Technical University of Crete, Greece
Department of Electronic and Computer Engineering

A CASE (Computer-Aided Software Engineering) Tool for Robot-Team Behavior-Control Development

Angeliki Topalidou-Kyniazopoulou

Thesis Committee
Assistant Professor Michail G. Lagoudakis (ECE)
Assistant Professor Aikaterini Mania (ECE)
Dr Nikolaos Spanoudakis (Department of Science)

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Τμημα Ηλεκτρονικων Μηχανικων και Μηχανικων Υπολογιστων

Ένα εργαλείο CASE (Computer-Aided Software Engineering) για την Ανάπτυξη Ρομποτικής Συμπεριφοράς Ελέγχου

Αγγελική Τοπαλίδου-Κυνιαζοπούλου

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Επίκουρος Καθηγητής Μιχαήλ Γ. Λαγουδάκης (ΗΜΜΥ)

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Abstract

The development of high-level behavior for autonomous robots is a time-consuming task even for experts. Computer-Aided Software Engineering (CASE) tools improve productivity and quality in software development, however they are not widely used for robot behavior development, even in domains, such as the RoboCup (robotic soccer) competition, where robot behavior needs to be quite frequently modified. This thesis presents a CASE tool, named Kouretes Statechart Editor (KSE), which enables the developer to easily specify a desired robot behavior as a statechart model utilizing a variety of base robot functionalities (vision, localization, locomotion, motion skills, communication). A statechart is a compact platform-independent formal model used widely in software engineering for designing software systems. KSE adopts the model-driven Agent Systems Engineering Methodology (ASEME) and guides the developer through a series of design steps within a graphical environment that leads to automatic source code generation. More specifically, KSE supports (a) the automatic generation of the initial abstract statechart model using compact liveness formulas, (b) the graphical editing of the statechart model and the addition of the required transition expressions, and (c) the automatic source code generation for compilation and execution on the robot. KSE has been developed using the Eclipse Modeling Project technologies and has been integrated with the Monas software architecture and the Narukom communication framework, which provide the base functionalities. KSE is used for developing the behavior of the Aldebaran Nao humanoid robots of our team Kouretes competing in the RoboCup Standard Platform League. As a result, the process of behavior development and modification has become much quicker and less error-prone. The flexible design of KSE allows its use in other behavior specification domains and its configuration for source code generation compatible with other software architectures.

Περίληψη

Η ανάπτυξη συμπεριφοράς υψηλού επιπέδου για αυτόνομα ρομπότ είναι μια χρονοβόρα διαδικασία, ακόμη και για έμπειρους μηχανικούς. Τα εργαλεία CASE (Computer-Aided Software Engineering) βελτιώνουν την παραγωγικότητα και την ποιότητα στην ανάπτυξη λογισμικού, ωστόσο δεν χρησιμοποιούνται ευρέως για την ανάπτυξη ρομποτικής συμπεριφοράς, ακόμα και σε τομείς όπως ο διαγωνισμός ρομποτικού ποδοσφαίρου RoboCup, όπου η συμπεριφορά των ρομπότ εξάνάγκης τροποποιείται αρκετά συχνά. Στην παρούσα εργασία παρουσιάζεται ένα εργαλείο CASE, με την επωνυμία Kouretes Statechart Editor (KSE), το οποίο επιτρέπει στον προγραμματιστή να καθορίσει εύκολα μια επιθυμητή ρομποτική συμπεριφορά με τη μορφή ενός μοντέλου διαγράμματος καταστάσεων (statechart) χρησιμοποιώντας μια ποικιλία βασικών ρομποτικών λειτουργιών (όραση, εντοπισμός, μετακίνηση, κινητικές δεξιότητες, επικοινωνία). Το διάγραμμα καταστάσεων είναι ένα συμπαγές τυπικό μοντέλο ανεξάρτητο από την πλατφόρμα που χρησιμοποιείται ευρέως στην τεχνολογία λογισμικού για το σχεδιασμό συστημάτων λογισμικού. Το εργαλείο KSE υιοθετεί τη μεθοδολογία Agent Systems Engineering Methodology (ASEME) που βασίζεται στη χρήση μοντέλων και καθοδηγεί τον προγραμματιστή σε μια σειρά βημάτων σχεδιασμού μέσα σε γραφικό περιβάλλον που καταλήγει στην αυτόματη παραγωγή κώδικα. Πιο συγκεκριμένα, το εργαλείο KSE υποστηρίζει (α) την αυτόματη δημιουργία του αρχικού αφηρημένου διαγράμματος καταστάσεων χρησιμοποιώντας συμπαγείς liveness φόρμουλες, (β) τη γραφική επεξεργασία του διαγράμματος καταστάσεων και την προσθήκη των απαιτούμενων εκφράσεων μετάβασης, και (γ) την αυτόματη δημιουργία πηγαίου κώδικα για μεταγλώττιση και εκτέλεση στο ρομπότ. Το εργαλείο KSE έχει αναπτυχθεί με χρήση των τεχνολογιών του Eclipse Modeling Project και έχει ενοποιηθεί με την αρχιτεκτονική λογισμικού Monas και το πλαίσιο επικοινωνίας Narukom, τα οποία παρέχουν τις βασικές λειτουργίες. Το εργαλείο KSE χρησιμοποιείται για την ανάπτυξη της συμπεριφοράς των ανθρωποειδών ρομπότ Aldebaran Nao της ομάδας Κουρήτες που αγωνίζεται στο πρωτάθλημα Standard Platform League του RoboCup. Ως αποτέλεσμα, η διαδικασία της ανάπτυξης και τροποποίησης συμπεριφοράς έχει γίνει πολύ πιο γρήγορη και λιγότερο επιρρεπής σε σφάλματα. Ο ευέλικτος σχεδιασμός του εργαλείου KSE επιτρέπει τη χρήση του σε άλλους τομείς καθορισμού συμπεριφοράς και τη διαμόρφωσή του για την παραγωγή πηγαίου κώδικα συμβατού με άλλες αρχιτεκτονικές λογισμικού.

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Chapter 1

Introduction

1.1 Thesis Outline

The main contribution of this thesis is the presentation of a CASE tool, its implementation process, and the benefits of the Agent-Oriented System Engineering (AOSE) methodology for Robot-Team Behavior-Control Development.

In chapter 2 we discuss the technologies and methodologies that we used for this thesis. We make an acquaintance with the roboCup Soccer Team Kouretes. We introduce the robot platform that the Kouretes team uses, i.e. the NAO robot. Furthermore, we discuss the Kouretes team software architecture, Monas and the communication interface, Narukom. Agent Systems Engineering Methodology (ASEME) and Agent Modeling Language (AMOLA) models are introduced for agent behavior specification. At the last section of this chapter we present the Eclipse Modeling Project which has been used for this thesis implementation.

In chapter 3 we discuss the values and the needs of a soccer team, what a robot behavior is and how can anyone design a robot behavior. Which technologies are available for behavior development what are their advantages and disadvantages. We present the existing behavior desing tools and their characteristics.

In chapter 4 we present our proposal for a CASE tool for robot-team behavior-control development. In addition, we present the available means and the requirements for achieving the implementation of our proposal. We discuss about the functionalities that a CASE tool should provide and which design methodology we use for developing an agent behavior.

In chapter 5 we introduce the implementation of our approach, the used technologies and the problems that we faced during this procedure. We present the eclipse platform, which was used for the implementation and its modeling components, which are very useful for designing a costumized graphical editor for UML models or any kind of models designed with Eclipse Modeling Framework (EMF). We present the actions, commands, functions that we added to the eclipse graphical editor in order to implement a CASE tool how can anyone export an eclipse product for multiple platforms by using one package and one configuration file.

In chapter 6 we present the evaluation that we did for our CASE tool KSE (Kouretes Statechart Editor). The first informal evaluation was made by Kouretes team members during the beta-testing period. In order to have official and objective evaluation results, ECE undergraduate students taking the Autonomous Agent course at the Technical University of Crete were asked to use *KSE* and evaluate it in one of their laboratory sessions. We present graphs with the responders answers, discuss their suggestions and present the ones that were implemented after this evaluation.

In chapter 7 we compare our CASE tool with other available CASE tools that are used for behavior control in RoboCup competition and at the market.

At the appendix A we present the KSE user manual.

Chapter 2

Background

2.1 RoboCup

There are few events that match the complexity of RoboCup. It is a venue for artificial intelligence, intelligent robotics research and a display of the achieved advancements. The RoboCup Competition, in its short history, has grown to a well-established annual event bringing together the best robotics researchers from all over the world, in Robocup 2011 which was held in Istanbul, Turkey, the participant teams were from 40 different countries. The initial conception by Hiroaki Kitano [1] in 1993 led to the formation of the RoboCup Federation with a bold vision: "By the year 2050, to develop a team of fully autonomous humanoid robots that can win against the human world soccer champions". The uniqueness of RoboCup stems from the real-world challenge it poses, whereby the core problems of robotics (perception, cognition, action, coordination) must be addressed simultaneously under real-time constraints. The proposed solutions are tested on a common benchmark environment through soccer games, rescue quests and human-machine interaction at home in various leagues, with the goal of promoting the best approaches, and ultimately advancing the state-of-the-art in the area. The robocup Competition has leagues for soccer, rescue, @home, and logistics. There are also competitions for junior students. Seeing the advancements in the leagues each year as 2050 becomes a closer date, our hope in meeting the challenge increases more.

Figure 2.1: Robocup 2011 logo.

2.2 RoboCup Competitions

RoboCup consists of four major competitions RoboCupSoccer, RoboCupRescue, RoboCup@Home and RoboCupJunior. Every competition of the above, except RoboCup@Home, has more than one leages that present contests that take place in a real field or a simulated one. A lot of progress has been made so far in many disciplines of robotics and RoboCup has been established in one of the most important events around the world.

2.3 RoboCupRescue

RoboCupRescue is a competition in which real or simulated robots perform a quest for objects in a hostile environment(Figure 2.2). RoboCupRescue initiated from the need of people to create robots capable of operating in those environments instead of humans. This area is very motivating in terms of helping the humanity while promoting robotics. RoboCupRescue is to promote research and development in this socially significant domain at various levels involving multi-agent team work coordination, physical robotic agents for search and rescue, information infrastructures, personal digital assistants, a standard simulator and decision support systems, evaluation benchmarks for rescue strategies and robotic systems that are all integrated into a comprehensive systems in future.

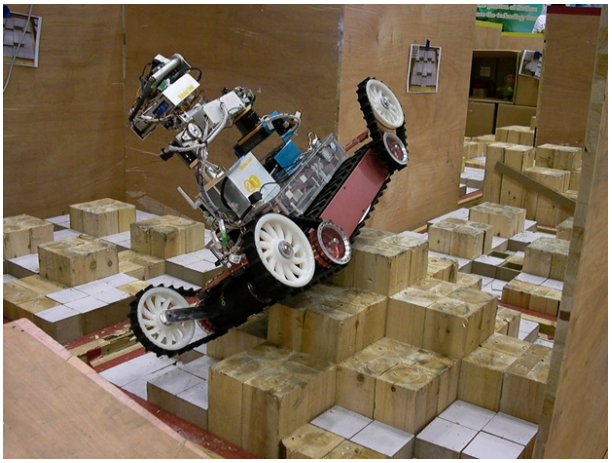


Figure 2.2: RoboCupRescue environments simulate hostile environments that exist in the real world.

2.4 RoboCup@Home

The RoboCup@Home competition focuses on real-world applications and human-machine interaction with autonomous robots. The aim is to develop service and assistive robot technology with high relevance for future personal domestic applications. It is the largest international annual competition for autonomous service robots and is part of the RoboCup initiative. A set of benchmark tests is used to evaluate the robots' abilities and performance in a realistic non-standardized home environment setting (Figure 2.3).

The research domains of this competition include Human-Robot-Interaction and Cooperation, Navigation and Mapping in dynamic environments, Computer Vision and Object Recognition under natural light conditions, Object Manipulation, Adaptive Behaviors, Behavior Integration, Ambient Intelligence, Standardization and System Integration.

Figure 2.3: Robocup@Home represents a social aspect of robotics interacting with people.

2.5 RoboCupJunior

RoboCupJunior is a project-oriented educational initiative for students up to the age of 19. It is a new and exciting way to understand science and technology through hands-on experiences with electronics, hardware and software. RoboCupJunior also offers opportunities to learn about teamwork while sharing ideas with friends. This competition has leagues such as Dance League, Rescue League, Soccer League and CoSpace League, so the young students can choose among a variety of contests to participate in. The development of study materials and innovative teaching methods are among RoboCupJunior's aims. It is very important to understand that this competition has nothing to be jealous of the other leagues, but in fact share the same vision and the required dedication to excel.

2.6 RoboCupSoccer League

The RoboCupSoccer League, is the domain with the most fans and consists of simulated and real-field matches. In this league researchers combine their technical knowledge in order to prepare the best robotic soccer team among other

universities and research institutions. We will focus more in this league, as this thesis is related to a robot soccer team software.

2.6.1 Simulation League

Simulation league consists of 2 different leagues, 2D simulation league and 3D simulation league. In these leagues teams don't need to maintain hardware, because their players are autonomous software programs(agents). Every match runs on a server and the crowd can watch the matches on a big screen(Figure 2.4). The 3D simulation competition increases the realism of the simulated environment used in other simulation leagues by adding an extra dimension and more complex physics. This shifted the aim of the 3D simulation competition from the design of strategic behaviors of in playing soccer towards the low level control of humanoid robots and the creation of basic behaviors like walking, kicking, turning and standing up, among others. The interest in the 3D simulation competition is growing fast and research is slowly getting back to the design and implementation of multi agent higher level behaviors based on solid low level behavior architectures for realistic humanoid robot teams.

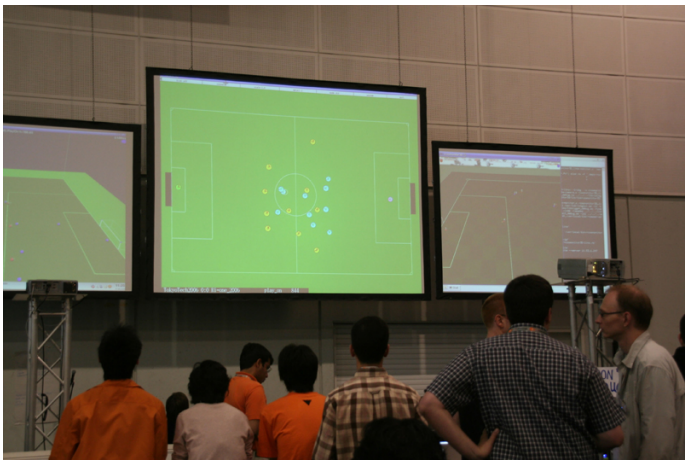


Figure 2.4: Crowd watching simulation soccer games.

2.6.2 Small Size League

A Small Size robot soccer game takes place between two teams of five robots each. Each robot must conform to the special specifications relating to the size according to their vision type, on board or global. Global vision robots, by far the most common variety, use an overhead camera and off-field PC to identify and track the robots as they move around the field. The overhead camera is attached to a camera bar located 4m above the playing surface. Local vision robots have their sensing on the robot itself. The vision information is either processed on-board the robot or is transmitted back to the off-field PC for processing. An off-field PC is used to communicate referee commands and, in the case of overhead vision, position information to the robots. Typically the off-field PC also performs most, if not all, of the processing required for coordination and control of the robots. Communication is wireless and typically uses dedicated commercial FM transmitter/receiver units.

2.6.3 Middle Size League

In the Middle size league according to 2011 rules, two teams of up to 6 robots play soccer on an $18m \times 12m$ indoor field. Each robot is equipped with sensors and an on-board computer to analyse the current game situation and successfully play soccer. Communication among robots (if any) is supported on wireless communications. These robots are the best players far among other leagues. The robots' bodies are heavy enough having powerful motors, heavy batteries, omni-directional camera, and a full laptop computer running in every robot; characteristics that make this league a great domain for research. In recent years research made good progress. Until 2010, the robots were only able to distinguish their own goal from the opponent goal by the goal color (the goals were colored yellow and blue respectively). From 2011's tournament all teams were able to play with net goals only. The ball is the only item that is still color-marked. The official FIFA winter ball is used - it is red. Middle Size is more competitive and demanding, having the largest field dimensions among other leagues (Figure 2.5).

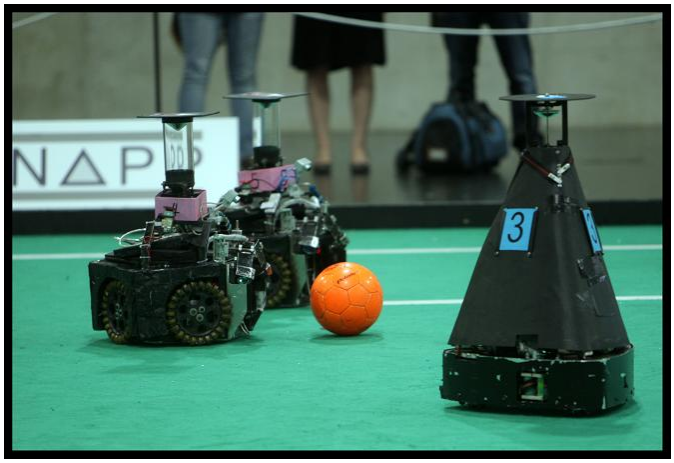


Figure 2.5: Middle size league game in Robocup 2010.

2.6.4 Humanoid League

In the Humanoid League, autonomous robots with a human-like body plan and human-like senses play soccer against each other. Unlike humanoid robots outside the Humanoid League the task of perception and world modelling is not simplified by using non-human like range sensors. In addition to soccer competitions technical challenges take place. Dynamic walking, running, and kicking the ball while maintaining balance, visual perception of the ball, other players, and the field, self-localization, and team play are among the many research issues investigated in the Humanoid League. Several of the best autonomous humanoid robots in the world compete in this league. The robots are divided into three size classes: KidSize ($30-60cm$ height), TeenSize ($100-120cm$) and AdultSize ($130cm$ and taller). In the KidSize soccer competition teams of three, highly dynamic autonomous robots compete with each other. For the first time, the TeenSize soccer competition will have teams of two autonomous robots competing with each other. In AdultSize soccer, a striker robot plays against a goal keeper robot first and then they play with exchanged roles against each other. The Humanoid League is one of the most dynamically progressing leagues and the one closest to the 2050's goal.

2.6.5 Standard Platform League

In Standard Platform League all teams use identical robots and is the most popular. Therefore, the teams concentrate on software development only, while still using state-of-the-art robots. The robots operate fully autonomously, i.e. there is no external control, neither by humans nor by computers. In 2008 the league goes through a transition from the four-legged Sony AIBO to the humanoid Aldebaran Nao (Figure 2.6). Every team has four players and the games take place in a $4m \times 6m$ field marked with thick white lines on a green carpet. The two colored goals (sky-blue and yellow until 2011) also serve as landmarks for localizing the robots in the field. Each game consists of two 10-minute halves and teams switch colors and sides at half-time. There are several rules enforced by human referees during the game. For example, a player is punished with a 30-seconds removal from the field if he performs an illegal action, such as pushing an opponent for more than three seconds, grabbing the ball between his legs for more than three seconds, or entering his own goal area as a defender. The main

Figure 2.6: Standard Platform League game in Robocup 2008(Opponents should be in different colors, but there was a lack of Nao robots in that event due to malfunctions)

characteristic of the Standard Platform League is that no hardware changes are

allowed; all teams use the exact same robotic platform, which is developed by an external robotics company and differ only in terms of their software. Given that the underlying robotic hardware is common for all competing teams, research effort has been focused on maximizing the efficiency of the hardware, the development of more efficient algorithms and techniques for visual perception, active localization, omni-directional motion, skill learning, and coordination strategies. During the course of the years, one could easily notice a clear progress in all research directions.

2.7 *Kouretes* Team

Kouretes Team,is a robotic team that participates in *SPL*(Standard Platform League) based at the Intelligent Systems Laboratory at the Department of Electronic and Computer Engineering. Until this date is the first Greek team participating in Robocup Soccer competition and especially in the Standard Platform League and the MSRS Simulation League.*Kouretes* Team was founded in 2006 by Michail G. Lagoudakis, assistant professor at Department of Electronic and Computer Engineering. The team's name, *Kouretes*, comes from the Ancient Greek Mythology and refers to *Kouretes* brothers Epimedes, Paionaios, Iasios, Idas and Hercules.

Since 2008 and the transition in RoboCup SPL from the AIBO robot to the NAO robot *Kouretes* Team develop their own open source code and their own customized to their needs system tools. The team aims to develop independent platform code for robots, but is still in early stages. The software architecture that the teams uses separates the platform characteristics from the modules that process the information taken from the environment and configures those modules for the specific platform. The main modules that *Kouretes*' code is highly and occasionally absolutely bound to the robot's middle-ware is the localization(*Kouretes* use the robot model given from Aldebaran-robotics) and the motion(Aldebaran walk) of the robot. *Kouretes* Team doesn't use source code from other teams, but uses the gained knowledge from their research in order to develop efficient

algorithms and techniques for information processing.

Kouretes have participated in many competitions, exhibitions, and affairs, but the highlights of the steep orbit the team followed were the second place in Robocup 2007, Atlanta, USA in the MSRS Simulation League, the first and third place in Robocup 2008, Suzhou, China in the MSRS Simulation League, and the Standard Platform League accordingly and the second place in Standard Platform League's Open Challenge Competition in Robocup 2011, Istanbul, Turkey.

Figure 2.7: Kouretes team 2011 in Istanbul. From left to right sitting down are Astero-Dimitra Tzanetatou, Iris Kyranou, Angeliki Topalidou- Kyniazopoulou. From left to right standing up Emmanouel Orfanoudakis, Eleutherios Chatzilaris, Nikolaos Spanoudakis, Michael Lagoudakis and Evangelos Vazaios .

More information and news of the team but also its members can be found at http://www.kouretes.gr.

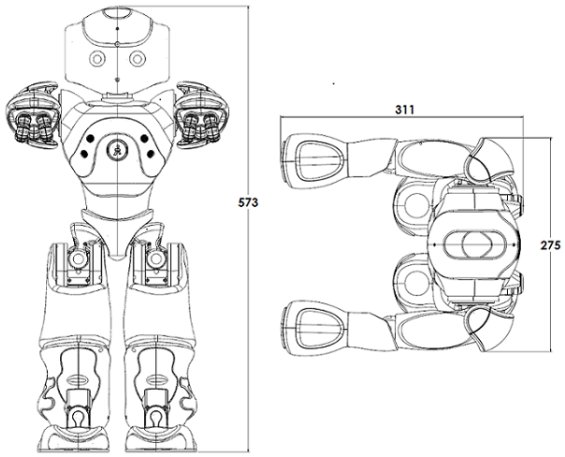


Figure 2.8: Nao's overview.

2.8 NAO Robot

NAO (Figure 2.8), in its final version, is 58 cm tall humanoid robot and weights 5.2 Kg. In 2012 Nao will be commercially released. According to Aldebaran-robotics over one thousand NAO robots have been sold since 2008 and until 2011 to universities and research institutions. The initial limited edition of the robot (RoboCup edition v2) made its debut at RoboCup 2008. The Nao robot v4 that will be out to the market in 2012 carries a full computer on board with an ATOM Z530 processor at 1.6 GHz, 1 GB RAM, and 2 GB flash memory running an Embedded Linux distribution. It is powered by a Lithium-Ion battery which provides about 60 minutes on active use or 90 minutes on normal use. NAO robot communicates with remote computers via an IEEE 802.11g wireless or a wired ethernet link. The NAO robot features a variety of sensors and actuators, in order to understand the environment and act in it.

NAO has two cameras(Figure 2.9) on its head of type SOC Image sensor which produce 30 images of 960p per sec. These two cameras can not function simultaneously, the robot can use only one camera at the time, so the choice of which camera is on, is due to whether the object to observe is near or far away from the robot. The perception of the environment concludes with the output of the two

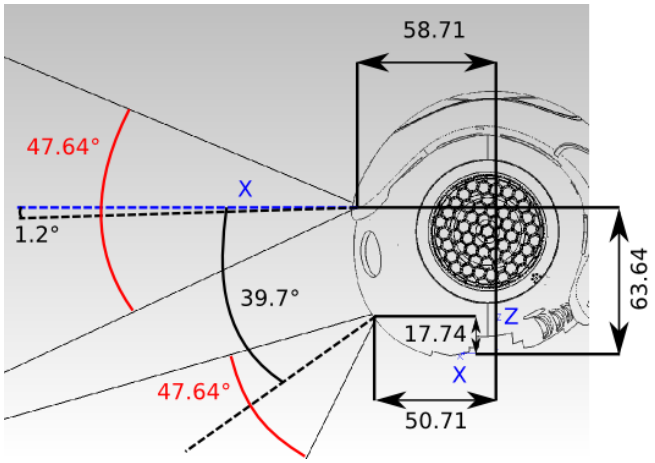


Figure 2.9: Nao's field of View

ultrasonic sensors(also referred as sonars) that represent the obstacles that stand 25cm to 255cm away from the robot.In case an object is in front of the robot in distance less than 15cm there is no information about the position of the object, but only for its existence.

A rich inertial unit (two 1-axis gyrometer and a 3-axis accelerometer) in the robot's torso provides real-time information about its instantaneous body movements. An array of force sensitive resistors on each foot delivers feedback on the forces aplied to the feet, while encoders on all servos record the actual joint position at each time and two bumpers on the feet provide information on collisions of the feet with obstacles. Finally, a pair of microphones allows for stereo audio perception. The Nao robot has a total of 21 degrees of freedom; 4 in each arm, 5 in each leg, 2 in the head, and 1 in the pelvis (there are 2 pelvis joints which are coupled together on one servo and cannot move independently). Stereo loudspeakers and a series of LEDs complement its motion capabilities with auditory and visual actions. Connecting to a robot is a major concept, thus Aldebaran provide us two means of connection. The NAO robot, can be connected directly or sharing the same network, through a wired ethernet link. Additionally, an IEEE 802.11g wireless card is available, which is the frequent way of connection, due to the lack of forces applied to the robot through the network cable. Through the wireless

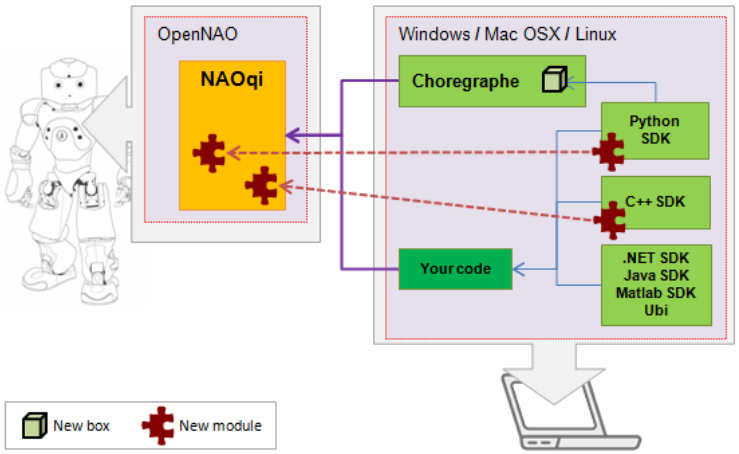


Figure 2.10: Embedded and Desktop software.

connection robots exchange data and during the soccer matches robots receive the referee's decisions. The NAO programming environment (Figure 2.10) is based on the proprietary NaoQi framework which serves as a middle-ware between the robot and high-level languages, such as C, C++, and Python. NaoQi offers a distributed programming and debugging environment which can run embedded on the robot or remotely on a computer offering an abstraction for event-based, parallel and sequential execution. Its architecture is based on modules and brokers which can be executed on board on the robot or remotely on pc's and allows the seamless integration of various heterogeneous components, including proprietary and custom-made functionality.

In overall, Aldebaran Robotics designed and assembled a low-cost robot, which can be a great platform used not only for scientific purposes, but entertainment as well, easily programmable, focusing on the wide audience of robotics' researchers and fans. The development of humanoid robots is a tough procedure that only few universities and companies have undergone, and even fewer were located in Europe.

To be fair, we have to admit that the first version of Nao was not functional to the level that Robocup teams would be satisfied. Nevertheless, most teams were

able to present some basic soccer behaviors, confirming that even under these limitations and the minimum available time for development, people involved in Robocup gave their best shot.

2.9 *Monas* architecture

Monas architecture [2] is the software architecture developed by team *Kouretes* for the NAO robot and for the robocup competition. While designing this architecture the engineer considers the robot as a collection of agents. Software modules are running concurrently, having their own goals. They can use any information available not only on the robot itself, but also information available on the robot's broader environment, for example other connected robots and computers. Thus, the *Monas* framework aims to manage the robot's software modules, allocate the resources appropriately, and provide a principled process for developing new modules. Additionally, *Monas* provides the necessary abstraction and platform independence, in both robots and computers, to allow for source code reusability among software tools that ease the development of agent's components. The above, offers a justification for the architecture's name: *Monas*. According to the ancient Greek philosophers, the Pythagoreans, *Monas* represents the first being, the indivisible, but also the totality of all beings. Its symbol, a circle with a point at its center, has also been used in astronomy to symbolize the sun, as well as by alchemists to represent gold. Hence, *Monas*, or *Μονάς* in Greek, being a software architecture for robotic agents represents the totality of the robot.

A major challenge for any software architecture is to provide a sufficient level of abstraction for organizing the source code. To this end *Monas* decomposes each module into activities. An activity refers to a simple discrete task that the agent has the ability to perform. The activity is supposed to be as simple as possible, but this is not enforced. *Monas* provided the developer with the necessary structure for organizing the code without compromising his/her freedom. To deal with larger activities, *Monas* provides further decomposition of activities into functionalities. Functionalities are implementations of what an activity

does and each activity must be associated with at least one functionality. Functionalities are source elements that implement very specific features found in the bottom of the hierarchy. Although the latter decomposition step is not optional in the design, it can be omitted in practice when there is no gain in decomposing the corresponding activity, for example when the implementation of the activity-functionality pair counts only a few lines of code. Agent decomposition also improves the code reusability as functionalities and activities can be freely used without modification in as many activities and agents respectively as the user likes. The developer can also trace the execution of the activities and thus the modification and data creation throughout the agent cycle yielding better debugging performance. Another advantage of the activity model is that agents can be modified at runtime by adding and/or removing modules without having to stop the execution of the architecture or even of the agent.

Monas architecture is designed to be a mobile architecture framework that supports a variety of robotic platforms. The only platform requirements posed by the architecture are the availability of a cpp (cross-) compiler for the on-board computer and the appropriate configuration to accomplish the building. In order to separate the user's source code from the underlaying platform, *Monas* introduces an abstraction layer that consists form a set of interfaces. The set is divided into two major sections: one that manages the robots sensors and actuators, and one for managing platform specific and operating system issues. That approach is appropriate because it separates the robot from its operating system and enables the architecture to run on a personal computer while is configured for a specific robotic platform.

To control the agent creation a primitive agent management system was implemented. Agents are defined in an XML file and instantiate at runtime. Each agent runs at its own thread with its activities executed sequentially. The proposed approach has the advantage that is very easy to understand and use efficiently. Managing agents from an XML file that is required at the start of the architecture, gives the developer the freedom to change the components of the agent and create new agents without the necessity to recompile the source code.

Monas also supports to start and terminate agents on the fly, by sending the appropriate network message. Agent modification is also supported over the network but the interface is not implemented yet.

Another feature of *Monas* architecture is the use of statecharts. Following the Agent System Engineering MEthodology, as described in section 2.11, it is very easy to design and develop an agent or a multi-agent system. At this point statecharts are used by team *Kouretes* as an agent that controls the robot's behavior. Statecharts' major difference from finite state machines and its derivatives is that they natively support concurrency. The advantage of statecharts is that it allows more than one state to be active simultaneously, in contrast to finite machines that allow only one state to be active at the time. To support that in the engine itself, without introducing loss of the system responsiveness, we split the execution of the engine into two parts. The first part is responsible for stepping the engine and is executed in its own thread, whereas the second one is responsible for executing all the activities that are active at the time, implemented as a thread pool. The implementation enables the developer to specify the maximum number of activities that can be active simultaneously, managing the CPU load and taking advantage of multi-cores CPU's.

Monas' statechart engine, can be used with the *Narukom* communication system for inter-activity and inter- statechart communication, giving the ability to every activity, action and transition to directly access a Narukom instance, which is unique within the underlaying statechart, and to a blackboard instance. Thus, activities can communicate, actions can interact with the environment and transitions evaluate their conditions using the publish-subscribe system. The blackboard instance is not one for every statechart instantiation but its is scoped. The scope include all the states between the lowest level OR-state that is a common ancestor of both the source and target states. As a result, activities that live in a different region of an AND-state will not have the same data at a specific time, this does also apply to the evaluation of transitions expressions in which the same condition may evaluate to true in a region whereas in an other one to false. The communication model solves the synchronization issues that arise, such as

the consumer-producer problem which occurs when an activity is executed more times than another activity which uses data provided by the first, as well as the starvation problem when multiple threads try to lock the same mutex simultaneously, that would have been occurred if have used a shared-memory model for the communication.

Monas statechart engine implementation has slightly different semantics from the Harrel's Rhapsody tool [3]. Beyond the OR-state, AND-state and BASIC-state, it defines the START-state and END-state, as in UML. Theses states are introduced to formalize the default transition inside an OR-state and to indicate that the inner state has reach its end of execution respectively. These states are useful because they ease not only the development of the engine but also the visual representation of the statechart. Also transition expressions can, of course, be included in their outgoing and incoming transitions making further control of the entrance and exit of an OR-stage formalized. Every state can have an entry and an exit action. Actions differ from activities as they do not consider to consume any, significant, computational time. Both actions are optional and will be executed in the activation and deactivation of the state. An activity must be assigned to a BASIC-state. On the activation of the state, the activity is enqueued to the thread pool and is then executed, according to the thread pool internal algorithm, on a separate thread. The activity is not executed endlessly as long as the state is active but it only runs once. As long as the activity is running, a shared mutex is locked so the states which share the same blackboard can not step to ensure the correct execution of the statechart. Transition segments support transition expressions which are represented visually as e[c]/a with 'e' denotes the event, 'c' the condition and 'a' the action. The transition expressions controls the execution of the transition: if the event match and the condition evaluate to true only then the action is executed. In the transition algorithm the event is disambiguated by the cpp typeid which indicates the class type of an object at runtime. Transition segments can orientate and/or reach the states that are described above or special states called connectors, forming compound transitions. A compound transition can be either executed as a whole, which means that every transition segment that participate must be executed, or not

executed at all. From the connectors introduced in Rhapsody only the condition connector is implemented. Other connectors can be implemented with ease as the engine is written to be expandable. Transition segments are template classes with arguments the source and the destination type. The type, which can be either a normal state or the condition connector, is used by the compiler to select the appropriate transition algorithm at compile time.

2.10 Narukom

Narukom [4] is the communication framework that the *Kouretes* team has developed and has been using for inter- and intra- robot communication as well as robot-to-computer communication. *Narukom* is a message-based architecture and provides a simple, efficient and flexible way of exchanging messages between robots, without imposing restrictions on the type of the data transferred over the network. The framework is based on the publish/subscribe paradigm and provides maximal decoupling not only between nodes, but also between threads on the same node.

The *Narukom* framework uses Google Protocol Buffers for the creation of its messages. Protocol Buffers are a way of encoding structured data in an efficient, flexible and extensible format and is being used by Google for almost all of its internal Remote Procedure Call protocols and file formats. Data serialization and de-serialization which is needed for network transmissions, especially between different platforms, is carried out by Protocol Buffers. Each message differs, except from data type and data, in topic and message type. In order to read a message the receiver should know where the desired message is published, ie its topic and subscribe to that specific topic. The receiver should also know what the type of the message is, Signal, State or Data. The publisher of the message determines the topic and the type of the message and different publishers can publish in the same or in a different way the same message. The meta-data contains the sender node name, the publisher name as well as integrated temporal information in order to address synchronization needs. Moreover, *Narukom* provides a blackboard to the publish/subscribe architecture. The blackboard is a software architecture

model, in which multiple individuals share a common knowledge base. Individuals can read or update the contents of the blackboard and therefore cooperate to solve a problem. It is common for blackboards to organize the containing knowledge as efficiently as possible to enable quick retrieval of data. The blackboard in *Narukom* is available only between individuals that run on the same thread of execution and provides full access, read/write, on local information and read-only access to information that arrives from third-parties.

2.11 ASEME Methodology

The *Agent Systems Engineering MEthodology (ASEME)* [5] is an Agent Oriented Software Engineering (AOSE) methodology for developing multi-agent systems. It uses the *Agent MOdeling LAnguage (AMOLA)*, which provides the syntax and semantics for creating models of multi-agent systems covering the analysis and design phases of a software development process. It supports a modular agent design approach and introduces the concepts of intra- and inter-agent control. The former defines the agent's behavior by co-ordinating the different modules that implement his capabilities, while the latter defines the protocols that govern the coordination of the society of the agents. *ASEME* applies a model driven engineering approach to multi-agent systems development, so that the models of a previous development phase can be transformed to models of the next phase. Thus, different models are created for each development phase and the transition from one phase to another is assisted by automatic model transformation, including model to model (M2M), text to model (T2M), and model to text (M2T) transformations leading from requirements to computer programs. The ASEME Platform Independent Model (PIM), which is the output of the design phase, is a statechart that can be instantiated in a number of platforms using existing Computer Aided System Engineering (CASE) tools, like the one that this thesis presents.

The *Agent Modelling Language (AMOLA)* [6] describes both an agent and a multi-agent system. The concept of functionality is defined to represent the thinking, thought and senses characteristics of an agent. Then, the concept of

capability is defined as the ability to achieve specific goals (e.g. the goal to decide in which restaurant to have a diner this evening) that requires the use of one or more functionalities. Therefore, the agent is an entity with certain capabilities, including inter and intra-agent communication. Each of the capabilities requires certain functionalities and can be defined separately from the other capabilities. The capabilities are the modules that are integrated using the intra-agent control concept to define an agent. Each agent is considered a part of a community of agents, i.e. a multi-agent system. Thus, the multi-agent system's modules are the agents and they are integrated into it using the inter-agent control concept. The intra-agent control concept allows the assembly of an agent by coordinating a set of modules, which are themselves implementations of capabilities that are based on functionalities. Here, the concepts of capability and functionality are distinct and complementary.

The agent developer can use the same modules, but different assembling strategies, proposing a different ordering of the modules execution producing in that way different profiles of an agent. This approach provides an agent with a decision making capability that is based on an argumentation based decision making functionality. Another implementation of the same capability could be based on a different functionality, e.g. multi-criteria decision making based functionality. Then, in order to represent system designs, *AMOLA* is based on statecharts, a well-known and general language and does not make any assumptions on the ontology, communication model, reasoning process or the mental attitudes (e.g. belief-desire-intentions) of the agents giving this freedom to the designer. The AMOLA models are related to the requirements analysis, analysis and design phases of the software development process. *AMOLA* aims to model the agent community by defining the protocols that govern agent interactions and each part of the community, the agent, focusing in defining the agent capabilities and the functionalities for achieving them. The details that instantiate the agent's functionalities are beyond the scope of *AMOLA* that has the assumption that they can be achieved using classical software engineering techniques.

The *Agent System Engineering Methodology* consists of three phases, the requirement analysis phase, the analysis phase and the design phase. In each phase one or more models are created in order to produce the final output, the statechart that describes each part (agent) of the desired multi-agent system. In the requirements analysis phase, *AMOLA* defines the *System Actors and Goals* (*SAG*) and the *Requirements Per Goal* (*RPG*) models. In the analysis phase *AMOLA* defines the *System Use Cases model* (*SUC*), the *Agent Interaction Protocol* (*AIP*) model, the *System Roles Model* (*SRM*) and the *Functionality Table* (*FT*). In the design phase *AMOLA* defines the *Inter-Agent Control* (*EAC*) model and the *Intra-Agent Control* (*IAC*) model. Although this thesis isn't directly connected to all of the *ASEME* phases, but to some of them it is useful to explain shortly each developing phase.

The model for the requirements analysis phase according to *AMOLA* and *ASEME* is the *SAG* model that is composed by the Actor diagram, containing the actors and their goals. The *SAG* model is a graph involving actors who each have individual goals. A goal of one actor may be dependent for its realization to another actor; such a goal is also called *dependum*. The *depender* actor depends on the *dependee* in order to achieve the *dependum*. Graphically, actors are represented as circles and goals as rounded rectangles. Dependencies are navigable from the *depender* to the *dependum* and from the *dependum* to the *dependee*. Note that for simplicity of presentation, if a goal has no *dependees* is just drawn next to the *depender*. The goals are then related to functional and non-functional requirements in plain text form. An entity can qualify as an actor if it represents a real world entity (e.g. a "broker", the "director of the department", etc).

After creating the *SAG* model the developer can pass the next step of requirements analysis phase in which is necessary to describe the requirements of the desired goal. The *Requirements Per Goal (RPG)* is a simple model aiming to associate *SAG* goals to requirements presented in plain text form. In order to form the *RPG* model the engineer would have to answer to the following questions for each *SAG*'s goal:

- Why does the actor have this goal and why does he depend to another for it (this is the most important question and its answer is usually the goal's name)
- What is the outcome of achieving the goal (identify related resources)
- How is he expected to achieve this goal (identify the task to be performed for reaching this goal)
- When is this goal valid (identify timing requirements)

After completing successfully the first *ASEME* phase(Requirements analysis phase) the engineering can now easily develop the models of the next phase, the Analysis Phase. The main models associated with this phase are the *System Use Cases* model (*SUC*), the *Agent Interaction Protocol* model (*AIP*), the *System Roles Model* (*SRM*) and the *Functionality Table* (*FT*). The *SUC* is an extended *UML* use case diagram and the *SRM* is mainly inspired by the *Gaia* methodology [7]. Thus, a Gaia roles model method fragment can be used with minimal transformation effort.

The use case diagram (*SUC*) helps to visualize the system including its interaction with external entities, be they humans or other systems. No new elements are needed other than those proposed by UML. However, the semantics change. In a use case diagram, the actor "enters" the system and assumes a role and agents are modelled as roles, either within the system box (for the agents that are to be developed) or outside the system box (for existing agents in the environment). Human actors are represented as roles outside the system box (like in traditional *UML* use case diagrams). The human roles are distinguished by their name that is written in italics. This approach aims to show the concept that we are modelling artificial agents interacting with other artificial agents or human agents. The different use cases must be directly related to at least one artificial agent role. The general use cases, also referred as capabilities, can be decomposed to simpler ones using the include use case relationship. A use case that connects two or more (agent) roles implies the definition of a special capability type: the participation of the agent in an interaction protocol. A use case that connects

Operator	Interpretation
x . y	x followed by y
x | y	x or y occurs
x⋆	x occurs 0 or more times
x+	x occurs 1 or more times
x˜	x occurs infinitely
$[x]$	x is optional
x || y	x and y interleaved

Table 2.1: Operators for Liveness Formula(Table 1 from "THE AGENT SYSTEMS ENGINEERING METHODOLOGY (ASEME)")

a human and an artificial agent implies the need for defining a human-machine interface (*HMI*), another agent capability. A use case can include a second one showing that its successful completion requires that the second also takes place.

An *AIP* (the reader should take care not to confuse it with the *AIP* model of *AUML* [8], for the remainder of this document *AIP* will refer to the *AMOLA* model) defines one or more participating agent roles, the rules for engaging (why would the roles participate in this protocol), the outcomes that they should expect in successful completion and the process that they would follow in the form of a liveness formula. The liveness formula is a process model that describes the dynamic behavior of the role inside the protocol. It connects all the role's activities using the *Gaia* operators (Table 2.1). The liveness formula defines the dynamic aspect of the role, that is which activities execute sequentially, which concurrently and which are repeating.

The *System Roles Model* (*SRM*) is mainly inspired by the Gaia roles model [7,

9]. A role model is defined for each agent role. The role model contains the following elements: a) the interaction protocols that this agent will be able to participate in, b) the liveness model that describes the role's behavior. The liveness model has a formula at the first line (root formula) where activities or capabilities can be added. A capability must be decomposed to activities in a following formula. The liveness formula grammar has not been defined formally in the literature, thus it is defined here using the Extended Backus-Naur Form (EBNF) [10], which is a metasyntax or metametamodel notation used to express context-free grammars. It is a formal way to describe computer programming languages and other formal languages. It is an extension of the basic Backus-Naur Form (BNF) metasyntax notation. EBNF was originally developed by Niklaus Wirth (1996). The EBNF syntax for the liveness formula (Table 2.2), using the BNF style followed by Russell and Norvig [11], i.e. terminal symbols are written in bold.

The *Functionality Table* (*FT*) the last step of the analysis phase is where the analyst associates each activity participating in the liveness formulas of the *SRM* to the technology or tool (functionality) that it will use.

After completing the functionality Table the engineer can pass to the design phase in which *EAC* and *IAC* models are created. The *Inter-Agent Control* (*EAC*) is defined as a statechart. It should be initialized by transforming the agent interaction protocols of the analysis phase to statecharts. Harel and Kugler (2004) [3] present the statechart language adequately, but not formally. David's UML semantics [12] for statecharts has been used as basis for the definition of the AMOLA statecharts as it is the first intended for object-oriented language implementation. These models not only formally describe the elements of the statechart, they also focus on the execution semantics. It is assumed that, as long as the language of statecharts is not altered, a statechart can be executed with any semantics available depending on the available CASE tool. The formal model that is adopted here-in is a subset of the ones presented in the literature as there are several features of the statecharts not used herein, such as the history

liveness	→formula
formula	→leftHandSide " = " expression
leftHandSide	→string
expression	→term →| parallelExpression →| orExpression →| sequantialExpression
parallelExpression	→term "||" term "||" ... "||" term
orExpression	→term "|" term "|" ... "|" term
sequentialExpression	→term "." term "." ... "." term
term	→basicTerm |"(" expression ")" →|"[" expression "]" →| term " ⋆ " →| term+ →| term " ˜ " →|"|" term " ˜ |" number
basicTerm	→string
number	→digit | digit number
digit	→"1"|"2"|"3"| ...
string	→letter | letter string
letter	→"a"|"b"|"c"| ...

Table 2.2: The liveness formula grammar in EBNF format

states (which are also defined differently in these works).

Before formally defining the statechart for the *EAC* model, the elements that compose the transition expressions are examined. Then, the transition expressions are defined in *EBNF*. Transitions are usually triggered by events. Such events can be:

1. a sent or received (or perceived, in general) inter-agent message
2. a change in one of the executing state's variables (also referred to as an intra-agent message)
3. a time-out
4. the ending of the executing state activity

The latter case is also true for a transition with no expression. Note that each state automatically starts its activity on entrance. A message event is expressed by P(x,y,c) where P is the performative, x is the sender role, y the receiver role and c the message body. The items that the designer can use for defining the state transition expressions are the message performatives, the ontology used for defining the messages content and the timers. An agent can define timers as normal variables initializing them to a value representing the number of milliseconds until they time-out (at which time their value is equal to zero). The transition expressions can use the time-out unary predicate, which is evaluated to true if the timer value is equal to zero, and false otherwise. Timers are initialized in the action part of a transition expression, while the time-out predicate can be used in both the event and condition parts of the transition expression depending on the needs of the designer.

Besides inter-agent messages and timers there is another kind of events, the intra-agent messages. The change of a value of a variable can have consequences in the execution of a protocol. The variables taking part in a transition expression imply the fact that they are defined in the closest common ancestor OR

state of the source and target states of the transition or higher in the state-chart nodes hierarchy. The intention regarding the performative definition is not to enumerate all possible performatives, the modeler can define such as he sees fit.

In the agent level, the *Intra-Agent Control* (*IAC*) is defined using statecharts in the same way with the *Inter-Agent Control* model (*EAC*). The difference is that the top level state (root) corresponds to the modeled agent (which is named after the agent type). One *IAC* is defined for each agent type.

2.12 Eclipse Modeling Project

The Eclipse Modeling Project (*EMP*) [13] provides several frameworks for defining a Domain Specific Language (DSL) and develop software for this language. *EMP* allows the developer to createtools supporting for Model-Driven Software Development (*MDSD*), which is useful for the development of agents. *EMP* consists of *EMF* (Eclipse Modeling Framework) [14], *QVT* (Query: Validation: Transaction), *M2M* (Model-to-Model transformation), *M2T* (Model-to-Text transformation), *TMF* (Textual Modeling Framework) and *GMF* (Graphical Modeling Framework). *EMF* allows the developer to define a *DSL* language in an abstract syntax. *EMF* has as an output a model that describes a new language. *QVT* provides query, validation and transaction features for the *EMF* models. *M2M* provides Operational Mapping Language that allows model-to-model transformation for *EMF* models. *M2T* allows model-to-text by using JET (Java Emitter Template) or *Xpand* as a template engine. *TMF* is still under development and does not offer a lot of capabilities, but its purpose is to provide a textual editors with syntax highlighting, code completion and build for *EMF* models. In the other hand, *GMF* provides graphical editors for *EMF* models.

2.13 Xpand and IAC-2-Monas

Xpand language was proposed by Open Architecture Ware (oAW) and is used for Model-to-Text (M2T) transformations. The language is offered as part of the Eclipse Modeling Project (EMP). The language allows the developer to define a

set of templates that transform objects that exist in an instance of a model into text. Major advantages of Xpand are the fact that it is source model independent, which is usually source code but it can be whatever text the user desires, and its vocabulary is limited, allowing for a quick learning curve. The language requires as input a model instance, the model and the transformation templates. Xpand first validates the instance through the provided model and then, as the name suggests, expands the objects found in the instance with the input templates. It allows the user to define, except form the expansion templates, functions implemented in Java language using the Xtext functionality. Xpand is a markup language and uses the "<<" and ">>" to mark the start and the end of the markup context. Enables code expansion using the model structure (i.e. expanding all child elements of a specific type inside a node) and supports if-then-else structure. Functions call be called inside markup. The advantages of Xpand are the fact that it is source model independent, its vocabulary is limited allowing for a quick learning curve while the integration with Xtend allows for handling complex requirements. Then, EMP allows for defining workflows that can help a modeler to achieve multiple parsings of the model with different goals.

IAC-2-Monas is a code generator, which extracts a statechart model in C++ language compatible with *Monas* architecture (see section 2.9) from a *IAC* model (see section 2.11). *IAC-2-Monas* was developed by Alexandros Paraschos [2] for *Kouretes*. *IAC-2-Monas* is developed in Xpand and java language and uses these java packages:

- `org.eclipse.emf.mwe.utils.Reader`
- `org.eclipse.xpand2`
- `java.util.HashSet`
- `java.util.List`
- `java.util.Set`
- `java.util.StringTokenizer`

- `java.util.regex.Matcher`
- `java.util.regex.Pattern`
- `java.util.Comparator`
- `IAC`

Chapter 3

Problem Statement

3.1 Soccer Team Formation

The main properties of a soccer team are the coach, the players and the formations the team uses during the matches. Every player has a specific role in a match and especially in every formation. It is very important for a soccer team to have various formations available for each match, and its players role to be flexible enough for every situation. All of the above are part of coach's job. The coach is responsible for the harmonic cooperation of all teammates and the district soccer player roles.

3.2 Robot Behavior

Every robot is an autonomous agent. In order to design an agent (robot) that reacts with the environment in a desired way, one would have to define the robot's behavior. The behavior of the robot is the module, or the part of the robot's software that collects the calculated information from the environment and makes decisions. So, the decision making module of the robot is called behavior. It is important for the developer to be able to define or change the robot's behavior in a simple and quick way and that's what thesis presents to you.

3.3 Design Behavior

It is very important for software engineers, who compete in RoboCup Soccer competitions to be able to adjust easily and fast the existing robot behaviors to any occasion. It is also important to have the ability to design quickly a robot behavior in an abstract way from scratch and develop modules that would be reusable for other behaviors too. *Kouretes* team having previous experience, since the team competes in *Standard Platform League* since 2006, has concluded in the need of developing a handful tool for easy editing of an agent in the form of statechart and given a semi-automated code generation. The team has designed its software architecture, *Monas*, in a way that it would fit to the *ASEME* methodology output. *ASEME* gives the programmer a structured methodology of designing an agent or even a multi-agent system. That is the value of *ASEME* that *Kouretes* team wanted to exploit in every mean. In order to do so it is critical to design an application or a software tool that connects the *ASEME* output to the *Monas* code. As described in section 2.11 *ASEME*'s output is a statechart for the inter and intra-agent that lays in an abstract form. Hence, *Kouretes* would have to find an easy way to implement the "abstract" *ASEME*'s output to compatible code for *Monas*.

3.4 Related work

Although there are a lot of CASE tools available, we will present three of them that are quite similar to our approach and used technologies.

3.4.1 Yakindu

Yakindu (Figure 3.2) is an free toolkit for the model driven development of embedded systems. Through the systematic use of models, it aims at an integrated development process as well as an increase in quality and maintainability. The *Yakindu* toolkit supports the development of both reactive, event-driven and data flow-oriented systems with the help of statecharts and block diagrams. The continuous support begins with graphical modelling tools, includes integrated

validation and simulation, that allows for the early assessment of the models and offers efficient code-generators for the generation of source code for a target platform. Technologically, it is based on Eclipse-platform and integrates itself seamlessly into Eclipse-based workbenches and extends this in the direction of model-driven development. The *Yakindu* toolkit allows to design embedded systems by using both statecharts and block-diagrams (Figure 3.1).

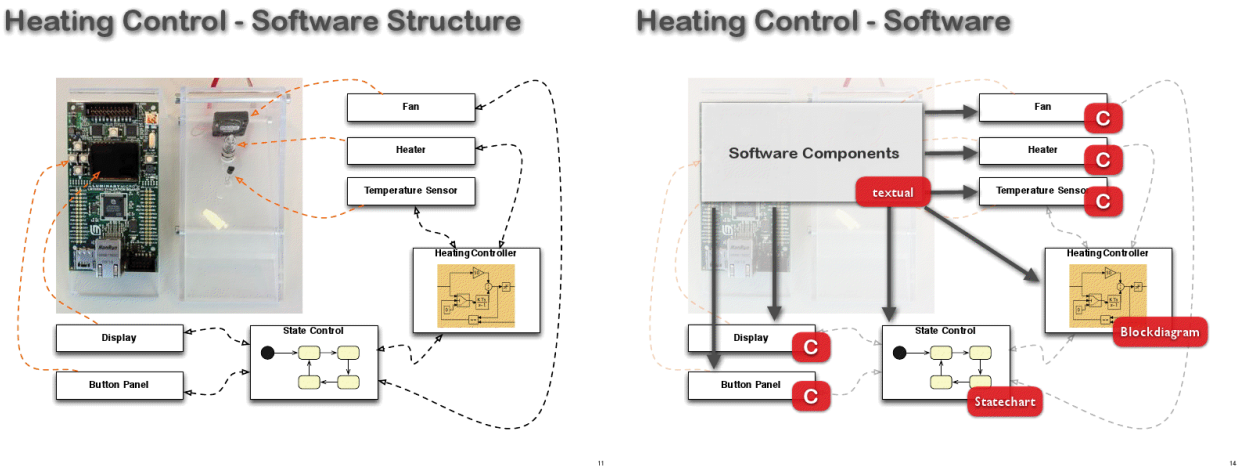


Figure 3.1: Design of an Heating Control embedded system.

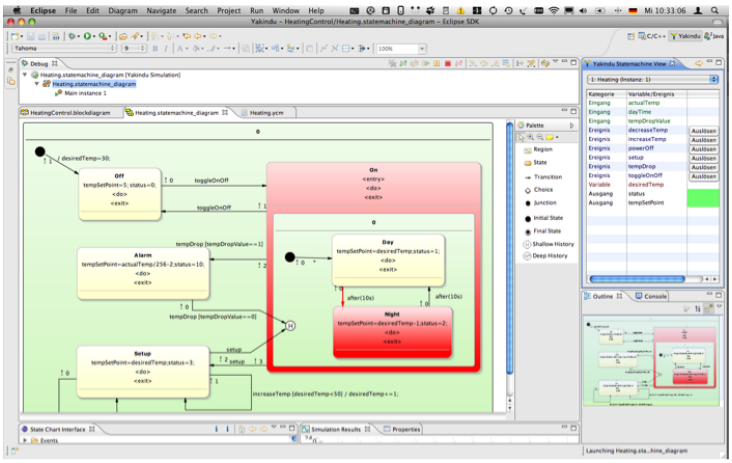


Figure 3.2: *Yakindu* Environment

The Yakindu Statechart Tools (SCT) allow graphical modeling based on Harel-statecharts [15]. They support all essential concepts like extended state variables, hierarchical states, orthogonal states (also known as And-States or parallel regions) or History-States. This corresponds to the concepts that are used in modelling languages such as UML. The convenient model-editor integrates features such as model validation and simulation as well as the generation of source code.

Furthermore, the "Yakindu Toolkit" includes the data flow-oriented modelling environment Damos (Figure 3.3), which enables the generation of block diagrams, the simulation of models and the code generation for a target platform. Due to the modular and open structure, aspects of the modelling environment can be adapted to individual needs. This includes the development of one's own blocks, whereby here the tailored data flow-oriented systems scripting language Mscript can be used to specify the behavior of the blocks.

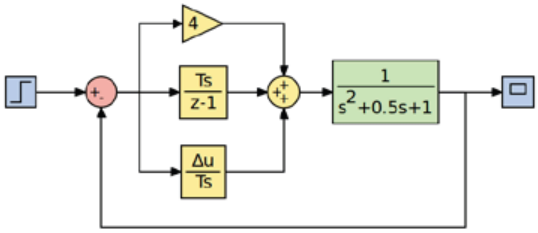


Figure 3.3: Damos Block Diagram

Both SCT and Damos already during the modelling execute consistency checks on the models. Examples are the tests for unavailable conditions in statecharts and the verification for correct calculations with SI-units in Damos. During the processing of the models, the developer receives with it a feedback or an acknowledgment early on if such consistency conditions are violated.

Through the simulation(Figure 3.4, the actual run-time behavior of finite-state machines and block diagrams are tested and validated early on in the development process as to whether the models implement the requirements of the system correctly. As a result, a class of errors found by the consistency checks described above can remain undetected and can just be poorly traced through visual inspection. The simulation engines of SCT and Damos integrate themselves into the Eclipse-Workbench and allow the direct execution of the models.

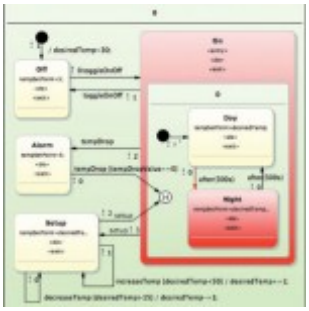


Figure 3.4: Simulation

The Damos and SCT-Code-Generators allow the automatic mapping of the models to source code that can be integrated into the respective embedded software. Both Damos as well as SCT support Out-Of-The-Box C as a target language-SCT additionally also Java. These code generators can be directly applied and generate efficient implementations.

3.4.2 Xabsl Editor

The *Extended Agent Behavior Specification Language* (*XABSL*) [16] is a simple language to describe behaviors for autonomous agents based on hierarchical finite state machines. *XABSL* was developed by the RoboCup Soccer team *GermanTeam* to design the behavior of soccer robots. The usage of the language is not restricted to robotic soccer. *XABSL* is a good choice to describe behaviors for all

kinds of autonomous robots or virtual agents like characters in computer games.

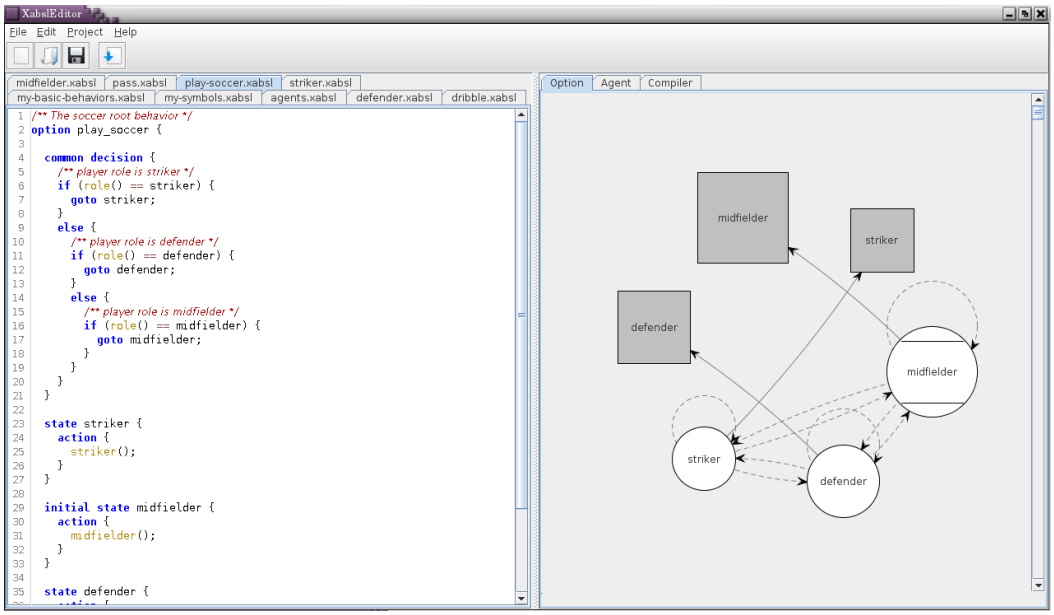


Figure 3.5: *XABSLEditor*

For *XABSL* there is a corresponding editor, the *XABSLEditor* (Figure 3.5). The *XABSLEditor* was developed by the *Nao Team Humbolt* in 2008 and allows the user to describe agents and behaviors by using the *XABSL* language. This editor is basically a text editor for *XABSL*, but also represents graphically the hierarchical finite state machines that describe the agents behavior. It also provides a compiler for *XABSL*.

XABSLEditor:

- runs on all platforms (since it is written in Java)
- open source (all used components are open source to)
- has syntax highlighting
- provides live view of the state graph

- has auto completiona ability:
  - completion of symbols with parameters and enums
  - live documentation (generated from comments)
- has live syntax check (errors are red underlined, without of recompiling of the whole project)
- has multiple tabs, thus multiple open editors
- can jump to an option definition (a click on an used option opens the file were the option is defined)
- has a build in compiler (ruby has not to be necessary installed)
- has a search feature (in files and in the whole project)
- allows unlimited undo/redo

3.4.3 An Interactive Editor For The Statechart's Graphical Language

The *Statechart Editor*, which was developed by Stephen Edwards for Statechart's graphical language, which uses a hierarchy of interacting finite-state machines. The editor is written using the *incr Tcl* add-on to the Tcl/Tk language.

The editor keeps transitions attached, and allows for multiple, consistent views of the database. The objective of this project was to produce a graphical, interactive editor for the Statechart's graphical language, which uses hierarchically-arranged finite state machines.

A Statechart (Figure 3.6) contains two sorts of entities: states, which are boxes with names, and transitions, which are curved arrows connecting two states.

The editor can:

- add and delete states and transitions

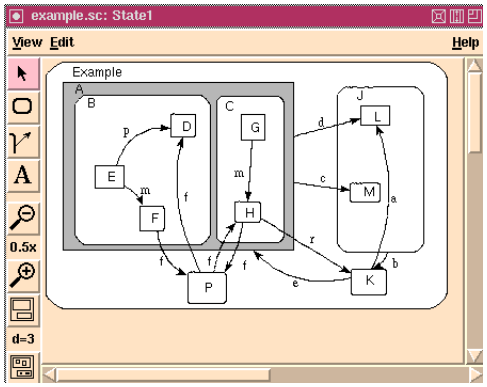


Figure 3.6: Interactive Editor For The Statechart's Graphical Language

- move states and transitions, either preserving hierarchy or modifying it
- When states move, transitions remain attached. Transitions' shapes either come from a single index of curvature, or can be specified arbitrarily by the user.
- edit multiple views of the database, each starting from a different state in the hierarchy, going down a different depth, and with different magnification
- edit attributes (fonts, colors, shape) of states and transitions in dialogs read and write the database to disk
- print a view of the database to a PostScript file

This editor is written using McLennan's *incr Tcl* package, which brings an object-oriented data model to Tcl.

Chapter 4

Our Approach

4.1 The Design of a Behavior

Kouretes team needs a tool for soccer player behavior development. This tool should allow the user to design quickly a new behavior or change easily an existing behavior. A nice and user friendly way of describing a behavior is by describing it graphically. The behavior of an (robot) agent usually consists of `if/else if` loops, because it has to describe an action for every possible event. A good way of describing such a behavior is an Finite State Machine, or any kind of state machines. It is very common to design state graphs in order to describe system behavior, data flow, class hierarchy or even an algorithm.

4.2 Graphs

For an algorithm represantation, one could use a flow chart. For a class hierachy representation he could use a UML diagram. If someone would like to describe the "flow" of data through an information system, he could use a data flow diagram. In case of system behavior, someone could use Finite State Machines(FSM) (Figure 4.1) hierarchical or not and statecharts. For our appoach we chose statecharts(Figure 4.1). Statecharts offer the great values of FSMs and multi-thread execution, since when *AND* nodes exist in a statechart the children nodes *OR* are executed in parallel. In an FSM only one state can be active, that'

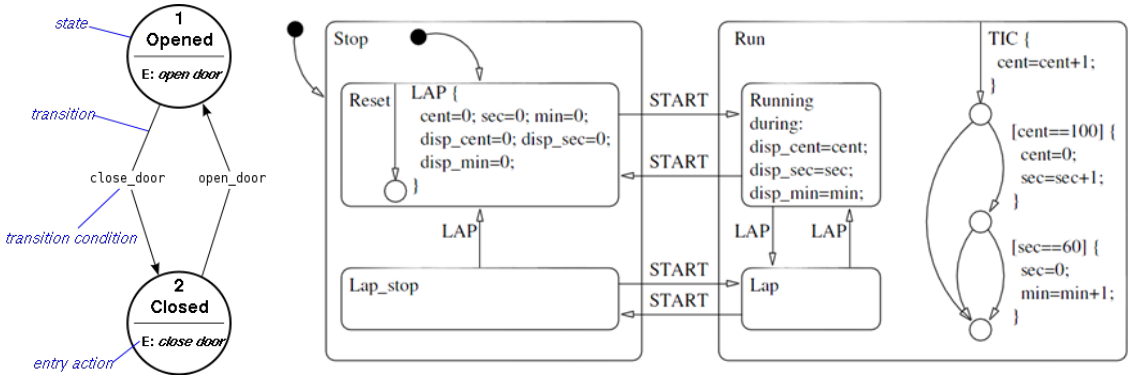


Figure 4.1: Left image: FSM. Right image: statechart.

s not the case with statecharts because of the parallel execution.

4.3 The Representation of a Behavior

It is crucial to a behavior developer to have a graphical representation of the designed behavior or even to be able to design and edit it graphically. *Kouretes* team for years had been developing agent behavior as one class that makes the decision for robot's actions. That approach leads to a huge class full of `if/else if` loops and overpopulated functions in one block, which is also difficult to understand and debug. *Kouretes* team decided that a graphical representation of an agent as a statechart would be more clear to a developer and also easier to design and edit. So, *Kouretes* now design robot behaviors as statecharts, which facilitate the graphical representation of complex behaviors.

4.4 Methodology of designing robot behaviors

On the one hand statecharts provide a useful representation of a complex behavior, on the other hand it is time consuming to describe graphically a complex behavior state by state and transition by transition. In conclusion it is easy to understand an existing statechart with a graphical representation, but it is "difficult" to create one from scratch. In order to overcome the time consuming initial representation *Kouretes* team decided to exploit the *ASEME* models. *ASEME*

provides an analysis phase and a design phase. The analysis phase helps the developer make clear the desired goals of the agent and the way of achieving them. In addition, the liveness formula that lies at the analysis phase allows the user to describe in quick and comprehensive way a complex behavior. The design phase allows the developer to describe the model of behavior that came out from the analysis phase. The developer can and should describe the model's functionalities int he analysis phase and the transitions' expressions int the design phase. So, we would need a tool, which provides the means for editing the models from the analysis and design phase as well. The model from the analysis phase would be described by liveness formulas has text form and the model, which would come out as a result, is the *IAC* model (Figure 4.2) that has the form of a statechart. As you can conclude *ASEME* can provide us the representation of the desired behavior in a statechart at the end of the two phases.

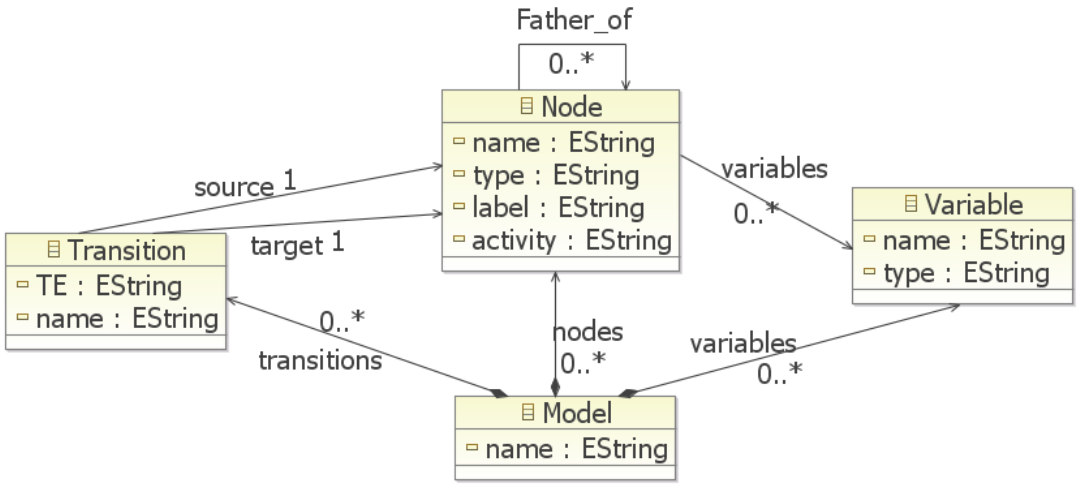


Figure 4.2: *IAC* model according to *EMF*

IAC model consists of:

- Model has a name and contains nodes, transitions and variables and represents the statechart
- Node contains one or more variables and nodes and represents statechart's states and has:

  - name
  - label, which is unique and indicates the state's execution sequence
  - type, which indicates state's type(values: OR, AND, START, END, CONDITION and BASIC)
  - activity, this attribute is null for every type of states except BASIC states and contains the state's source code or a reference to a source file

- Transition has name and TE (Transition Expression), TE consists of transition's event, condition and action. Transition has as source and target a model's node
- Variable has a name and a type and belongs to one or more nodes.

4.5 From Statechart Description to Robot Behavior

Statecharts in a model form or an image form is something that a machine (robot) can not "understand". So, we would have to find a way to translate the statecharts into source code. *Monas* architecture has a statechart engine that executes statecharts on the robot. Statecharts as source code for *Monas* consist of these classes:

- Statechart that represents the execution sequence of states and transitions
- States (or, and, start, end, condition, and basic)
- Activitiies of each basic state
- Transition and its parts:
  - Event
  - Condition
  - Action

For this purpose a code generator is necessary to use. The code generator should translate the statechart's model from *IAC* model to the *Monas*' statechart architecture. So, a *IAC*'s TE will we be generated as event, condition and/or action classes, basic state's activity we be generated as activity, model will be generated as statechart and it will contain model's states and transitions.

4.6 CASE tool Functionlities

Considering the above, *Kouretes* team needs a CASE tool that allows the developer to edit the liveness formulas, in text form, and the statechart, in a graphical way. So, a text editor for liveness formulas and a graphical editor is necessary. Besides the editors, a CASE tool should provide more functions in order to facilitate the developer's work. An important charectistic of the *ASEME*'s *IAC* model is that its node has a label that is unique and indicates the execution sequence. If someone designs a statechart graphically without writing the liveness formulas from the analysis phase, he would have to add each state's label very carefully in order to obtain label's uniqueness and sequence indication. That's is a functionality that a tool should do automatically whenever the developer thinks it is necessary.

Furthermore, a code generator should be part of a CASE tool, since the purpose of a CASE tool is system development. In order to describe the functionalities of each statechart class we would have either to write code on the diagram for each element or edit each element's code in a seperate editor. For complex behaviors it would be chaotic to represent each elements code on the diagram, so it would be better to write only the descritpion of transitions and edit state's code in a seperate editor.

When desinging a statechart it is very important to know if the model obeys to the defined syntax and/or semantics. Since the *IAC* model describes a statechart that follows the Harel's statemate's semantics and rules, there should be a validation functionality that alerts the developer for any mistakes and misuses of the rules.

Chapter 5

Implementation

Kouretes team needed a graphical user interface(GUI) for creating soccer player behaviors following the *ASEME* methodology. Although a soccer player behavior is an agent and *ASEME* is a methodology for developing agents, *Kouretes* do not perform all the steps and do not design all the models of *ASEME*. In summary, the procedure needed for the design of a soccer player behavior for *Kouretes* is:

- Creation of liveness formula (according to *AMOLA*)
- Liveness to statechart transformation (according to *ASEME*'s *IAC* model)
- Graphical representation and editing of the created statechart
- Statechart model to C++ code for Monas transformation

5.1 The choice of platform and its benefits

In order to design the CASE tool for the *Kouretes* team, it is necessary to choose the platform of implementation. As the *IAC* model was implemented as an *EMF* (Eclipse Modeling Framework) model and the liveness to statechart transformation was implemented in java, it was dictated to develop the CASE tool in java by using the *GMF* (Graphical Modeling Framework) provided by IBM and eclipse. For every new class that we add to the generated *GMF* application we have to declare it to the MANIFEST.MF file to the extension points and add the required dependencies to the homonym MANIFEST's section. For implementing

this thesis we had to install the Eclipse Modeling Tools release of eclipse and some additional packages and components:

- Eclipse Modeling Framework
- Graphical Modeling Framework
- OCL tools
- Xpand SDK
- Xtext SDK
- delta pack

5.2 The *GMF* models

The *GMF* provides some models in order to initialize the graphical definition of an *EMF* model. The models are simple and provide a large variety of shapes and colors. In order to use correctly the *GMF* we used the *GMF* DashBoard (Figure 5.1), which shows all the necessary models for implementation and their dependencies. Since the developer has described the desired *EMF* model, he can define its graphical definition via the *Graphical Definition Model*. Another model that the developer should describe, is the *Tooling Definition Model*, which is responsible for the *EMF* model's creation tools definition. As long as the developer has defined the models mentioned above, he can link the desired graphical representation to the respectively creation tool via the definition of the *Mapping Model*. The developer can also define the rules that the model should obey via the same model. After the completion of the steps mentioned above, the developer can create and edit the *Diagram Editor Generate Model* in order to complete the definition of the *EMF* model's graphical editor and finally generate it.

During the process of development it became clear that the *IAC* model (Figure 4.2) needed to be changed in order to represent graphically the models as desired, thankfully only one small change made the difference. *IAC*, as implemented, did not give us the ability to design the children nodes inside the parent

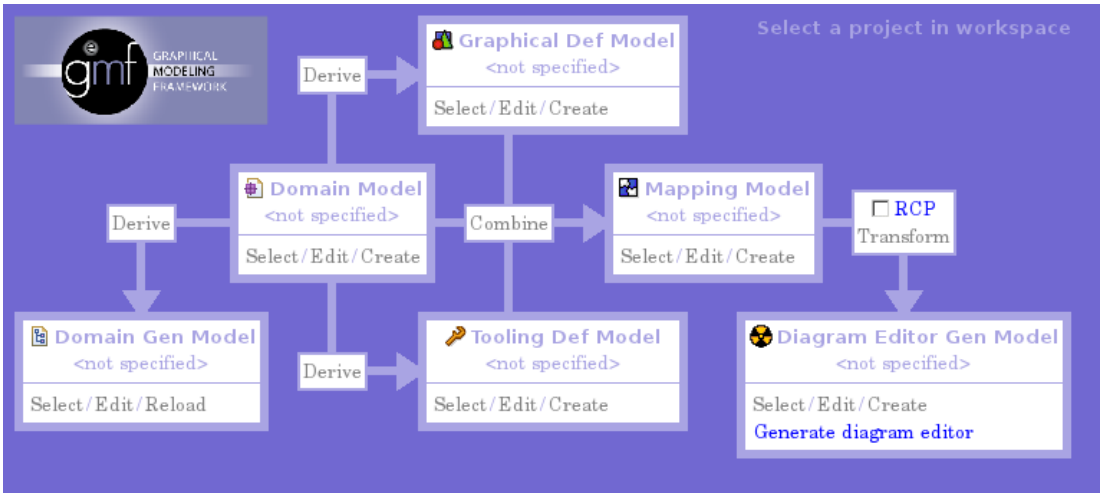


Figure 5.1: The implementation procedure for GMF.

node, but it only allowed us to represent them in a tree form. The solution was very easy to implement and didn't affect the characteristics of the model, a new relationship was entered which defined that a node can contain nodes as children. The new *EMF* model has been named *StateChart* with file extension stct (Figure 5.2) and its graphical representation looks alike the STATEMATE semantics of statecharts [17].

In order to make clear that the *IAC* model was not serving our purpose, we created a simple *GMF* graphical editor and initialized *Kouretes* Goalie behavior(Figure 5.3) and did the same for *STCT* representation (Figure 5.4) that has been developed for this thesis.

As you can see the representation of *IAC* model makes it difficult to navigate through the designed model in comparison to the representation of the *STCT* model. Since we had a handy *EMF* model we had to describe the graphical representation of each model element as the *Graphical Definition Model* of *GMF*. Nodes of different type should have different representation :

- START node should be a small black circle
- CONDITION node should be a circled C
- OR node should be a yellow labeled rectangle that contains START, CONDITION, OR, BASIC, AND and END nodes

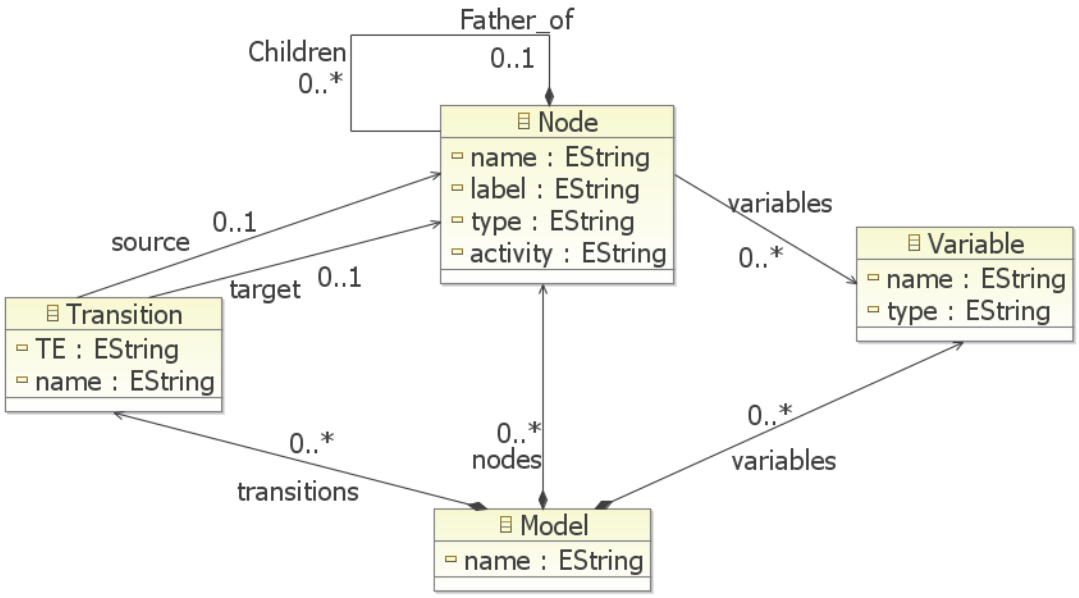


Figure 5.2: *STCT* model according to *EMF*

- AND node should be a light blue rectangle that contains two or more OR nodes
- BASIC node should be a green rectangle
- END node should be a white circle with a small black circle in its center.

Although the model has a lot of relationships between its elements it was a necessity to not represent all of them in order to keep the diagram simple and clean. The relationships that are represented are :

- transitions between nodes as an arrowed connection starting from the source node and pointing to the target node
- children nodes of an OR or an AND node inside of the parent node

In addition, variables are represented as a bright green rectangle outside the nodes. For setting a variable as a node's variable we should select the desired

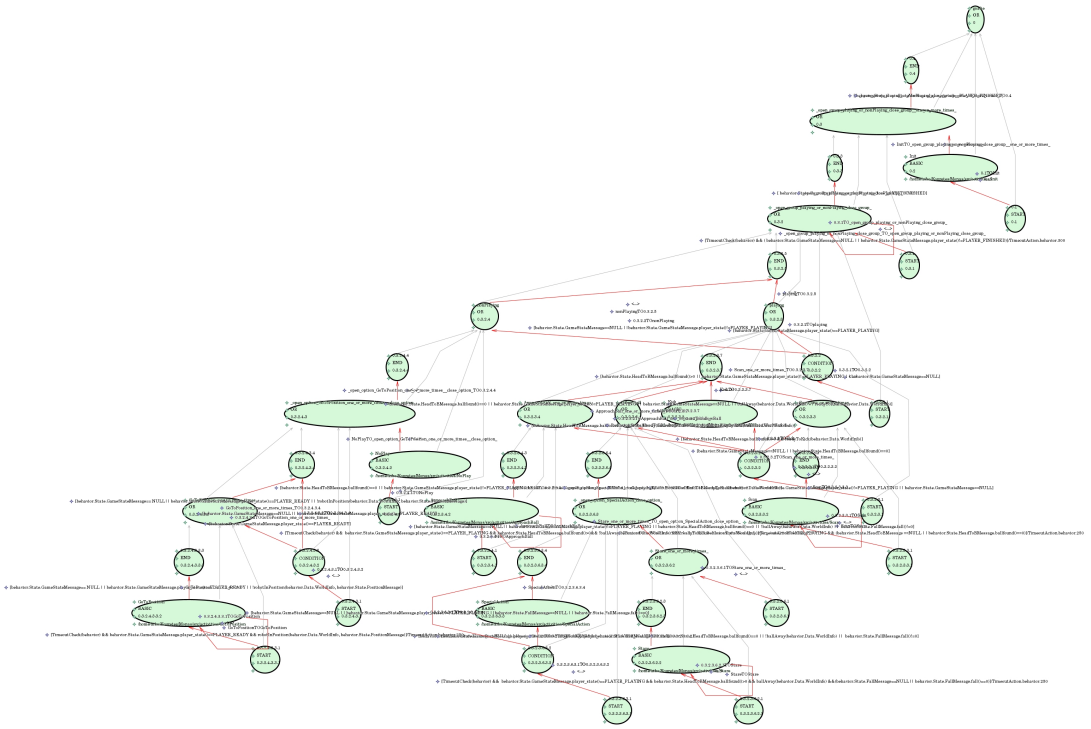


Figure 5.3: Goalie example in *IAC* representation

node and select the variables relationship from the properties view.

According to *GMF* after creating the *Graphical Definition Model* it is necessary to define the creation tools of its element in the *Tooling Definition Model*. It is important to mention that we didn't add creation tools for every element and relationship of the *EMF* model. We could not have a creation tool for the relationship "variables", because we didn't defined its representation. We also could not define a creation tool for the relationship "children", this relationship is created as the user adds the new node in an another node.

Since the *Graphical Definition Model* and the *Tooling Definition Model* are defined we then need to connect them through the definition of the *Mapping Model*. At this phase the programmer can define the validation rules of the model, if any, and its error or warning messages. Since we have different representations

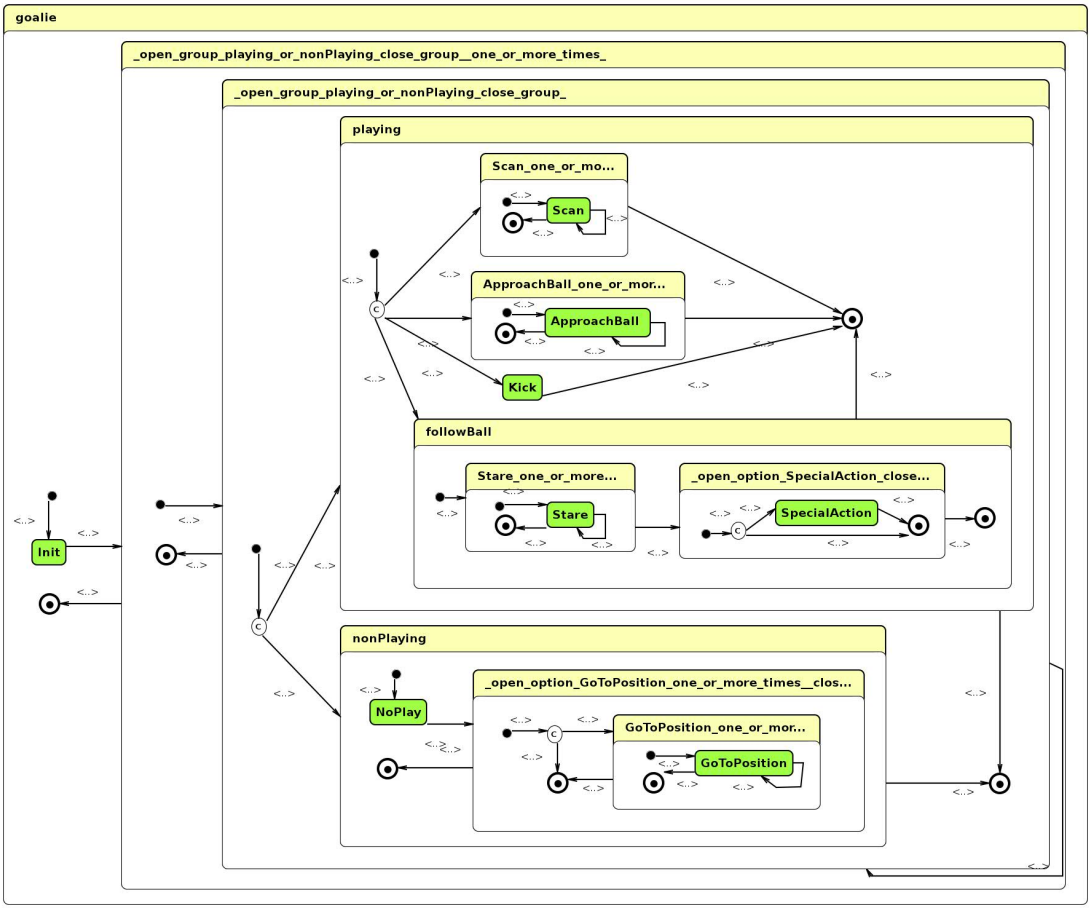


Figure 5.4: Goalie example in *STCT* representation

and creation tools for the element node, according to the value of its "type", we have to use the *OCL* and define the constrains and restrictions for each different representation and creation tool. For the validation rules we chose *java* as the language of implementation and we will analyze this phase of implementation at the next section.

When all the above definitions are complete the programmer can define some extra features for the graphical editor, such as print action, live or not validation, the file's extension etc in the *Diagram Editor Gen Model*, which is the model that organize the code generation for the defined graphical editor. For our im-

plementation we chose the extra features: live validation, validation decorators, print action and the generation of the editor as an eclipse application. Now the programmer can use the *GMF* generator for generating the basic functions of the Statechart editor. The generated application is based on eclipse environment and it is basically a customized eclipse. If the target group of users use the eclipse modeling components it is more convenient for them to use the eclipse plug-in, but if they do not use the eclipse modeling version or not even the eclipse platform, the generated application is the best choice.

The generated application uses the GMF runtime package and provides implemented actions, commands, view edit parts, view policies, view provider, validation provider, properties sheet etc. If someone wants to develop easily a graphical editor for a model *GMF* provides various functionalities and makes a great case, but it has some problems also. The *GMF*'s disadvantage is that the implemented provider for cut-copy-paste actions is not functional and the programmer should write its implementation by hand. Another disadvantage of *GMF* is that once the programmer describes the graphical representation of an element that can't change. For example, if someone wants to select when an element's attribute will be visible and when not, that is not possible.

5.3 Validation Rules

In order to be able to create a statechart that obeys to the ASEME rules and the transition's grammar we had to define some validation rules. Firstly, we had to be sure that the designed statechart follows the statechart rules, which are:

- StateChart Model can have only one root node of type OR.
- Every OR node should have exactly one START node as a child.
- Every OR node can't have more than one END nodes as children.
- A START node can only be a source node for an transition.
- An END node can only be a target node for a transition.

- An AND node can only have OR nodes as children.

In order to have code generation for the transitions, we had to define EBNF grammar that enables the easy description of a more complicated class definition. Since the EBNF grammar has been declared, we had to add a validation system. The grammar that should be checked is:

TransitionExpression = [event]["[" condition"]"][/actions]
event = string
condition = expr
| expr (compOp | logicOp) condition
| "("condition")"
| notOp condition
actions = TimeoutAction
| Actions
Actions = Actions connectiveOp action
action = "process_messages"
| "publish_all"
| "publish" "." topic"."commType"."msgType"."membersetfunction"("val")"
TimeoutAction = TimeoutAction"."topic"."time
expr = varVal | func "(" args ")"
func = < *any_valid_cpp_decleared_function_name* >
| TimeoutCheck "(" topic ")"
args = varVal
| varVal "," args
varVal = message | variable | value
value = constant | stringLiteral | number+
compOp = " < "|" <= "|" > "|" >= "|" == "|"! = "
logicOp = "&&" | "||"
notOp = "!"
connectiveOp = ";"
message = topic "." commType "." msgType

variable = message ”.” member
commType = ”*Signal*”|”*State*”|”*Data*”
host = string
topic = string
msgType = string
member = string ”(” number⋆ ”)” (”.”string ”(” number⋆ ”)”)
membersetfunction = string (”(” number⋆ ”)” ”.” string)⋆
time = number +
stringLiteral = ” string ”
string = letter (letter | number | ”_”)⋆
letter = ”a” | ”A” | ”b” | ” B” | ”c” | ”C” | ”d” | ”D” | ...
number = ”0” | ”1” | ”2” | ”3” ...

We also added validation for the variables, a variable's name should start with letter or ”_” and its type should be described as Narukom message, ie as the messages described at the transition's grammar.

For the above rule definitions we had to edit the generated code, since we chose *java* as the language of implementation. The generated functions that we had to edit were the ”validate” empty functions for every rule that were part of the ValidationProvider class. For the correct description of a transition and a variable we used regular expressions. For every part of the generated code that we edited we had to put the flag:

```
/*
 * generated NOT
 */
```

in order to keep that code unchanged from a possible next code generation, for example if we wanted to change the representation of a model's element or add a new rule.

5.4 From graphical editor to CASE tool

The *GMF* Framework enabled us to describe graphically our model and create easily an application that allows us to edit it, but this is not enough for making an application that helps a code developer to design a behavior for a robot soccer player. Our purpose is to design and implement a useful CASE tool for model-driven software development. This CASE tool has been named *KSE* (Kouretes Statechart Editor). For our *KSE* implementation the statechart editor from *GMF* can not be considered as a CASE tool. There are missing a lot of functions, such as:

- liveness formula editor
- liveness formula to statechart transformation (Text-to-Model (T2M) transformation)
- copy-cut-paste functionality for graphical views, this is not supported by *GMF*
- statechart to *Monas statechart* transformation (Model-to-Text (M2T)), also known as code generation
- statechart connection to *Monas* architecture and local repository
- editing of activities, BASIC states that are already implemented in C++ code in users' local repository
- the automated labeling of model's elements for proper code generation

5.4.1 Liveness Formula Editor

A special editor has been implemented for liveness formula (Figure 5.5). The user can enter the model's/formula's name and the liveness formula itself. This editor is implemented as a `JFrame` class from `javax.swing` package and has a plain `JTextArea` from the same package for editing the formula's name and another one for editing formulas as well. The same editor appears when the user chooses the action "Open Formula" from the file menu.

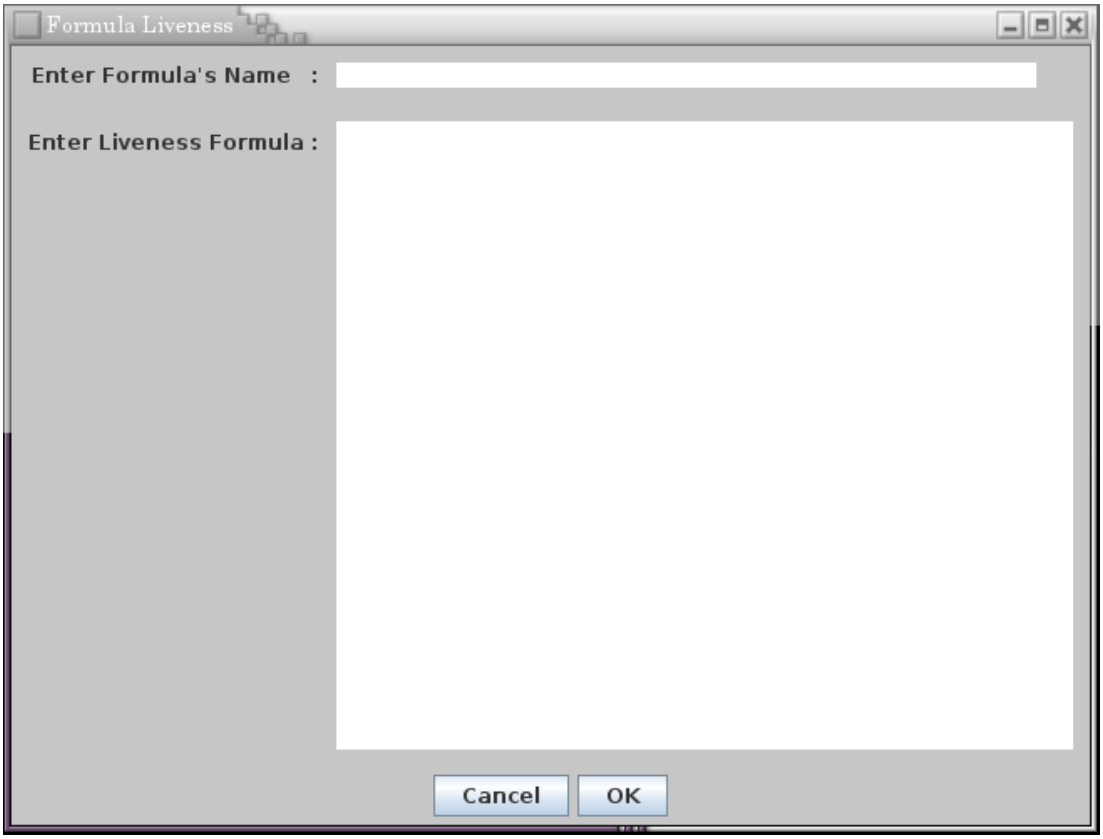


Figure 5.5: The Liveness Formula Editor

5.4.2 Liveness Formula to Statechart Transformation

The transformation of liveness formula to *IAC* has been implemented by Nikolaos Spanoudakis as part of the *ASEME* project. The transformation creates an "abstract" *IAC* model with "empty" transition and "empty" BASIC states. An "empty" transition has `TE = null` and an "empty" BASIC state has `activity = null`. That means that every transition's condition is true and every BASIC state has no functionality, ie no decision is taken. Since we haven't used the *IAC* model for the graphical representation of the statechart, but we have used the *STCT* instead, we had to define a transformation of the liveness formulas to an STCT model. To do that we changed the existing liveness2IAC transformation and defined the liveness2Statechart transformation. We changed the addition of new nodes to the model, since for *STCT* you have to add the children nodes

to the parent node and not to the model as *IAC* model requires. So, firstly we add the root node to the model and then only add children nodes to the parent nodes. One node can have one or no parent node, but more than one children. The parsing of the liveness formula has not changed, but the search function for already created nodes has changed, since the the model has only one node and that node contains the rest of the nodes as its children or its children children and so. The "abstract" *STCT* model that is generated from this transformation has the same characteristics as the *IAC* described above (Figure 5.6). The liveness formulas for Goalie statechart(Figure 5.6) is shown below:

```
goalie = Init.(playing | nonPlaying)+
nonPlaying = NoPlay .[GoToPosition+]
playing = Scan+ | ApproachBall+ | Kick | followBall
followBall = Stare+.[SpecialAction]
```

5.4.3 Copy-Cut-Paste Functionality

Although *GMF* provides an easy implementation of graphical editors with a variety of functionalities for *EMF* models, the functionality of copy-cut-paste is not implemented successfully. So, we had to implement the above functionality hard-coded and specified for our model editing. In our situation, the action copy-paste is not as plain as copy-paste for simple text editors. It is very significant for our model, each node to have a unique label that describes the node's priority for execution, because of that the copy-paste action is not exactly copy-paste as the nodes' labels get updated according to the new position in the statechart. As consequence of the new nodes' labels transitions' names get updated accordingly.

For that purpose we had to import our implementation of the cut-copy-paste action handler and provider and ignore the *GMF* implementations which have "bugs". For our handler and provider implementations we used abstract classes from `org.eclipse.gmf.runtime` package, specifically for our handler, StateChartClipboardSupportGlobalActionHandler, we used the DiagramGlobal-ActionHandler class, and for our action provider, StateChartActionProvider, we

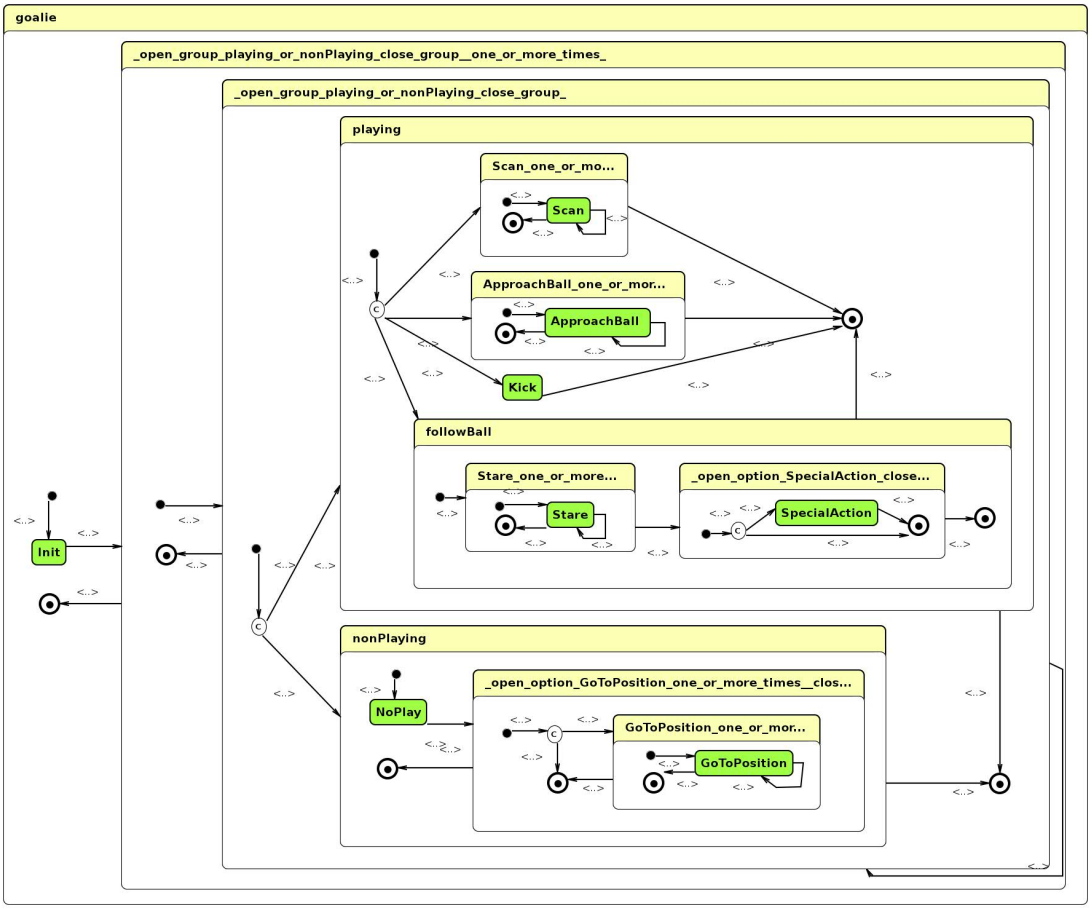


Figure 5.6: The abstract statechart as generated by liveness to statechart transformation

used the AbstractProvider class and the IGlobalActionHandlerProvider interface. Since the action handler and provider is ready for use, we had to implement the commands for cut, copy, and paste. For the cut and copy commands the implementation is similar. The most important part of this implementation is that when the user chooses an OR or AND node to copy or cut, their children nodes, transitions, and variables should get copied to our clipboard too. For the paste command implementation, firstly we had to check whether the elements to paste have a valid paste target in the diagram. As long as the paste target is valid and the elements to paste are valid too, we can add them to the diagram, but we

have to obtain the *STCT* model's characteristic for the labels, we have to obtain the uniqueness of its label and its value should indicate the execution sequence. As the reader can understand the copy-paste function for *KSE* is not actually copy-paste as we know it, the label attribute of its node has to change accordingly. After adding the new elements to the target, we have to refresh the edit policies for every item. For each item we have to refresh its SemanticEditPolicy, ConnectionEditPolicy, and CanonicalEditPolicy and we start from the root item, the model and then refresh the rest of them.

5.4.4 StateChart to Text Transformation

The purpose of creating a *STCT* model is to describe a behavior for a robot soccer player, which for *Kouretes* team needs should be implemented in C++ language and accordingly to *Monas* architecture. The described application allows the user to create a *STCT* model, but that is not enough for code development. The *STCT* model should be transformed to C++ code for *Monas* architecture's statechart engine *YASE* [2]. A plain code generator had been implemented by Alexandros Paraschos, the *IAC-2-Monas*. The first version of *IAC-2-Monas* (Figure 5.7) could just create template classes for activities (Figure 5.8) and transitions and an implemented class for the model's description (Figure 5.9). *IAC-2-Monas* generates the statechart's model class which describes the execution priority of the nodes and the transitions. For doing that correctly and be sure that the Statechart Engine will execute it in the right sequence the node's attribute *label*, which is unique and represents the depth of the node in execution and the sequence in execution for the nodes with the same depth. For example, the root node has *label* "0" and its first child "0.1".

The second version of *IAC-2-Monas*, which had also been implemented by Alexandros Paraschos could additionally transform the transition's expression to C++ classes, such as event, condition and action. The first and second versions of *IAC-2-Monas* ran through the eclipse application by using a workflow file, so it couldn't be used in *KSE*.

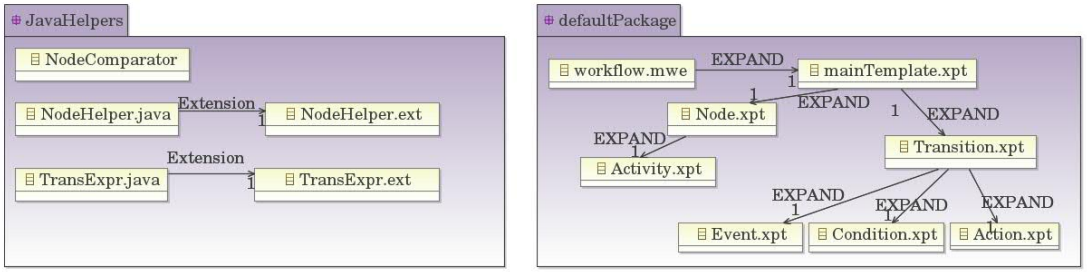


Figure 5.7: The IAC-2-Monas code generator class diagram.

```
#ifndef _test_h_
#define _test_h_ 1

#include "architecture/IActivity.h"
class test : public IActivity {
public:
  int Execute ();
  void UserInit ();
  std::string GetName ();
};
#endif // _test_h_
```

```
#include "test.h"
namespace{ ActivityRegistrar<test>::Type temp("test"); }
int test::Execute() {
  return 0;
}
void test::UserInit () {  }

std::string test::GetName () {
  return "test";
}
```

Figure 5.8: The generated Activity template class, header and .cpp, without any variables, the same with version two.

For the *KSE* a third version and currently the last of *IAC-2-Monas* (Figure 5.11) has been implemented. In this version the code generator adds node's variables as input messages to the generated activity class template (Figure 5.10). In order to generate code for the transition classes we used the *EBNF* grammar that was used in validation. The developer can choose, whether logger calls will be added to transition's condition or not. For transition's action, the TimeoutAction as an action implementation has been added and the expression "TimeoutCheck(topic)" for the TimeoutAction's expiration for the transition's condition has been added to the transition's grammar. If the developer wants to add a

```
#include "Goalie.h"
#include "transitionHeaders.h"
using namespace statechart_engine;

namespace {
  StatechartRegistrar<Goalie>::Type temp("Goalie");
}
Goalie::Goalie(Narukom* com) {

  _statechart = new Statechart ( "Node_Goalie", com );
  Statechart* Node_0 = _statechart;
  _states.push_back( Node_0 );

  StartState* Node_0_1 = new StartState ( "Node_0_1", Node_0 ); //Name:0.1
  _states.push_back( Node_0_1 );

  IActivity* NodeActivInst_0_2 = ActivityFactory::Instance()->CreateObject( "Init" );
  _activities.push_back( NodeActivInst_0_2 );
  BasicState* Node_0_2 = new BasicState( "Node_Init", Node_0, NodeActivInst_0_2 ); //Name:
      Init
  _states.push_back( Node_0_2 );

  OrState* Node_0_3 = new OrState ( "
      Node__open_group_playing_or_nonPlaying_close_group__one_or_more_times_", Node_0 ); //
      Name:_gr_playing_or_nonPlaying_one_or_more_times_
  _states.push_back( Node_0_3 );

  StartState* Node_0_3_1 = new StartState ( "Node_0_3_1", Node_0_3 ); //Name:0.3.1
  _states.push_back( Node_0_3_1 );

  OrState* Node_0_3_2 = new OrState ( "Node__open_group_playing_or_nonPlaying_close_group_",
      Node_0_3 );  //Name:_gr_playing_or_nonPlaying
  _states.push_back( Node_0_3_2 );

  StartState* Node_0_3_2_1 = new StartState ( "Node_0_3_2_1", Node_0_3_2 ); //Name:0.3.2.1
  _states.push_back( Node_0_3_2_1 );

  ConditionConnector* Node_0_3_2_2  = new ConditionConnector ( "Node_0_3_2_2", Node_0_3_2 );
      //Name:0.3.2.2
  _states.push_back( Node_0_3_2_2 );

  OrState* Node_0_3_2_3 = new OrState ( "Node_playing", Node_0_3_2 ); //Name:playing
  _states.push_back( Node_0_3_2_3 );

  StartState* Node_0_3_2_3_1 = new StartState ( "Node_0_3_2_3_1", Node_0_3_2_3 ); //Name
      :0.3.2.3.1
  _states.push_back( Node_0_3_2_3_1 );

  ConditionConnector* Node_0_3_2_3_2  = new ConditionConnector ( "Node_0_3_2_3_2",
      Node_0_3_2_3 ); //Name:0.3.2.3.2
  _states.push_back( Node_0_3_2_3_2 );

  OrState* Node_0_3_2_3_3 = new OrState ( "Node_Scan_one_or_more_times_", Node_0_3_2_3 ); //
      Name:Scan_one_or_more_times_
  _states.push_back( Node_0_3_2_3_3 );

  StartState* Node_0_3_2_3_3_1 = new StartState ( "Node_0_3_2_3_3_1", Node_0_3_2_3_3 ); //
      Name:0.3.2.3.3.1
  _states.push_back( Node_0_3_2_3_3_1 );
...
```

Figure 5.9: The generated model class for Goalie example.

TimeoutAction to a transition he would have to write the expiration check to the

```
#ifndef _test_h_
#define _test_h_ 1

#include "architecture/IActivity.h"
#include "messages/AllMessagesHeader.h"

class test : public IActivity {
public:
  int Execute ();
  void UserInit ();
  std::string GetName ();
private:
  void read_messages();
  boost::shared_ptr<const HeadToBMessage> hbm;
  boost::shared_ptr<const WorldInfo> worldInfo;
};
#endif // _test_h_
```

```
#include "test.h"
namespace {
    ActivityRegistrar<test>::Type temp("test");
}
int test::Execute() {
  read_messages();
  return 0;
}
void test::UserInit () {
  _blk->updateSubscription("behavior",msgentry::SUBSCRIBE_ON_TOPIC);
}
std::string test::GetName(){return "test"; }
void test::read_messages(){
  hbm = _blk->readState<HeadToBMessage> ("behavior" );
  worldInfo = _blk->readData<WorldInfo> ("behavior" );
}
```

Figure 5.10: The generated Activity template class, header and .cpp, with two variables.

transition's condition. So, for example, if he wants to activate a TimeoutAction in topic behavior for 250 msec he would have to write the transition's expression as:

`[TimeoutCheck(behavior)]/TimeoutAction.behavior.250`

The source code generated for this transition is in (Figure 5.12).

These were not the only changes made, the *IAC-2-Monas* was developed for *IAC* model and not for *STCT*, which *KSE* uses for the graphical representation. For this reason the java class "ModelConvertor", which transforms a *STCT* model to *IAC* model and vice versa, was implemented. "MainWindowApplication", a java class with main function was added, in order to export the generator's project from eclipse as a java runnable jar. "MainWindowApplication" gets as inputs, through the main function, the file of the *STCT* model to be generated and the

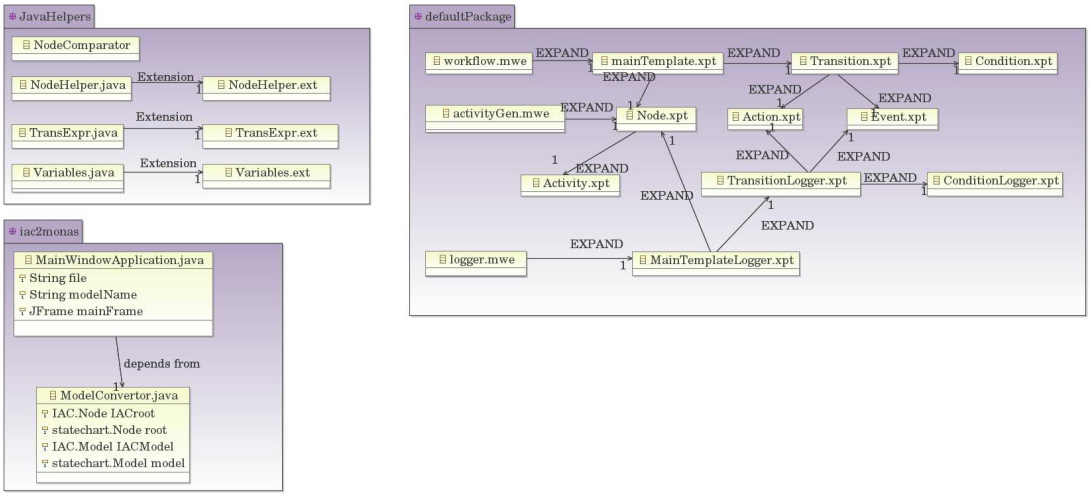


Figure 5.11: The IAC-2-Monas code generator final edition class diagram.

```
#include "architecture/statechartEngine/ICondition.h"
#include "messages/AllMessagesHeader.h"
#include "tools/BehaviorConst.h"
class TrCond_Goalie0_3_20_3_2 : public statechart_engine::ICondition {
public:
  void UserInit () { _blk->updateSubscription("behavior",msgentry::SUBSCRIBE_ON_TOPIC); }
  bool Eval() {
    /* TimeoutCheck(behavior) */
    boost::shared_ptr<const TimeoutMsg > msg = _blk->readState< TimeoutMsg > ("behavior");
    return ( (msg.get()!=0 && msg->wakeup()!="" &&
    boost::posix_time::from_iso_string(msg->wakeup())<boost::posix_time::microsec_clock::
        local_time()) );
    }
};

#include "architecture/statechartEngine/IAction.h"
#include "architecture/statechartEngine/TimoutAciton.h"
class TrAction_Goalie0_3_20_3_2:public statechart_engine::TimeoutAction{
  /* TimeoutAction.behavior.250 */
  public:TrAction_Goalie0_3_20_3_2():statechart_engine::TimeoutAction( "behavior", 250 ){;}
};
```

Figure 5.12: The generated Condition and Action classes

targeted folder for generation. "MainWindowApplication" uses the "ModelConvertor" for transforming the *STCT* model to *IAC* model. It also uses the "WorkflowRunner" from the package `org.eclipse.emf.mwe.core.WorkflowRunner` in order to run the project's .mwe files as workflows. This last version has three instead of one workflow file, as the previous two versions had. The "activityGen.mwe" file generates only the chosen BASIC state's activity class template. The "logger.mwe" generates code for the *STCT* model with logger calls in it's

transition's conditions. The "workflow.mwe" generates code for the *STCT* model without logger calls in it's transition's conditions.

5.4.5 Statechart's Connection to Local Code Repository

During the beta-testing of *KSE* the need of connecting the created *STCT* model to the user's local *Monas* repository was obvious. At first the generated code from the statechart model was saved in the application's workspace, which was not convenient, because once the user wanted to test it on the robot he/she would have to copy the folder with the generated code and paste it to the local *Monas* repository in folder *Monas/src/statecharts*, copy the generated and implemented statechart's activities in folder *Monas/src/activities*, then compile, and upload the binary files to the robot. This was not convenient at all, so every model that transforms to code through this applications has to be linked to a local folder. In case the user uses the *KSE* code generator and creates a link to an empty folder or a non *Monas* repository the code still gets generated according to *Monas* architecture.

5.4.6 Editing of BASIC States' activities

Since the *STCT* models are linked to a code repository, the implementation of transitions' classes is automatic, and the creation of a template activity class are done through this application it became necessary to be able to edit the activities' classes through this application (Figure 5.13). Although no C++ editor is implemented for this CASE tool, the user can open and edit the BASIC states' activities with a C++ editor of his/hers system through the application.

5.4.7 The automated labeling of model's elements for proper code generation

In case of someone uses this application to design a statechart without using the liveness formula, but just designs the statechart graphically, the need of automatic labeling for the statecharts elements is obvious. The *STCT* that we use for describing an agent, in order to be transformed in code correctly has to have

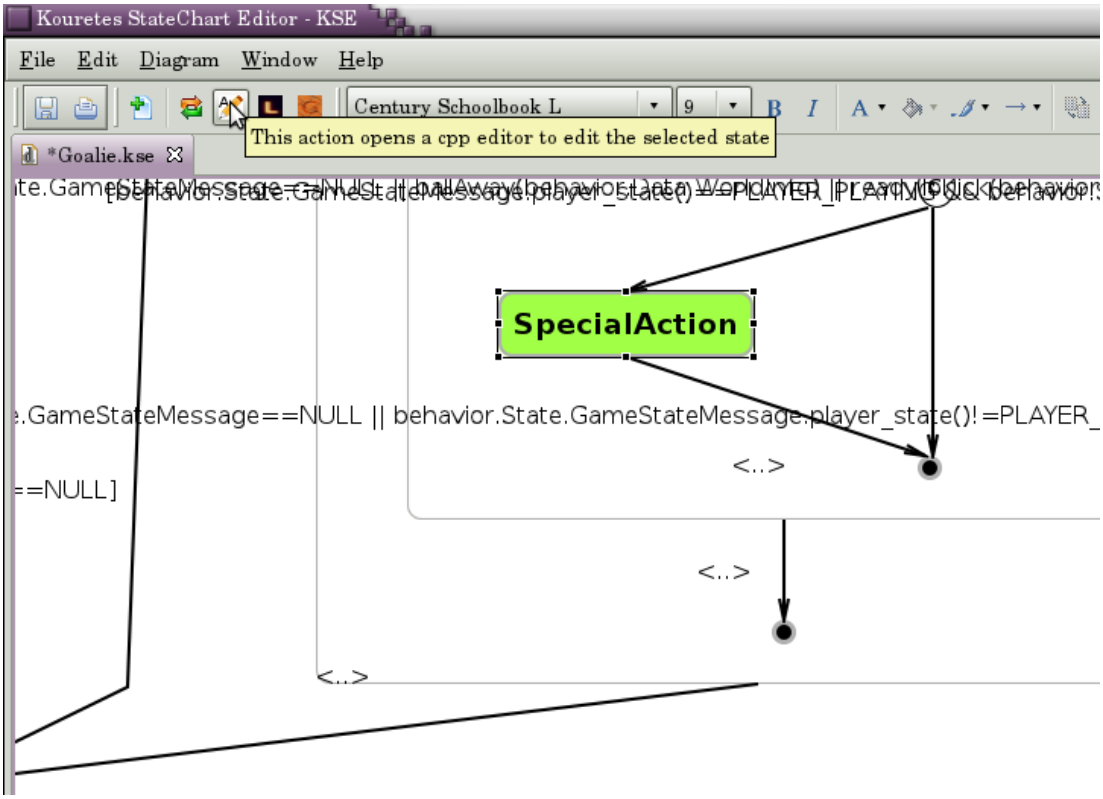


Figure 5.13: This action opens a C++ editor for the selected BASIC state's (SpecialAction) activity.

only labeled elements. When we are referring to labeled elements, we mean that every model's node has to have the attribute *label* completed, every label has to be unique, every label has to describe the priority of execution in the statechart and the transitions between nodes named.

5.4.8 Configuring *KSE*

Although *KSE* has been developed for *Kouretes* team and *Monas* architecture, it can be configured according to the users preferences. The user can define through a configuration dialog (Figure 5.14) the desired text editor for the activities' source code and the desired model's code generator.

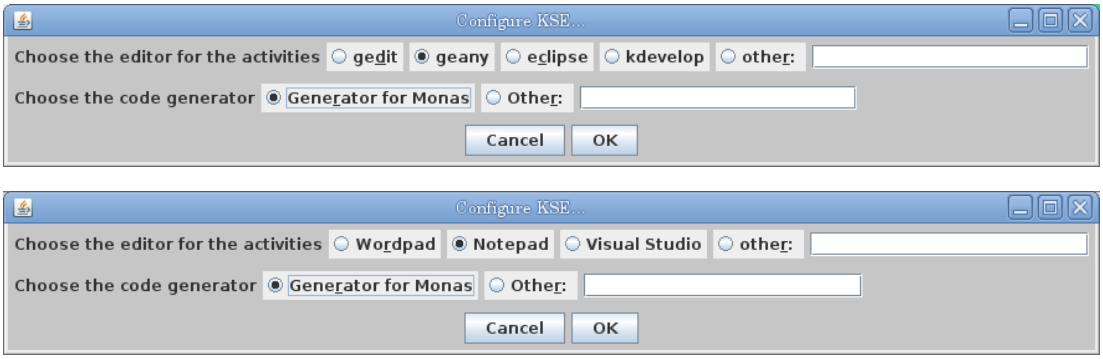


Figure 5.14: The *KSE* configuration dialog for Linux(up) and Windows(down).

5.4.9 Help section

A user manual and instructions have been added to the application in the help section. For this functionality, we added to the application's extension point the org.eclipse.ui.helpsupport extension point and we implemented the class AbstractHelpUI from the package `org.eclipse.ui.help`. For the help display system's browsers are used. the instructions are written in html files and if anyone wants to edit them or replace them, he can do it with any html editor. If anyone wants simply to change the sections of the html files, he can do it, but in order to be able to open them from the help menu he has to keep the toc.html file because it is the file that the application opens for the help action.

5.5 Exporting KSE from eclipse

The eclipse platform gives us the ability to export our application as an eclipse product. for doing so, we have to have the plug-in development component installed to our eclipse application. The plug-in development component provide us a configuration file of *product configuration* type. In this file the programmer can configure an eclipse product and export it as an individual application. In order to export it for multiple platforms you have to install first the delta pack to your eclipse and then configure the *product configuration* file. Although the rest required packages we installed them through the aclipse application,

for delta pack we had to do it manually. First we had to find the delta pack build which had the same build ID with our eclipse application, download it from http://download.eclipse.org/eclipse/downloads/ and follow the installation instructions from http://www.vogella.de/articles/EclipsePDEBuild/ar01s02.html. With the delta pack installed, we could export our application for any platform. We configured the exported applications through the *product configuration* file, we set the application's name, folder, runtime, package dependencies, launching icons, copyright and lincense. we used the Eclipse Product export wizard and chose the target platforms. A few minutes later, *KSE* is ready for use!

Chapter 6

Results

6.1 Evaluation of the CASE tool - KSE

The first evaluation for *KSE* came with a live user tutorial and the evaluators were the members of *Kouretes* team, lets notice that this was the beta-testing as well. Although the target group of users are the members of *Kouretes* team, the evaluation of my teammates was not as objective as it should be in order to present it in this thesis. It is important to notice that their comments and requests were considered seriously and the majority of them were implemented and added to *KSE*.

To obtain an objective evaluation of our CASE tool, 28 ECE undergraduate students taking the Autonomous Agent class at the Technical University of Crete were asked to use *KSE* and evaluate it in one of their laboratory sessions. The plan of this 2-hour lab session was to go through a short tutorial on using KSE, study a complete SPL Goalie behavior as an example (shown in Figure 5.4 without the transition expressions), and finally develop their own SPL Attacker behavior using KSE and the same functionalities of the Goalie behavior. The provided functionalities were supported by a Monas source code repository. The students worked in small teams of two or three people per team. None of them had any prior experience with CASE tools, KSE, Monas, SPL, or RoboCup in general. This lab session was run three times to accommodate all students in the four available work stations. At the end of each lab session, a quick SPL game

took place with the four attackers split in two teams of two players each.

The results were in general positive for *KSE* as a CASE tool, but also for the concept of *ASEME*-based behavior development. Both seemed to be pretty understandable, even though most students were not familiar with Agent-Oriented Software Engineering. All student teams were able to go through the provided material and deliver the requested SPL Attacker behavior. The great bet, won by *KSE* in this evaluation, was that all student participants succeeded to create a simple SPL robot behavior and even enjoyed watching their players in a game without having to go through the typical lengthy training procedures required for student members of an SPL team.

6.2 The evaluation's questionnaire

All student participants were asked to fill in an anonymous user satisfaction questionnaire after the lab session. The total amount of responders was 19. Although they were split in groups for the lab session, the questionnaire was answered individually. The overall assessment of KSE was positive. The main negative comment was that the long transition expressions on the model were cluttering the view of the statechart graph. Before handing out this thesis we tried to change the representation of long transition expressions (TE), the solution was to define them as a multiline string to the EMF model and the GMF representation includes only the first line of the transition expression. So, now you can see only the first line of the expression on the graph (Figure 6.2). The new representation is not that "crowded" as the one that the evaluators had to work with (Figure 6.1).

As you can see, there is a great improvement between the two versions of *KSE*, the users suggestions were taken seriously. For more information about the evaluation you can study the question graphs and judge the results.

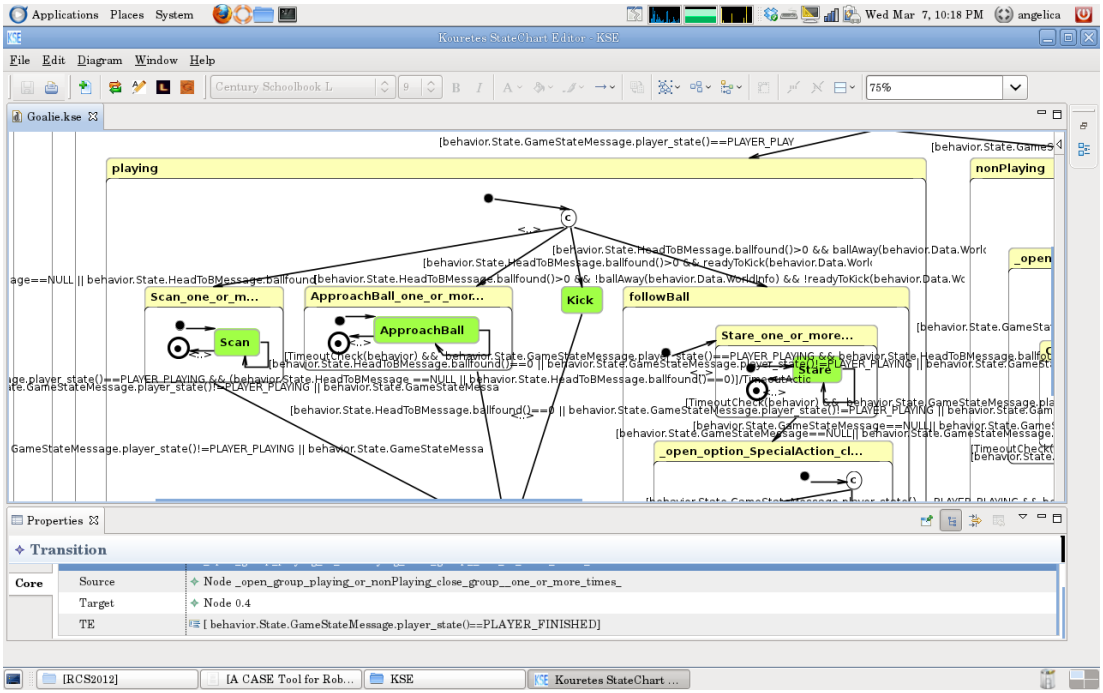


Figure 6.1: The statechart of the provided SPL Goalie behavior.

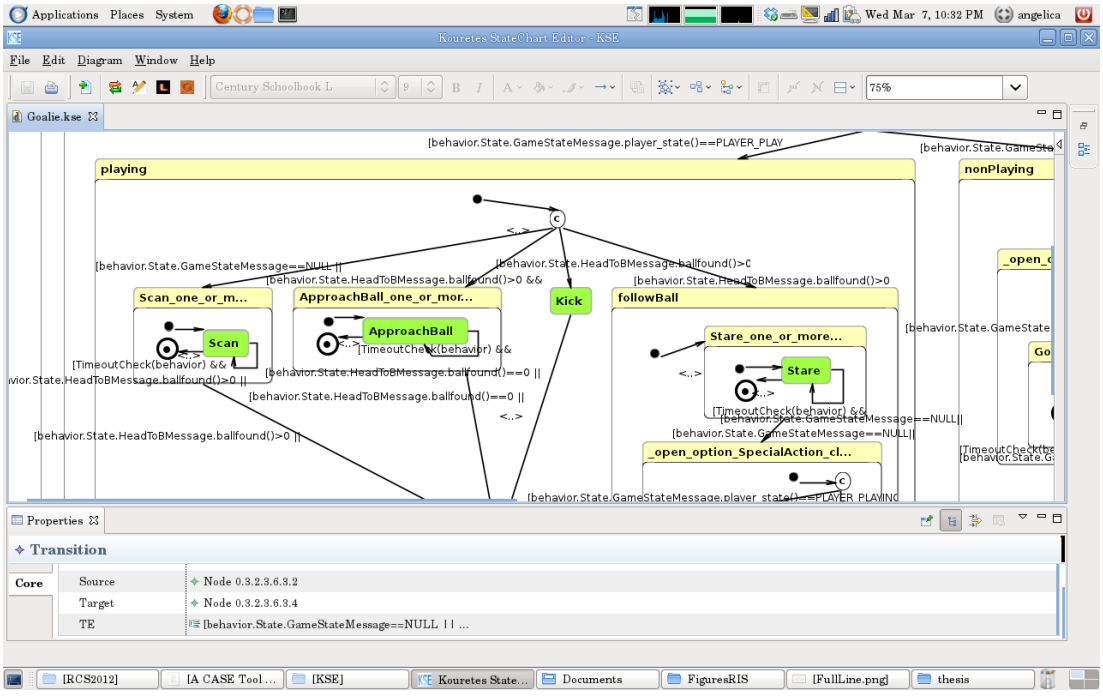
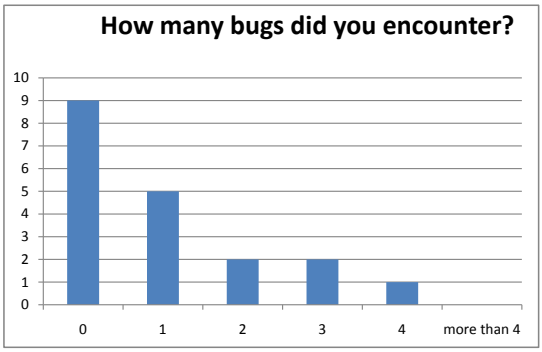
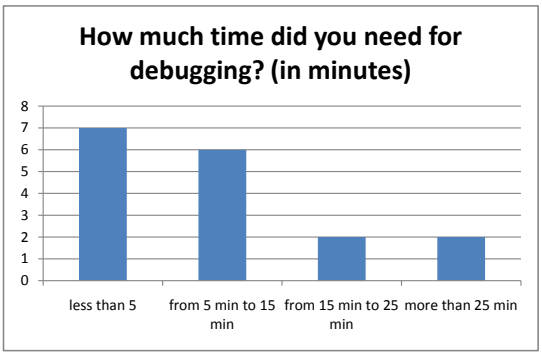
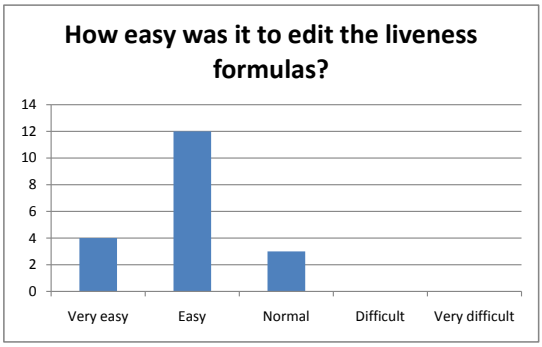
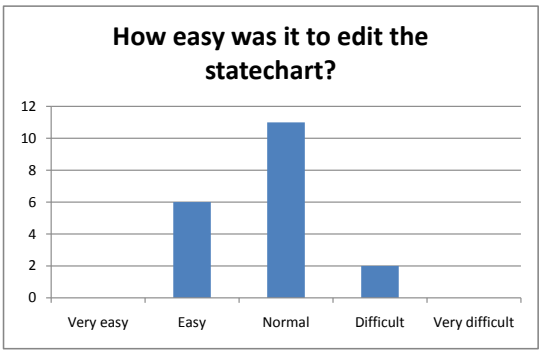


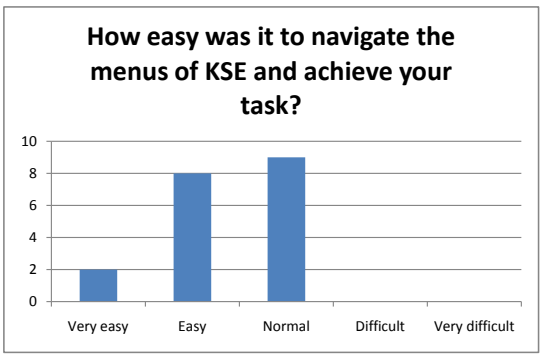
Figure 6.2: The statechart of the provided SPL Goalie behavior with the new representation.

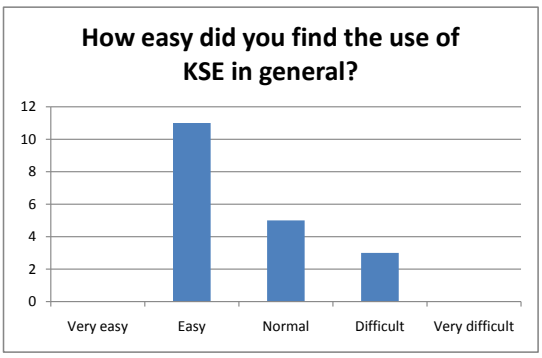

How many bugs did you encounter?
10
9
8
7
6
5
4
3
2
1
0
0
1
2
3
4
more than 4

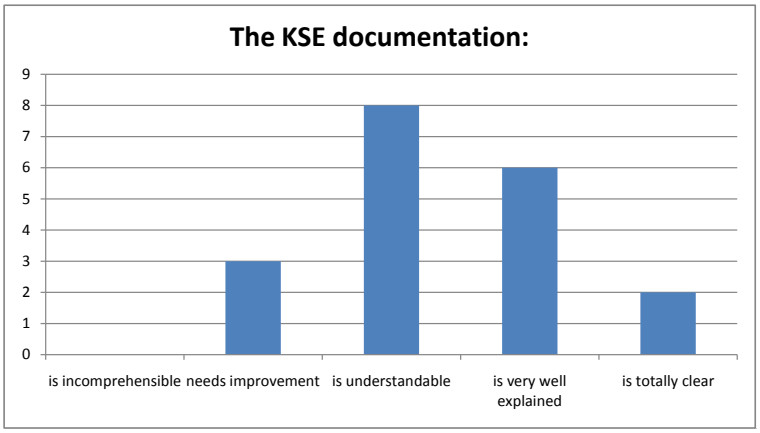

How much time did you need for debugging? (in minutes)
8
7
6
5
4
3
2
1
0
less than 5
from 5 min to 15 min
from 15 min to 25 min
more than 25 min

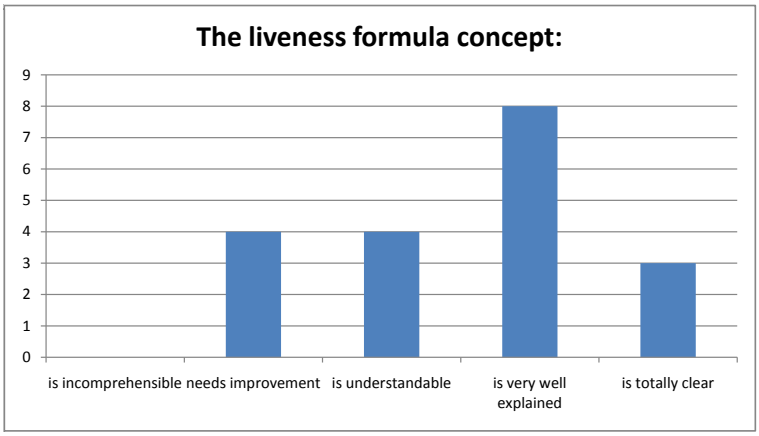

How easy was it to edit the liveness formulas?
14
12
10
8
6
4
2
0
Very easy
Easy
Normal
Difficult
Very difficult

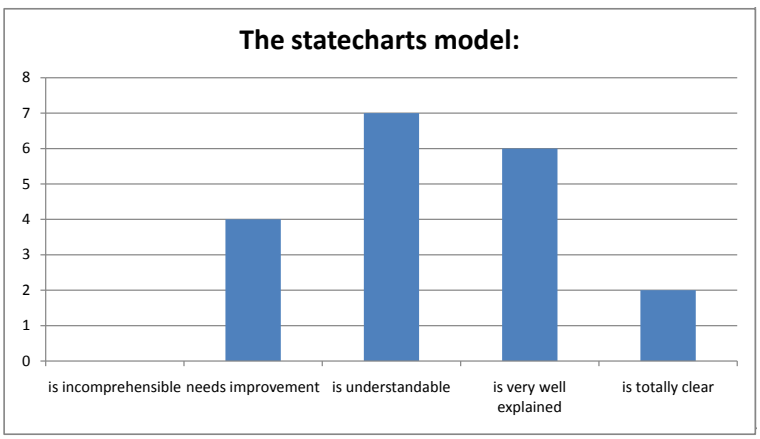

How easy was it to edit the statechart?
12
10
8
6
4
2
0
Very easy
Easy
Normal
Difficult
Very difficult

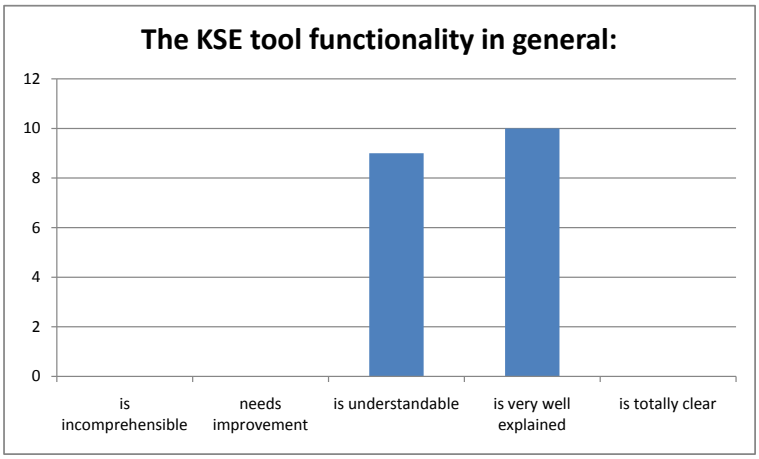

How easy was it to navigate the menus of KSE and achieve your task?
10
8
6
4
2
0
Very easy
Easy
Normal
Difficult
Very difficult

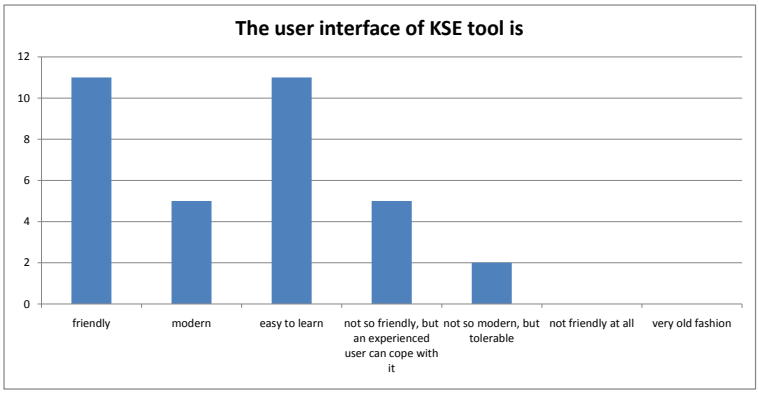

How easy did you find the use of KSE in general?
12
10
8
6
4
2
0
Very easy
Easy
Normal
Difficult
Very difficult

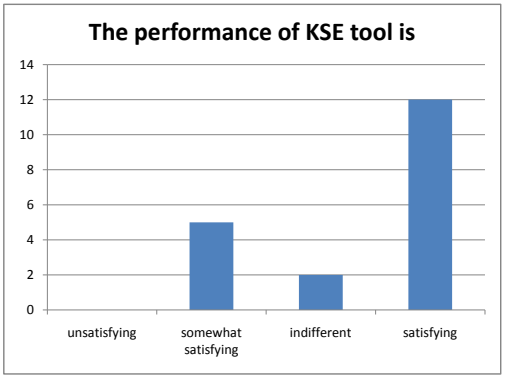

The KSE documentation:
9
8
7
6
5
4
3
2
1
0
is incomprehensible
needs improvement
is understandable
is very well explained
is totally clear

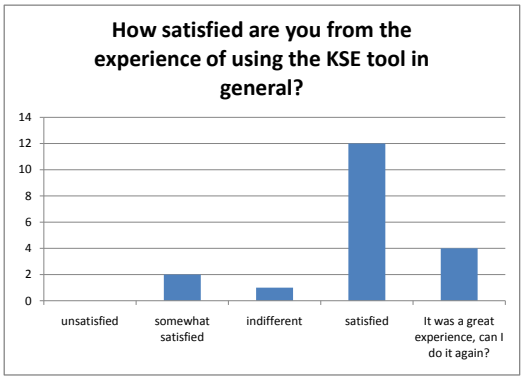

The liveness formula concept:
9
8
7
6
5
4
3
2
1
0
is incomprehensible
needs improvement
is understandable
is very well explained
is totally clear


The statecharts model:
8
7
6
5
4
3
2
1
0
is incomprehensible
needs improvement
is understandable
is very well explained
is totally clear

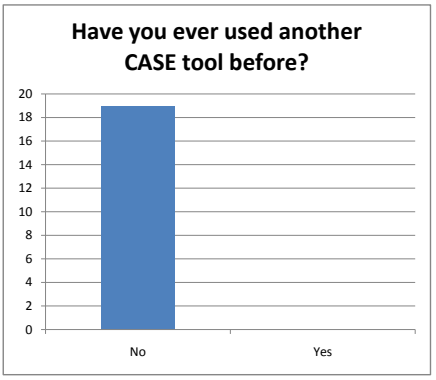

The KSE tool functionality in general:
12
10
8
6
4
2
0
is incomprehensible
needs improvement
is understandable
is very well explained
is totally clear

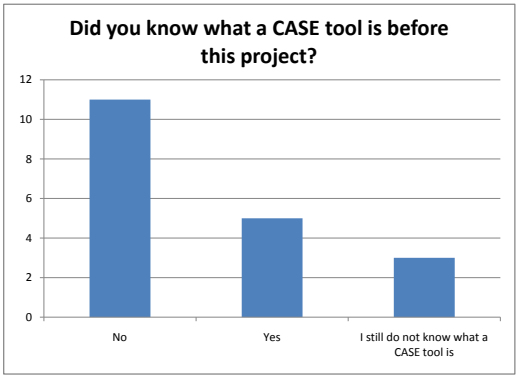

The user interface of KSE tool is
12
10
8
6
4
2
0
friendly
modern
easy to learn
not so friendly, but an experienced user can cope with it
not so modern, but tolerable
not friendly at all
very old fashion

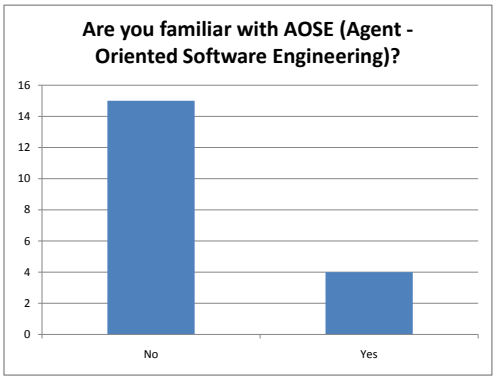

The performance of KSE tool is
14
12
10
8
6
4
2
0
unsatisfying
somewhat satisfying
indifferent
satisfying


How satisfied are you from the experience of using the KSE tool in general?
14
12
10
8
6
4
2
0
unsatisfied
somewhat satisfied
indifferent
satisfied
It was a great experience, can I do it again?


How experienced code developer are you?
16
14
12
10
8
6
4
2
0
I am very experienced
I am experienced
I am not that experienced
I lack of experience
I am not a code developer


Have you ever used another CASE tool before?
20
18
16
14
12
10
8
6
4
2
0
No
Yes


Did you know what a CASE tool is before this project?
12
10
8
6
4
2
0
No
Yes
I still do not know what a CASE tool is


Are you familiar with AOSE (Agent - Oriented Software Engineering)?
16
14
12
10
8
6
4
2
0
No
Yes

Chapter 7

Conclusions

7.1 Discussion

Our approach is not a breakthrough, but it is an honest effort of solving an existing problem. The CASE tools that are similar or have similar purposes as our own are XabslEditor and YAKINDU as mentioned in chapter 2. XabslEditor has been build for robocupSoccer and YAKINDU has been build in the same platform as *KSE*. We will now see what a tool build for robocup, as ours and a tool build with eclipse GMF as ours has to offer in comparison to *KSE*. It is important to notice that XabslEditor is an academic product as opposed to YAKINDU that is developed by a company.

As seen in the table 7.1 *KSE* offers has some characteristics that make the design of a behavior much easier. *KSE* offers graphical editing of the statechart, something that XabslEditor does not offer. XabslEditor provides only text editor with highlight for editing an FSM, which is visualized in another view. *KSE* offers an implementation of copy-paste of graphical components, something that neither of the two tools mentioned provide. Although what have been mentioned above, has made a good case; the biggest advantage of the *KSE* is the analysis tool, in which the user can describe the desired behavior by using the liveness formula. In addition the user can configure the *KSE* and use it with a different generator for the model than the one that *KSE* provides and can choose which one editor the *KSE* would open for the activities' editing. In that way anyone

Table 7.1: Feature comparison of XabslEditor, Yakindu, and KSE.

Feature	**XabslEditor**	**Yakindu**	**KSE**
Supported Platforms	java	eclipse helios	linux, windows
Open Source	√	free-ware	√
Model Validation	√	√	√
Analysis Tool			√
Model Simulation		√	
Multiple Editing Tabs	√	√	√
Symbol Auto-Completion	√		
Graphical Editing		√	√
Reusability of Graphical Components			√
Source Code Generation	√	√	√
Integrated Source Code Editing	√		√
Customization of Code Generator			√

can use the *KSE* for the editing of the liveness formula, the graphical editing and representation of the statechart and just develop a code generator for the desired purpose and has his own customized statechart editor.

7.2 Future Work

KSE is a CASE tool that provides a variety of functionalities, but every application needs improvements and has potential future work. The answers from the evaluation gave us some material for future projects.

A project that would be usefull for the development of a behavior is a soccer match and robot simulator. The simulator is quite useful, because it is easier to test and debug the system on your computer, whether on the robot. At the simulator one can test the developed behavior in a soccer match of two teams of four players, but in order to do that with real robot someone would have to own eight robots which is expensive. It is important to notice that a simulator would be fully connected to a specific robot platform and that would constrict the use

of *KSE*.

Another project that would make the debuging process for the developed behavior more convinient is a real-time monitor that would represent live and graphically the statechart and show which state is executed currently on the robot. That project would have dependency with *KSE* and the used robot communication.

Another way to enrich the *KSE* tool is by adding more editors for *ASEME* models.

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Appendix A

User Manual

A.1 Overview

KSE (Kouretes StateChart Editor) is the first CASE (Computer-Aided System Engineering) tool from the robocup team *Kouretes*. *KSE* is a graphical statechart editor that helps the developer to organize and edit code for a statechart according to *ASEME* methodology and Monas architecture. This CASE tool contains:

- Liveness formula editor
- EMF generator for the liveness formula
- Graphical Editor for statecharts
- C++ code generator for Monas architecture
- C++ Editor for code editing(one of your system's editors)
- Validation provider for statecharts that are developed according to ASEME and transition expressions that are written according to the given generator's grammar.

A.2 Requirements and Installation

KSE is developed on eclipse platform and it is an eclipse product. The required software for installing *KSE* at your pc is:

- java environment, minimum version jre 6.26.
- any Linux or Windows distribution, as long as you download the respectively *KSE* edition.

All you have to do is to download the application from http://www.kouretes.gr and extract the downloaded file. Linux users can start the application by double-click on the icon "KSE" or by typing in a terminal opened in the application's folder `./KSE`. Windows users can start the application by double-click on the icon "KSE.exe" or by typing in the command prompt `.\<path-of-KSE.exe>`.

A.3 KSE architecture

KSE gives the user the opportunity to develop C++ code from a model. *KSE* has several components (Figure A.3) for different functionalities, such as transformation from liveness formula to EMF Model, model's validation according to ASEME and Monas, code generation according to the model, editing of the model and editing of the code.

A.4 Configuration of KSE

You can configure partially the KSE tool through a dialog, for opening that dialog got to Edit → Configure KSE... . You can choose the editor for the activities. If you running the application on Linux software you can choose among `gedit, geany, eclipse, kdevelop` or you can specify the desired editor on a textbox. If you do not have eclipse installed on your pc through the system and want to use it, you would have to write on the text box `./<path-eclipse-application>`. the same thing you will have to do for any editor that is not installed in your system and does not appear on your application bar.

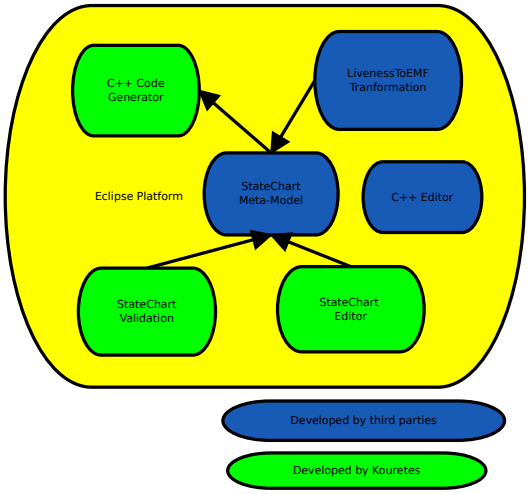

Figure A.1: Software Architecture

A.5 Design a statechart following the ASEME Methodology for Monas architecture Step By Step

First Step - Write Liveness Formula

If you want to create a new StateChart the easiest way to do it, is by writing the liveness formula according to ASEME methodology. Go to File → New StateChart → Formula. Or choose the respectively icon from the toolbar. A window appears, and all you have to do is first enter the name of the formu-

la/model in the respectively text box. Then write the Liveness Formula in the respectively text box. You should use the Gaia operators (Table A.1) in order to write the formula. After completing the above, click the OK button. You should now choose the source folder of the existing activities to connect your StateChart Model(EMF) which will be saved in your workspace, as an *.stct file. A file dialog will apear and you would have to select the folder for code generation. If your want to develop a behavior according to Monas architecture you would have to choose the `Monas/src/activities` folder for generation. The activities templates will be generated to activities folder and the statechart with its transitions in `Monas/src/statecharts` folder. Since you have chosen a folder the model is connected to a local code repository.

Table A.1: Operators for Liveness Formula(Table 1 from "THE AGENT SYSTEMS ENGINEERING METHODOLOGY (ASEME)")

Operator	**Interpretation**
x . y	x followed by y
x | y	x or y occurs
x⋆	x occurs 0 or more times
x+	x occurs 1 or more times
x˜	x occurs infinitely
$[x]$	x is optional
x || y	x and y interleaved

Second Step - Initialize and Edit the Diagram Model

After completing successfully first step your EMF Model's file is in your workspace as an *.stct file, so now you are able to initialize the model's graphical representation.

Go to File → Initialize kse diagram file. Choose the model you want to initialize click on Next button. Choose the element Model as the root element and click on Finish button. The Diagram (Graphical representation of the model) is now open on the editor.If the states are overpopulated or overlapped press ctrl+A and go to Diagram → Arrange → All, or choose the above actions from the toolbar. It is possible that you will have to arrange the diagram elements more than once. If you have followed all the steps carefully and no error has occurred, you can now add the input message variables to the BASIC states, which are unimplemented and choose from the toolbar to edit the BASIC state's activity. You can also fill the necessary transition expressions. For writing the transition's expression you need to follow the grammar's syntax. If you leave any transition expression empty, it means that it is always true. When you finish the editing of the model you can generate the C++ code for Monas architecture.

Third Step - Generate C++ Code For Monas Architecture

After finishing the editing of the model you can generate the Statechart's code for Monas architecture.

Go to File → Generate Code For Model. Or choose from the toolbar. The Diagram (Graphical representation of the model) that is now open on the editor will be generated. You should choose whether to add logger calls in transition's conditions generated code or not. It is recommended to do so, only for debugging, because logger calls increase significantly execution time. When the generation is completed you will be notified by a message.

If the statechart's activities are not implemented, you can edit their source files by clicking on the BASIC state and then go to Edit→ Edit Activity an editor will open for the class implementation.

A.6 Design a statechart from scratch - Graphically

First Step - Create an Empty Diagram File

If you want to create a new StateChart by creating the diagram instead of using the ASEME Methodology and liveness formula follow the next steps. Go to File → New → StateChart Diagram A wizard will appear and you will have to enter the filename for the diagram file and the EMF model file. We recommend you to create a new folder in your workspace for the new StateChart and save there your new diagram(.kse) and EMF model file(.stct). After completing all the steps of the wizard click on finish.

Second Step - Edit the Empty Diagram File

After completing successfully the first step your empty diagram will be opened in a new tab at the workbench of the StateChart Editor. You can now add the diagram's elements. Be careful to follow the ASEME rules so the model can be valid for the StateChart Engine of Monas architecture. For writing the transition's expression you need to follow the grammar's syntax. If you leave any transition expression empty, it means that it is always true and no action will occur. As soon as you finish the editing of the model you can connect the model to a source folder that contains the implemented activities or to the folder that you would like to be the folder of the activities. If you are creating a StateChart for Monas architecture you should choose the folder Monas/src/activities. After you connect the model to a source folder the code for the opened model will be generated to the selected folder.

Step - Generate C++ Code For Monas Architecture

After finishing the editing of the model you can generate the Statechart's code for Monas architecture.

Go to File → Generate Code For Model. Or choose from the toolbar.

The Diagram (Graphical representation of the model) that is now open on the editor will be generated. When the generation is completed you will be notified by a message.

If the statechart's activities are not implemented, you can edit their source files by clicking on the BASIC state and then go to Edit → Edit Activity an editor will open for the class implementation.

A.7 How to ...

How to configure KSE

Go to Edit → Configure KSE... and a Configuration dialog will open, choose an editor for your activities and whether you are going to use the Monas code generator or not. You can set as default generator any generator you would like, as long as you declare how to execute it. For example if your generator is in your home folder and it is a runnable jar file you have to write at the text box `java -jar home/user/generator.jar` and KSE will execute it with the models absolute path and the source code repository's path as inputs. The same declaration you would have to for the editor as well.

How to create new elements

Select the element you want to add from the palette and then select the point on the diagram that you want to put the new element. If you would like to add an transition after selecting the transition from the palette, you would have to click on the node that would be the transition's source node and drag on the transition's target node .

How to create an empty diagram

Go to File → New → StateChart Diagram.

How to create a new liveness formula

Go to File → New → StateChart Formula. Read the instructions for writing a formula.

How to Initialize a diagram for an existing .sct model

Go to File → Initialize sctd diagram file

How to open an existing diagram

Go to File → Open.. or Open URI.

How to open an existing formula

Go to File → Open Formula. BE CAREFUL if you click on OK the existing model will be overwritten. Read the instructions for writing a formula.

How to edit the elements

Edit the elements' attributes from properties view or by clicking on the visible attributes of the elements and pressing F2.

How to put automatically the nodes' label, name and transitions' name

Go to Edit → Labeling Diagram or click the respectively icon from the toolbar.

How to edit the activity of a BASIC state

Select the BASIC state you would like to edit and go to Edit → Edit Activity or clicking the respectively icon from the tool bar.

How to connect the opened model diagram to a source folder

Go to Edit → Connect Model to source folder or clicking from the toolbar.

How to generate code C++ for the opened model

Go to File → Generate Code for model or clicking the respectively icon from the toolbar.

How to zoom in or out

Go to Diagram → zoom or press Ctr+"+" for zoom in and Ctr+"-" for zoom out.

How to add rulers, page breakers or grid
Go to Diagram → view.

How to change a diagram element's view
Click on it and going to Diagram and choose the characteristic you would like to change, you can change font,line color and line style.

How to open a new window for the application
Go to Window → Open in new Window.

How to check if the StateChart is valid according to ASEME and transition's expression grammar
Go to Edit → Validate.

How to save diagram as image
Right-click on the top node of the part of the diagram you want to save as image and choosing from the pop-up menu File → save as image File....NOTE:The pdf format is unavailable, but you can save it as png, jpeg, jpg, svg, gif and bmp.

How to print the diagram
Click on the print button of the toolbar.

A.8 Transition's Grammar

This is the grammar for writing successfully a valid transition expression

TransitionExpression = [event]["[" condition"]"][/actions]
event = string
condition = expr
| expr (compOp | logicOp) condition
| "("condition")"
| notOp condition
actions = TimeoutAction
| Actions

Actions = Actions connectiveOp action
action = "process_messages"
| "publish_all"
| "publish" "." topic"."commType"."msgType"."membersetfunction"("val")"
TimeoutAction = TimeoutAction"."topic"."time
expr = varVal | func "(" args ")"
func = < *any_valid_cpp_decleared_function_name* >
| TimeoutCheck "(" topic ")"
args = varVal
| varVal "," args
varVal = message | variable | value
value = constant | stringLiteral | number+
compOp = " < "|" <= "|" > "|" >= "|" == "|"! = "
logicOp = "&&" | "||"
notOp = "!"
connectiveOp = ";"
message = topic "." commType "." msgType
variable = message "." member
commType = "*Signal*"|"*State*"|"*Data*"
host = string
topic = string
msgType = string
member = string "(" number⋆ ")" ("."string "(" number⋆ ")")
membersetfunction = string ("(" number⋆ ")" "." string)⋆
time = number +
stringLiteral = " string "
string = letter (letter | number | "_")⋆
letter = "a" | "A" | "b" | " B" | "c" | "C" | "d" | "D" | ...
number = "0" | "1" | "2" | "3" ...

Be careful, in case a message does not appear on the blackboard the evaluation of its condition becomes false. TimeoutCheck(topic) generates code for the check of TimeoutAction expiration.

A.9 Statechart's Rules

Every model that represents a statechart needs to obey some rules.

- StateChart Model can have only one root node of type OR.
- Every OR node should have exactly one START node as a child.
- Every OR node can't have more than one END nodes as children.
- A START node can only be a source node for an transition.
- An END node can only be a target node for a transition.
- An AND node can only have OR nodes as children.

A.10 Examples

In this section you can find examples of how to write a transition and how to write a liveness formula. You will also see examples of the generated code and EMF model.

A.10.1 Transition Expression Example

For the following expression the generated code will be like (Figure A.2)

```
[TimeoutCheck(behavior) &&
(behavior.State.GameStateMessage==NULL ||
behavior.State.GameStateMessage.player_state() != PLAYER_FINISHED)]
/TimeoutAction.behavior.250
```

For the following expression the generated code will be like (Figure A.3)

```
[behavior.State.HeadToBMessage.ballfound()!=0 &&
readyToKick( behavior.Data.WorldInfo )]
```

```
#include "architecture/statechartEngine/ICondition.h"
#include "messages/AllMessagesHeader.h"
#include "tools/BehaviorConst.h"
#include "tools/logger.h"
#include "tools/toString.h"
// decision_TO_decision
class TrCond_Goalie0_3_20_3_2:public statechart_engine::ICondition{
public:
  void UserInit(){
    _blk->updateSubscription("behavior",msgentry::SUBSCRIBE_ON_TOPIC);
  }
  bool Eval(){
    /* TimeoutCheck(behavior) && ( behavior.State.GameStateMessage==NULL || behavior.State.
        GameStateMessage.player_state()!=PLAYER_FINISHED) */
    boost::shared_ptr<const GameStateMessage> var_621149599 = _blk->readState<
        GameStateMessage> ("behavior" );
    boost::shared_ptr<const TimeoutMsg > msg = _blk->readState< TimeoutMsg > ("behavior");

    Logger::Instance().WriteMsg("decision_TO_decision, TimeoutCheck(behavior) && ( behavior.
        State.GameStateMessage==NULL || behavior.State.GameStateMessage.player_state()!=
        PLAYER_FINISHED)",
    _toString((msg.get()!=0&&msg->wakeup()!=""&&boost::posix_time::from_iso_string(msg->
        wakeup())<boost::posix_time::microsec_clock::local_time())&&(var_621149599.get()
        ==0||(var_621149599.get()!=0 && var_621149599->player_state()!=PLAYER_FINISHED))),
        Logger::Info);
    return ((msg.get()!=0&&msg->wakeup()!=""&&boost::posix_time::from_iso_string(msg->wakeup
        ())<boost::posix_time::microsec_clock::local_time())&&(var_621149599.get()==0||(
        var_621149599.get()!=0 && var_621149599->player_state()!=PLAYER_FINISHED)));
    }
};

#include "architecture/statechartEngine/IAction.h"
#include "architecture/statechartEngine/TimoutAciton.h"
// decision_TO_decision
class TrAction_Goalie0_3_20_3_2:public statechart_engine::TimeoutAction{
  /* TimeoutAction.behavior.300 */
  public:TrAction_Goalie0_3_20_3_2():statechart_engine::TimeoutAction("behavior", 300){;}
};
```

Figure A.2: The generated classes.

```
#include "architecture/statechartEngine/ICondition.h"
#include "messages/AllMessagesHeader.h"
#include "tools/BehaviorConst.h"
#include "tools/logger.h"
#include "tools/toString.h"
// 0.3.2.3.2TOKick
class TrCond_Goalie0_3_2_3_20_3_2_3_5 : public statechart_engine::ICondition {
public:
  void UserInit () {
    _blk->updateSubscription("behavior",msgentry::SUBSCRIBE_ON_TOPIC);
  }
  bool Eval() {
    /* behavior.State.HeadToBMessage.ballfound()>0 && readyToKick(behavior.Data.WorldInfo) */
    boost::shared_ptr<const HeadToBMessage> var_1901744185 = _blk->readState<HeadToBMessage>
        ("behavior");
    boost::shared_ptr<const WorldInfo> var_1071592760 = _blk->readData<WorldInfo> ("behavior"
        );
    Logger::Instance().WriteMsg("0.3.2.3.2TOKick, behavior.State.HeadToBMessage.ballfound()>0
        && readyToKick(behavior.Data.WorldInfo)",
    _toString((var_1901744185.get()!=0&&var_1901744185->ballfound()>0)&& readyToKick(
        var_1071592760)), Logger::Info);
    return ((var_1901744185.get()!=0&&var_1901744185->ballfound()>0)&& readyToKick(
        var_1071592760));
    }
};
```

Figure A.3: The generated classes.

A.10.2 Liveness Formula Examples

For the following formula the generated abstract model will be like (Figure A.4)

```
Attacker = Init.Play~
Play = Repulse|(AprroachBall+.Kick)
Repulse =CalculateSpeed+||(Stare+.SpecialAction)
```

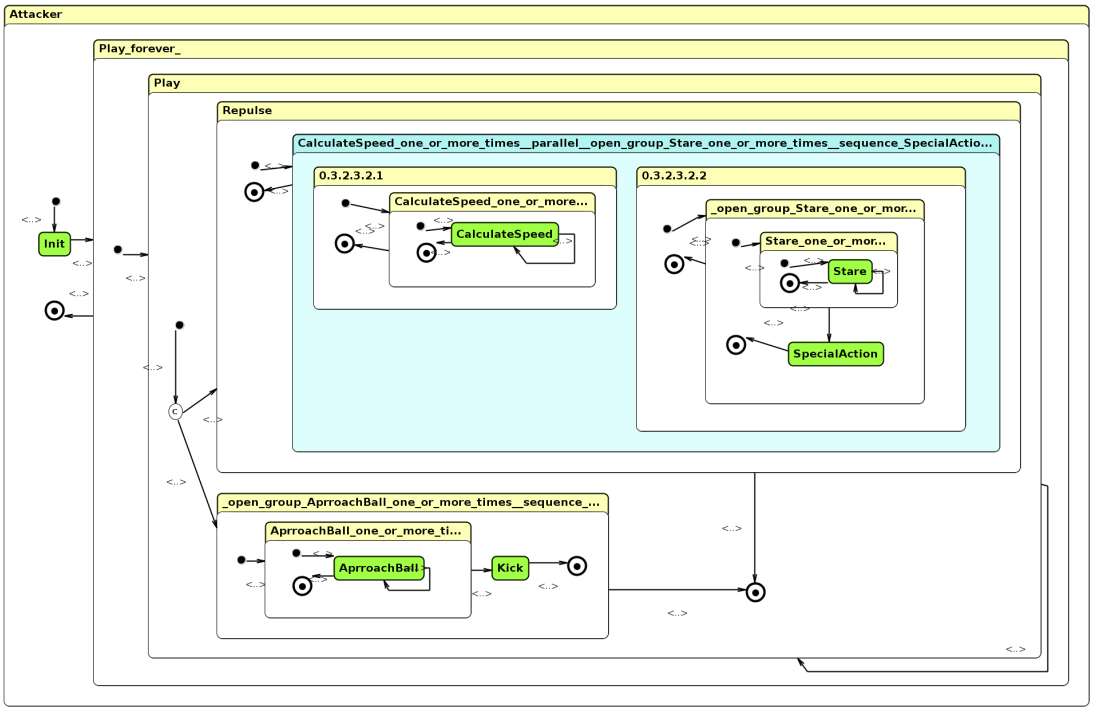

Figure A.4: The generated model for a liveness formula.