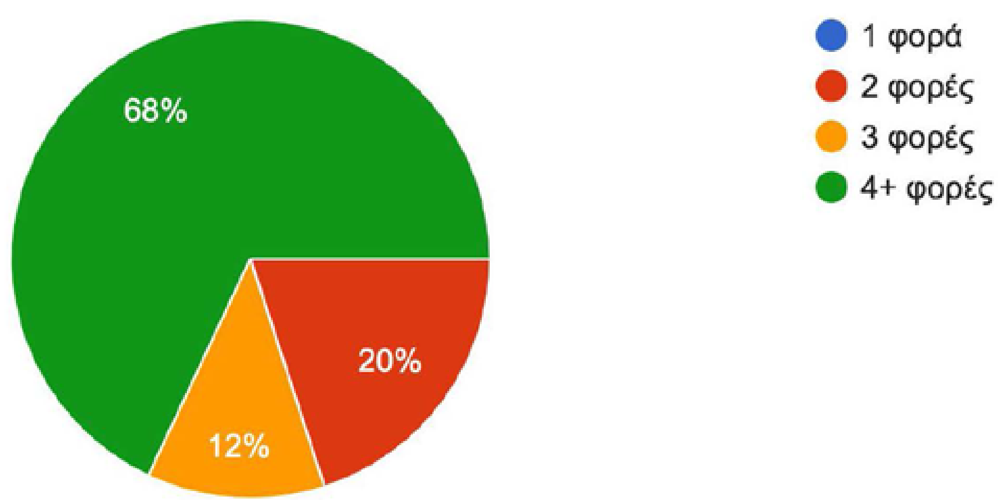
Περπατήσατε και στα τέσσερα άκρα του κτηρίου;

25 responses



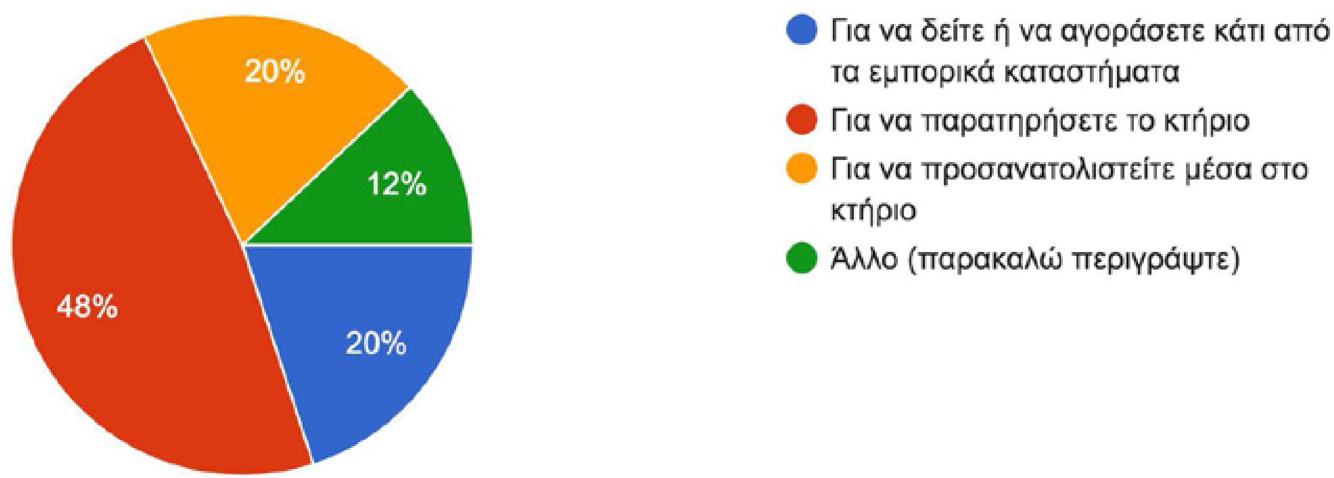
Πόσες φορές περάσατε από το κέντρο του κτηρίου;

25 responses



Στη διάρκεια της πορείας σας μέσα στο κτήριο, οι στάσεις που πραγματοποιήσατε ήταν:

25 responses



Ποιό σημείο του κτηρίου σας φάνηκε ενδιαφέρον αρχιτεκτονικά και γιατί;

Κατασκευή οροφής

Η εισοδος.Δινει την εντυπωση πως το κτιριο ειναι πολυ μεγαλυτερο απ οτι ειναι στην πραγματικοτητα

ο τροπος που εντάσσεται στο περιβάλλον εχει ενδιαφέρον καθως καταφέρνει να συνυπάρχει με αυτό με το περασμα των χρονων

το πως εντάσετε το κτηριο στο περιβάλλον

η διαφανεια της οροφης

βοηθουσα τα παιδια να συγχρονίσουν την εφαρμογή

Η οροφή λόγω της χρονολογίας της κατασκευής και των υλικών

Το κέντρο, ως πυρήνας των δραστηριοτήτων, ως σημείο συνάντησης, ως μέση του ταξιδιού.

Η οροφή

Η στέγη της αγοράς. Ειχε κατασκευαστικο ενδιαφέρον.

οροφη

Το μέγεθος της κύριας νότιας όψης αλλά και η κατασκευή του στεγάστρου της αγοράς

το δικτυωμα της οροφης

Ή στέγη, λόγω της ξύλινης δικτυωτής κατασκευής της

Ο οροφή

Η πίσω έξοδος, γτ είχε χαρακτηριστικά της αρχαίας κλασσικής περιόδου.

το μόνο σημείο του κτιρίου που μου φάνηκε ενδιαφέρον αρχιτεκτονικά ήταν η οροφή του κτιρίου (δεν μπορούσες να δεις κάτι περισσότερο γιατί τα μαγαζάκια είχαν καταλάβει τον περισσότερο χώρο) όπου διερχόταν εντόνως φωτισμός άλλα δύστυχος την είχαν παραμέληση με αποτέλεσμα να κάνουν φωλιές διάφορα ζώα, βρομιά, οξείδωση των μετάλλων κ. α.

Η κεντρική είσοδος ,καθώς σε αυτή έχουν διατηρηθεί αναλλοίωτα τα χαρακτηριστικά της στο πέρασμα του χρόνου "μεταφέροντας" μας σε μια άλλη εποχή.

Η εικόνα της αγοράς μαζι με την πλατεία κοιτώντας την απο μακριά καθως κατεβαίνεις απο Τζανακάκη (για παράδειγμα) .

δεν εκανα στασεις

Η οροφή του κτιρίου λόγο της κατασκευής

Η οροφή του κτηρίου λόγω της κατασκευής

Η στέγη λόγω της δομής της

Η κεντρικη εισοδος του κτηριου, νομιζω ειναι εντυπωσιακη

η είσοδος γιατί είναι πιο καλά διατηρημένη