PARAMETRIC DESIGN APPROACH AND OPTIMIZATION OF ERGONOMICS FOR RESIDENTIAL-PROFESSIONAL EQUIPMENT

THESIS

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POSTGRADUATE DEGREE IN: SPACE, DESIGN & CULTURE

UNIVERSITY: SCHOOL OF ARCHITECTURE

2020

Thesis Title: Parametric Design Approach and Optimization of Ergonomics for Residential-Professional Equipment

2021

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"A chair is a very difficult object. A skyscraper is almost easier. That is why Chippendale is famous."

Ludwig Mies van der Rohe

Acknowledgements

I would like to express my sincere gratitude to:

-All the Professors of the Post-graduate programme for their contribution during the semesters.

-My Supervisor Konstantinos-Alketas Ouggrinis, his positivity & scientific curiosity inspired me to experiment and redefine my approach for this study multiple times. Also his advice was essential and straightforward.

-Mappa team: Giannis Roussogianakis, Ourania Andrianopoulou, Sofia Mavroudi & Thomas Giatzidis, for our interesting discussions in our common course.

-Dimitra Xydaki, for her encouragement & her objective criticism.

-My parents for their undivided support.

Contents

Abstract

I have always believed that the human body was made to move. Proof of this is when the absence of movement creates health problems. Besides the technological exponential growth, in the last 20 years, I have noticed that the furniture market has remained stagnant for the last decades. The design of three seating furniture is based on three basic postures of the human body: supine position, then a position similar to semi-Fowler's position and finally a perching position, a stance between sitting and standing. Also, a social-urban seating is composed by using two of the produced furniture. Analysis started with the development of a graphical algorithm where a computer tomography scan of the user's spine is evaluated with a very simple machine learning component. Parameters like height and angles of the furniture change the outcome geometry according to the user.

More specifically, sitting chairs even nowadays are more based on designing principles and norms of the past, which are proven not to be optimum for the human body. Chair-sitting is now correlated with premature death from heart attack, stroke, and cancer. Not strange that the saying: "Sitting is the new smoking" is being reproduced more and more. However, they say that "the seat isn't killing you, but how you sit it is", I actually agree up to a certain degree but the inactivity of the furniture market will not let me fully.

Once, I had found a book by Galen Cranz a Professor of Architecture at the University of California, Berkeley, I totally agreed that rethinking and redesigning the chair was totally essential and an obligation to ourselves. Especially nowadays that the majority of jobs are sedentary and all of us spend at least 6 to 8 hours in a seated position. Of course, there is no perfect posture but "the next posture is the best posture" as Peter Opsvik, said. This thesis is not an effort of reinventing the wheel, but an approach of finding a static position more suitable and optimum for the human body, where the human spine is not curved (like a C instead of its S shape) after a while of sitting.

Although this is not an architectural problem completely, but it is a design problem which affects the architectural design of accommodation to a high extent.

Sitting is the new smoking," and all the exercise in the world won't make up for sitting eight or more hours a day.
Galen Cranz

History & Evolution of Chairs

Especially in western societies all human environments are "furnished" but it was not always like that. Archaeologists discovered that chairs, stools and benches were used in Egypt, Mesopotamia in 2850 BC, where commoners and slaves sat on stools, benches or on the floor and priests & kings sat on chairs. Also, in Ancient Greece, Greek klismos which were used like a lounge chair, and in Rome where throne and klismos were also used by them. From the 16th century of Renaissance to the 17th chairs had vertical backs, hard seats and they were pretty uncomfortable for the user. Moving on to the 18th century chairs were curved and couches had soft upholstery. In the 19th century Europe and America returned to postural standards where the studio couch replaced the settee seat. The 20th century was not particularly body conscious but instead it was mostly an experimentation era, as a result the seats cut under the thighs (there is not space for gluteus maximus) and forced the sitter to slump. Some eastern societies started much later from the western to adopt the "tyranny" of the chair, because even nowadays they prefer to sit on the floor. There are many cultures where people live and work without using chairs, even nowadays. Sitting is tiring and mostly it is stressful for the human nature. Truly deloading and rest is not possible in a chair of today, because it pushes the body organs inside. However, lying on a hard planar surface where the ribcage expands making room for the organs and enabling the disks between vertebrae of the back to plump up can be relieving .[3]

The well-known cultural anthropologist A. L. Kroeber once remarked that "posture is one of the most interesting matters in the whole range of customs." The human body is capable of more than 1.000 steady body positions according to Gordon W. Hewes General Anthropologist [1]. The human posture right now is a cultural norm which we were trained from children that it is comfortable despite the fact that it is not even though we think that it is. Before the 20th century, chairs did not have a serious imprint to human health because people sat on them only for special occasions, now people sit all day which is quite physically and psychologically harmful for the human nature. Even in the 21st century the majority of designing is based on status display instead of ergonomic feature.[3]

Image 1a| Chippendale chair (18th century).

Image 1b| [3] Greek klismos chair.

Back in 1997, a study by Volinn E. with the title “The Epidemiology of Low Back Pain in the Rest of the World: A Review of Surveys in Low- and Middle-Income Countries” ends up with the conclusion that low back pain (LBP) prevalence may be on the rise among vast numbers of workers as urbanization and rapid industrialization proceeds [54]. More specifically he mentions that the rate of lower back pain is 2-4 times higher among Swedish, German, and Belgium general populations than among Nigerian, southern Chinese, Indonesian, and Filipino farmers. This case makes a very clear point which can be confirmed today [54].

Image 2|Ubong tribesmen,Indonesia.

This brings me to Gokhale E. where she claims that our S shaped spine is the result of the western lifestyle, instead of the J shaped spine which is maintained in rural communities. Factors which have contributed to that “mutation” can be horse riding and later sitting. A very interesting point from Dr. Turchaninov R. is made where he compares the two spine arrangements. The typical S shaped spine absorbs the vertical load by the curvatures putting pressure in spinal nerves leading to disc herniation. On the contrary the J shaped spine absorbs the vertical load by the discs , distributing the load more evenly and less threatening to the body.[61 & 62]

Image 3|Greek statues.

This J shaped spine can be observed in Greek statues, in young children and in non-industrialized communities.

According to Jackson & McManus, curvature in the upper lumbar indicative of an S-spine shape was correlated with increased back pain, while curvature lower down which indicates a J-spine shape was not [55].

A typical spine nowadays curves at the top and then back again at the bottom. While sitting the bones must receive the load and transfer it down to the seat. Nowadays this is not possible in most cases, because of the geometry most seating furniture have. As a result, the average person ends up sitting on coccyx instead of ischial tuberosity.

One reason chair designers design so many crazy, different chairs is that subjective measures of comfort are extremely unreliable. This is another way of saying that people do not know what comfort is. One person can say what he thinks is comfortable, but invariably it will be different from what someone else thinks . Furthermore, what a person says is comfortable one day will not necessarily be what the same person says is comfortable the next. Frederick Matthias Alexander had a term for this effect: “debauched kinesthetic awareness”. The term refers to a person’s inability to tell what is going on in his or her own body because years of improper use have made it impossible for him or her to read internal feelings accurately [3].

Shoes come in different sizes but chairs do not, they are the same for everyone. Custom made chair & alteration of sitting posture must occur for maximum and true comfort for the human body.[3]

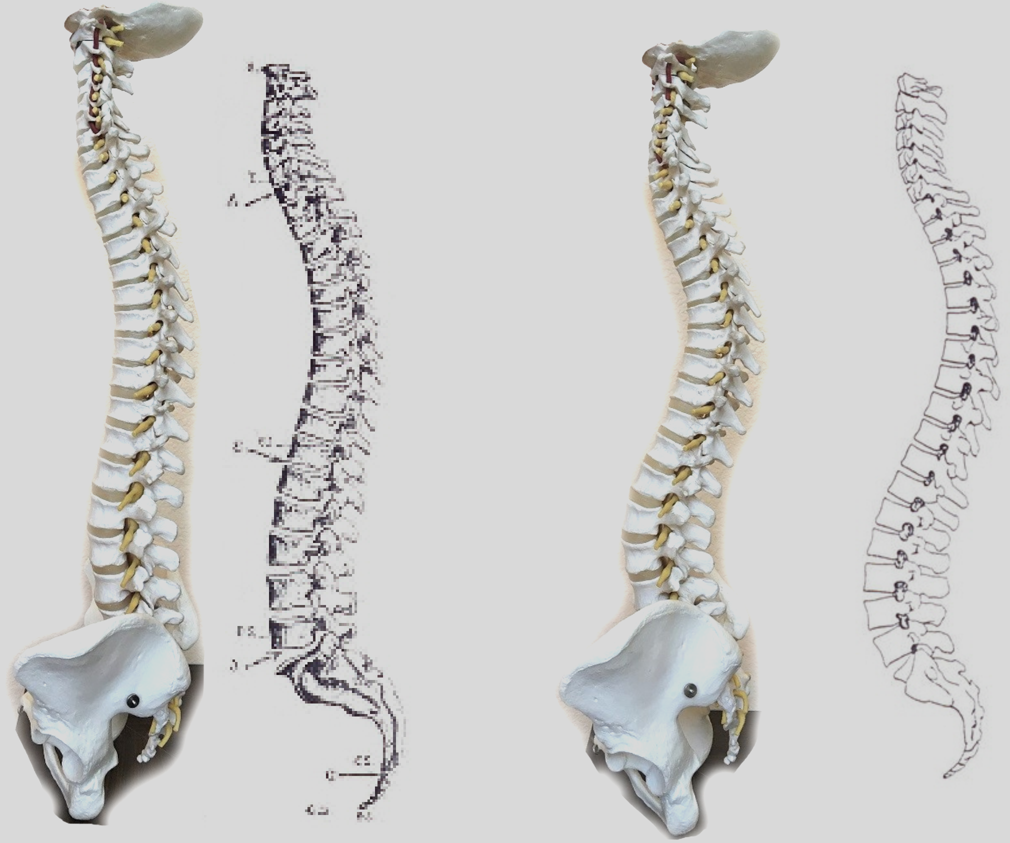


Image 4| [61 & 62] J shaped in comparison with S shaped spine.

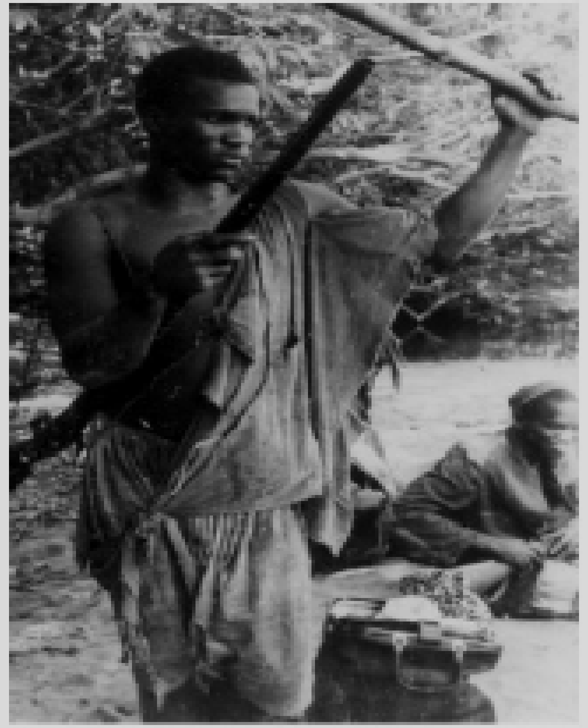


Image 5| [3] Guinea 1965-66. The man with excellent physiological development never sat in chairs as a youth. Photo by Helen Lightowlers Giovine.

Arched or Flexed?

There has been a controversy in the research literature over whether it is better to sit with a flattened/flexed or an arched/extended back.

Adams and Hutton in 1985, argued that flexed postures are advantageous, since flexion results in increased fluid flow and improved transport of nutrients into the intervertebral discs.[51]

However McGill in his in vivo study in 1992 showed that sitting with the back slouched for as little as 20 minutes can result in increased laxity of the posterior spinal ligaments (27 male and 20 female subjects). It may take 30 minutes or more for these ligaments to regain their previous level of stiffness. This research also showed that lumbar disc herniation may result from prolonged sitting in the typical flexed posture.[52]

Hedman and Fernie in their study in 1997 supported the lordotic position for sitting as preferable since such a posture helps to balance the loads on various spinal structures. This was an in vitro study in which 12 lumbar spines (L1-S1) were subjected to constant loading conditions while in flexed and extended seated postures. The specimens were loaded for 30 minutes with 500 newtons and forces on the anterior column and the facets were measured. Forces on the posterior ligaments, the disc shear and the facet impingement forces were computed via a quasi-static analysis from the data.[53]

Hedman and Fernie concluded that the “minimization of disc shear, tolerable levels of ligamentous tension, lower disc loads and a balancing of facet impingement and articular fact forces were found to be characteristics of prolonged erect sitting in this study”. “Based on these results, one would expect that the extended seated posture would reduce exasperation of tissues as compared to flexed postures.” They also concluded that the increased progression of forces in the tissues of the lumbar intervertebral joints in the flexed seated posture would likely result in increased degenerative changes in these joints.[53]

Although the vertical creep displacement was greater in the extended seated posture (3.22 mm versus 2.11 mm), the escalation of forces was more severe in the flexed posture. Disc shear force appears to dissipate to zero in the extended posture, whereas in the flexed posture it is much larger and increasing over the period of static loading. The conclusion to be drawn from this study is that the lordotic/extended position should be preferred for sitting over the flattened/flexed posture. It is interesting to note that in the study by Magora in 1972, people who rarely or never sit while on the job had the highest incidence of low back pain followed by those who predominantly sit, whereas those who sit frequently for a brief period have virtually no problem with low back pain.[53, 56]

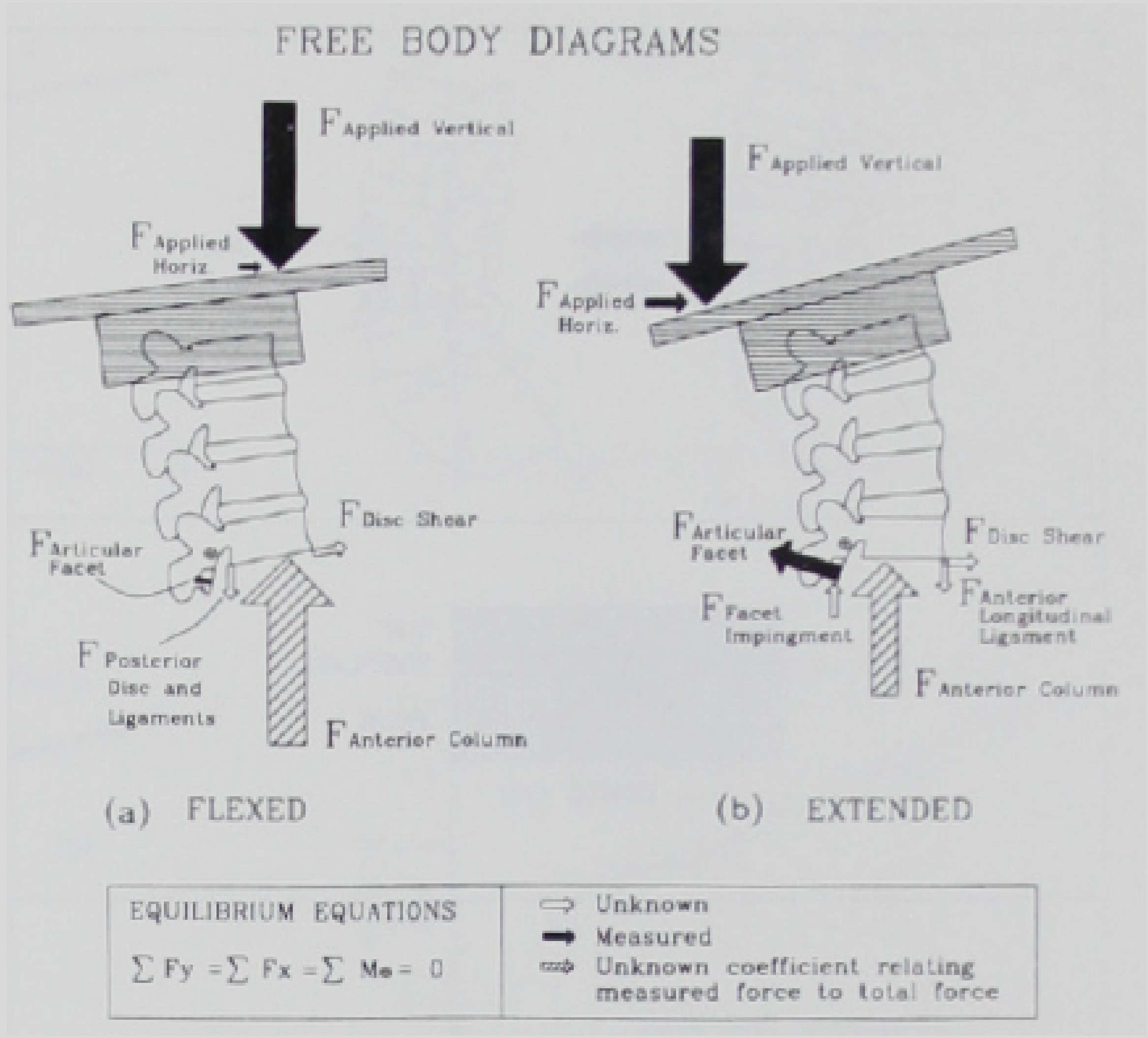


Image 6| [53] Schematic representation of principal component forces in the (a) flexed and (b) extended seated postures of these in vitro experiments. Only a part of the test specimen (L1-S1) is included in the diagram. A quasi-static analysis using the three equations of motion associated with each posture was used to compute each of the unknown forces.

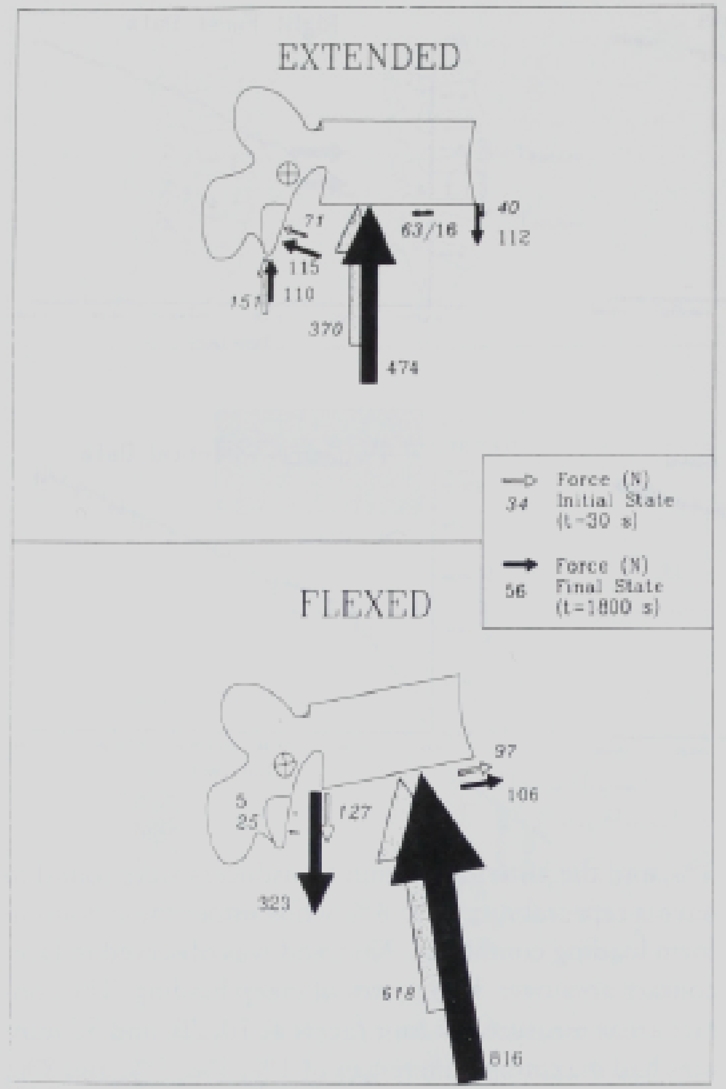


Image 7| [53] Schematic representation of principal component force progression over 30 minutes of static creep loading in two seated postures.. Disc shear force increased 9% in the flexed posture and decreased 75% in the extended posture.

The Alexander Technique

The Alexander Technique, was created in 1890 by the Australian Frederick Matthias Alexander, to retrain habitual patterns of movement and posture.

As G.Cranz states, “Standing tires the legs, and sitting tires the back, but halfway between sitting and standing is perching. This halfway posture is what Alexander called the `position of mechanical advantage,’ and what martial arts students recognize as the “horse stance”. This is what happens to your legs when you are floating in space, NASA calls it the neutral body posture (NBP) because it is when the muscles are the most relaxed. The angles regarding the spine are 128+-7.2 degrees between torso & thigh, 133+-8.4 degrees between thigh & calf, any deviation from those degrees of alignment, can increase the risk of spinal pain & injury.[4]

This posture offloads musculoskeletal stress and reduces pressure on the diaphragm and spine. Neutral body posture supports the natural curvature of the spine. A neutral spine that is not experiencing mechanical stress will curve inward at the neck (cervical region), outward at the upper back (thoracic region), and inward at the lower back (lumbar region).[64]

The advantage of the perching posture is that it distributes the loads evenly throughout the whole torso. A simple rule when you are sitting, is to detect where your knees are in relation to your hips. If your knees are below your hips, it is less possible to slouch or slump and bend to a C shape.[4]

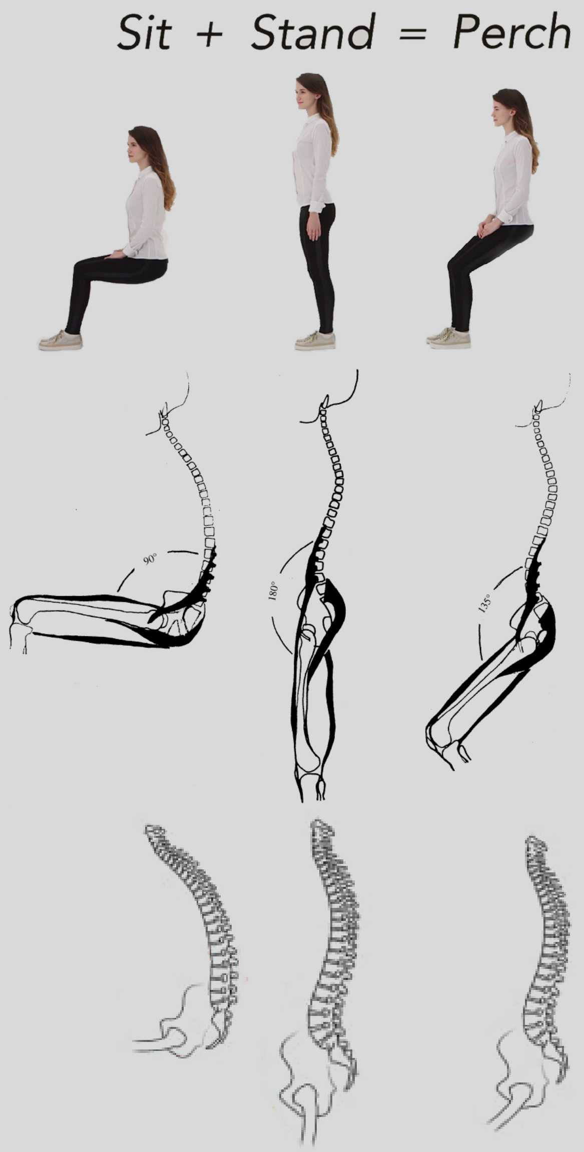


Image 8| [4] In the perch, halway between sitting and standing, the lumbar curve is retained automatically. Drawing by Denise Hall.

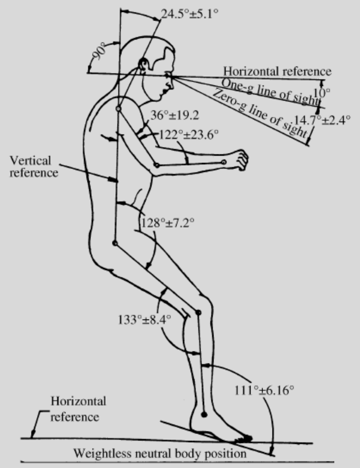


Image 9| [4] The position of the body in zero gravity, sometimes called astronauts’ position or neutral body posture(NBP). Drawing by NASA (National Aeronautics and Space Administration, USA).

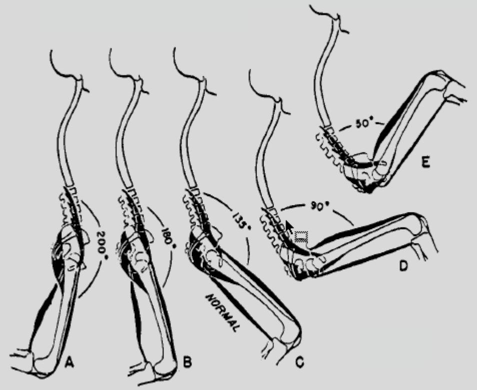


Image 10| [8] Effects of altering the thigh-trunk angle in the lateral recumbent posture.

Image 11|Flexed, Extended & Neutral seating positions.

The human spine is composed of 33 vertebrae (Images 13 & 14): 24 pre-sacral vertebrae (7 cervical, 12 thoracic and 5 lumbar) the sacrum (5 fused vertebrae) and the coccyx (4 fused vertebrae). The spine is the column where our loads (Table 1) are being distributed, the mentality which is going to be analyzed is that sitting back must have a similar topology with the curvature of the human spine & trunk-thigh angle must be in a specific range for an ergonomic outcome. There are many polynomial functions for the average adult curvature but this is not the point, neither a finite element analysis (f.e.m.) of an average adult human body would be helpful for the final form. The goal of this mentality will be approached by using a computed tomography scan from an average adult male spine. In addition to this, the algorithm is constructed in the environment of Grasshopper (plug in of Mcneel's Rhino) where plugins such us Medical 3d, Pufferfish, Milipede etc were also used.

First of all, a computer tomography (ct) scan (.nrrd file) of a male with a neutral spine is inserted in Rhino and a mesh is extracted with Medical3d (plug-in for Rhino). Analysis of the spine is focused only for the side view of the spine so lordosis and kyphosis can be detected but scoliosis will not be considered. After that, a curve extraction(Image 15) of the mesh is completed, and divided into Cervical, Thoracic and Lumbar segments (Image 16) according to Arvid Frostell, Ramil Hakim, Eric Peter Thelin, Per Mattsson and Mikael Svensson (Table 2). In stage 3, (Image 10) detection of possible lordosis or kyphosis and in which degree it is completed. Calculation of Cobb angles will be helpful, Thoracic Kyphosis angle (TK) and Lumbar Lordosis angle (LL). TK angle is measured between T4-T12 vertebrae & LL angle between L1-L5 vertebrae (Images 17, 18 & 19).

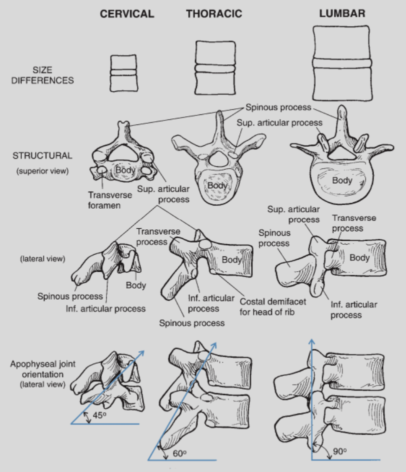
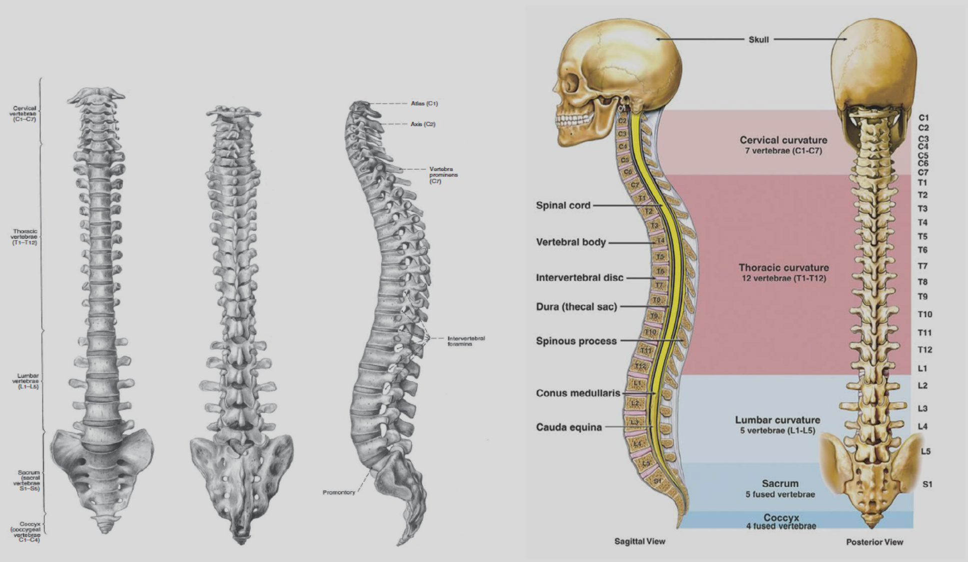


Image 12| [19] Vertebrae parts



Images 13 & 14| [19] Parts of the spine.

Body part	Mass kg
Head	4.42
Neck	0.88
Torso	18.00
Upper arm	6.67
Forearm	2.74
Thigh	15.07
Lower leg	6.65
Foot	2.14
Pelvis	10.24
Viscera (total)	8.00
Lumbar spine (total)	0.17
Sum	74.97

Table 1| [12] Mass of each body part.

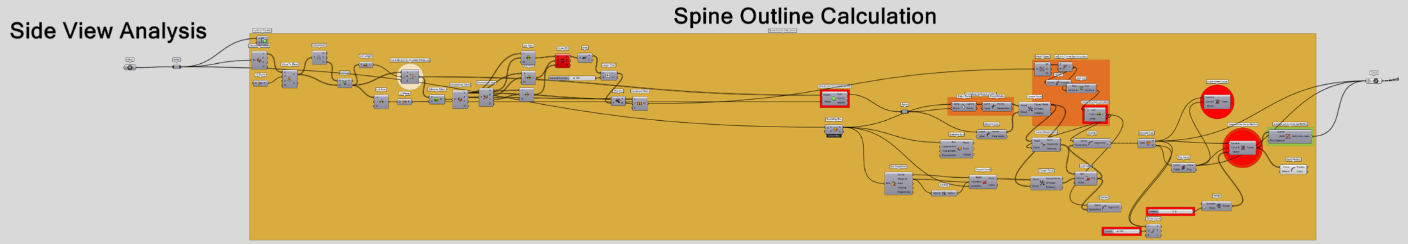
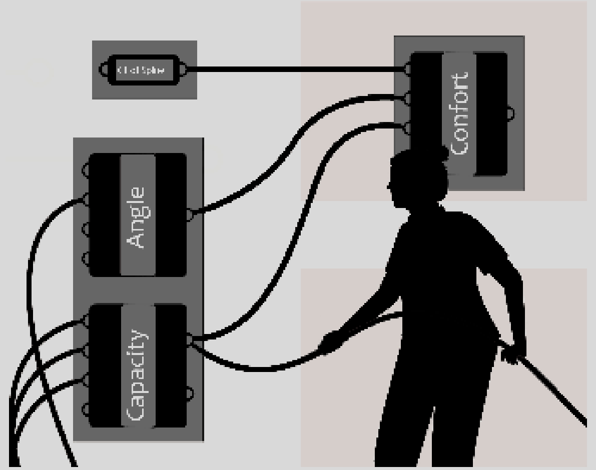


Image 15| Curvature of inserted spine.



Segment	Percentage of vertebral column	Cumulative percentage of vertebral column
C1	3.2[a]	3.2
C2	3.2[a]	6.4
C3	2.8	9.1
C4	2.7	11.9
C5	2.7	14.6
C6	2.6	17.2
C7	3.1	20.2
T1	3.4	23.6
T2	3.7	27.3
T3	3.7	31.1
T4	3.9	34.9
T5	3.9	38.8
T6	4.2	42.9
T7	4.3	47.3
T8	4.5	51.7
T9	4.6	56.3
T10	4.8	61.2
T11	5.1	66.2
T12	5.4	71.7
L1	5.7	77.3
L2	5.8	83.1
L3	5.7	88.8
L4	5.7	94.6
L5	5.5	100

Table 2| [10] Relative lengths of human vertebral bony segments.

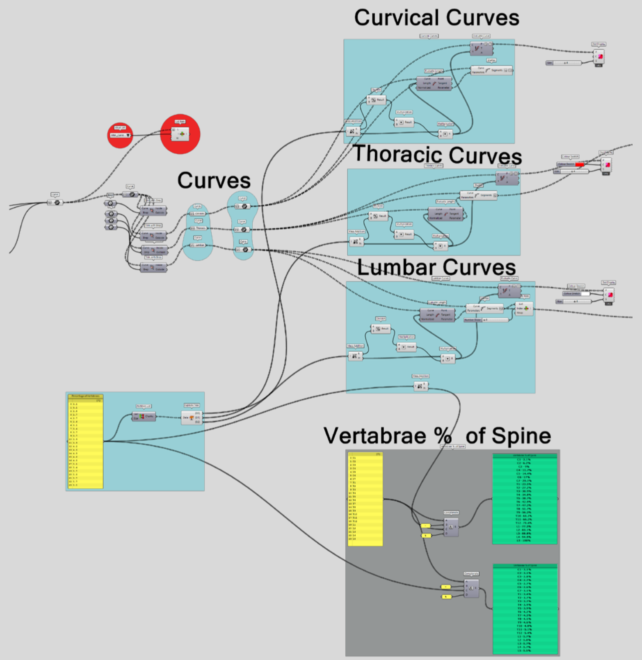
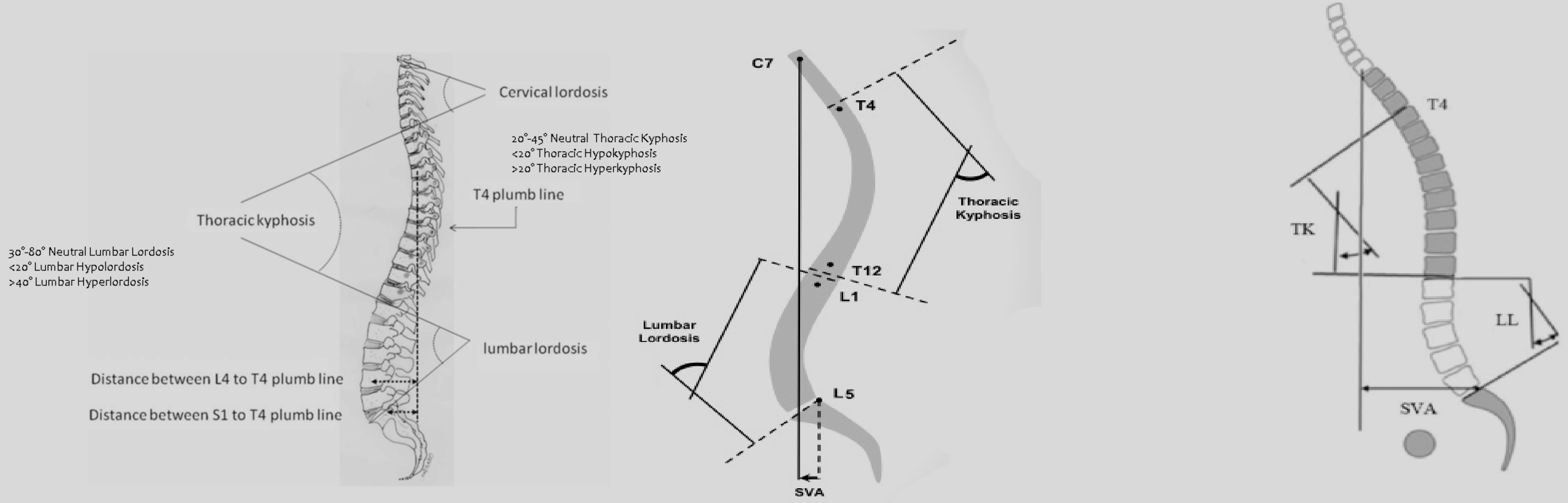


Image 16| Curve is separated in Curvical, Thoracic & Lumbar curves.



Images 17, 18, 19| Schematic explanation of TK & LL angles calculation.

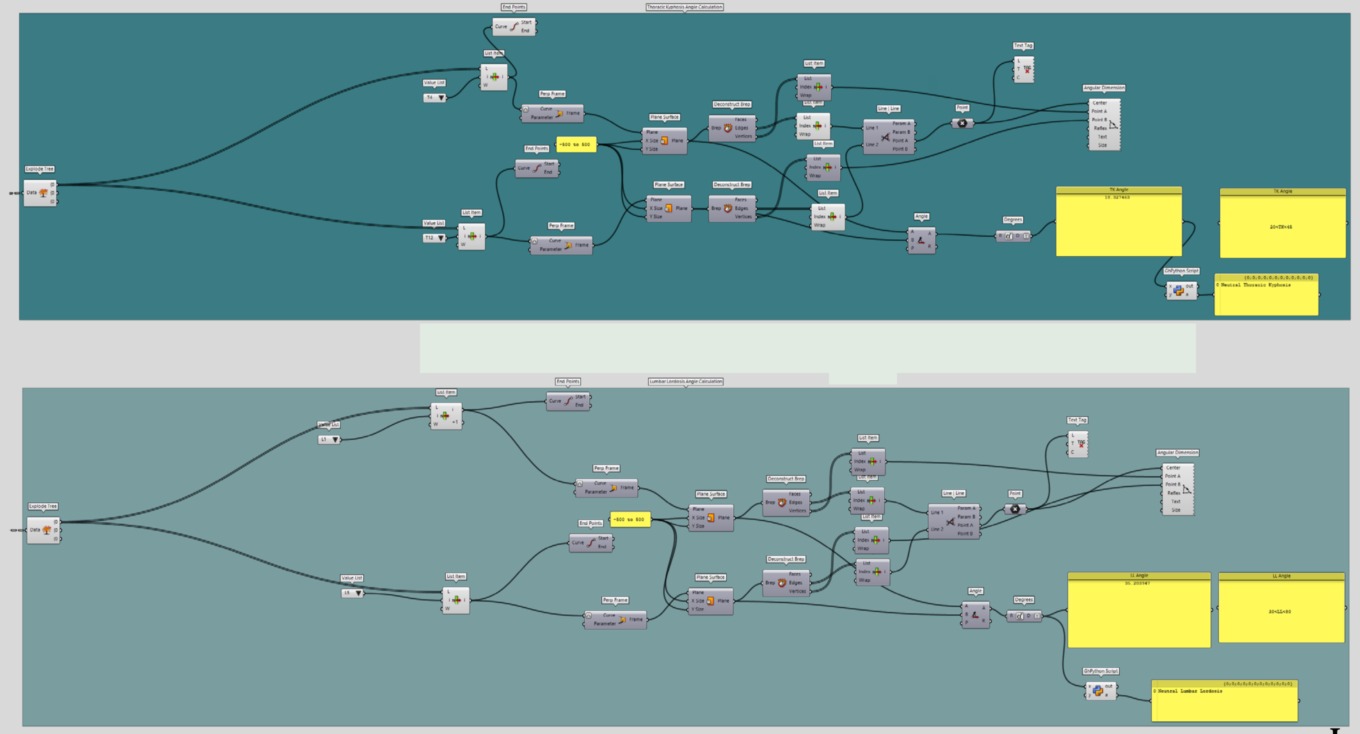


Image 20| Calculation of TK & LL angles.

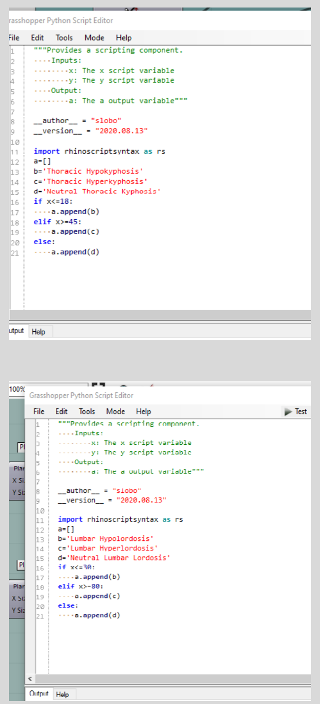


Image 21| Python scripts with the use of conditional statements for spine characterization.

Stage 3, notes that TK & LL angles are in desirable ranges and the input spine is characterized as neutral. In stage 4 curve is being rebuilded (image 26) in a 4th degree curve of 73 cm length (from C1 vertebra to the end of coccyx).

Modularity, Computational Design, Parametricism and now Artificial Intelligence a science which blends statistical principles with computation is a new approach that can improve over the drawbacks of parametric architecture which could not be skipped. Machine Learning (ML) techniques support design optimization and creates a variety of designs for the designers in a short amount of time. Stage 5 takes (image 26a) into account of ML not in a designing perspective but as an evaluation tool, where the input geometry will be characterized from a simple algorithm of Lunchbox plug-in, as neutral, kyphotic or lordotic spine. An additional check after stage 3 where other parameters are considered, such as length, vector and area of the closed curve for the training of the model.

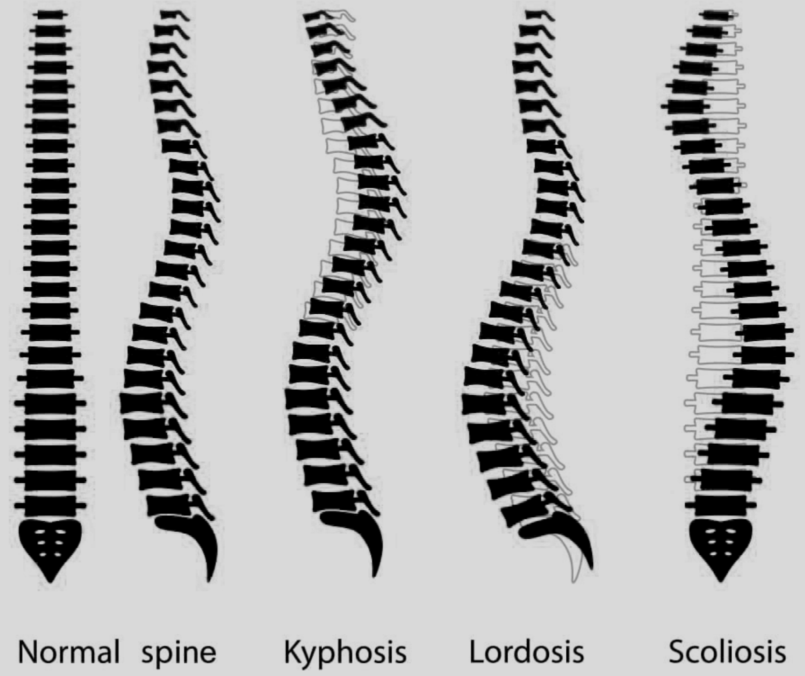


Image 22| Different conditions of human spine.

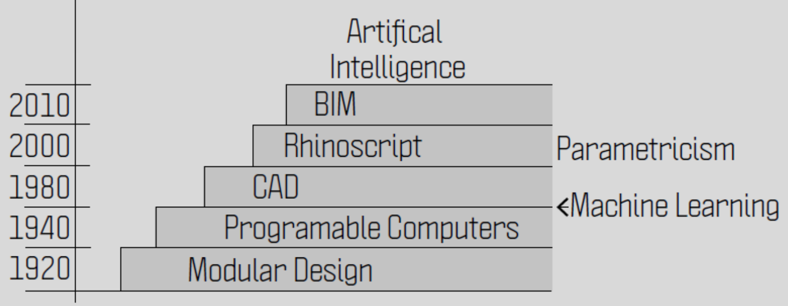


Image 23| [23] Movements of architecture design throught the years.

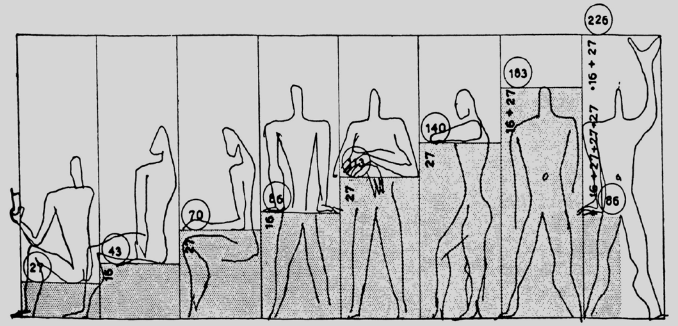


Image 24| [23] Le Corbusier: Modular Man,1955.

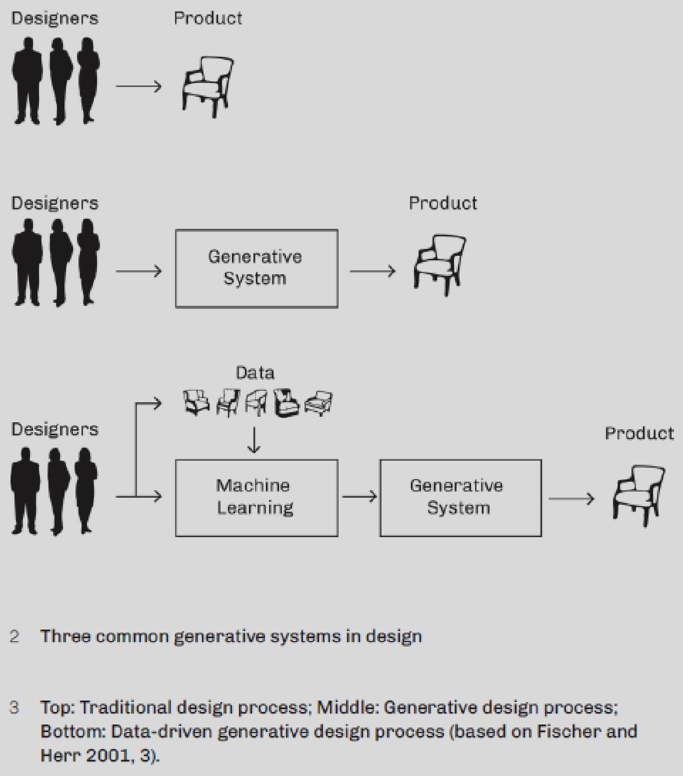


Image 25| [16] Traditional,Generative & Data-driven design process.

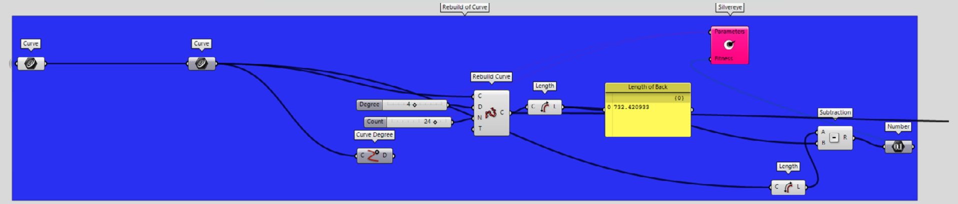


Image 26|Curve is rebuilded.

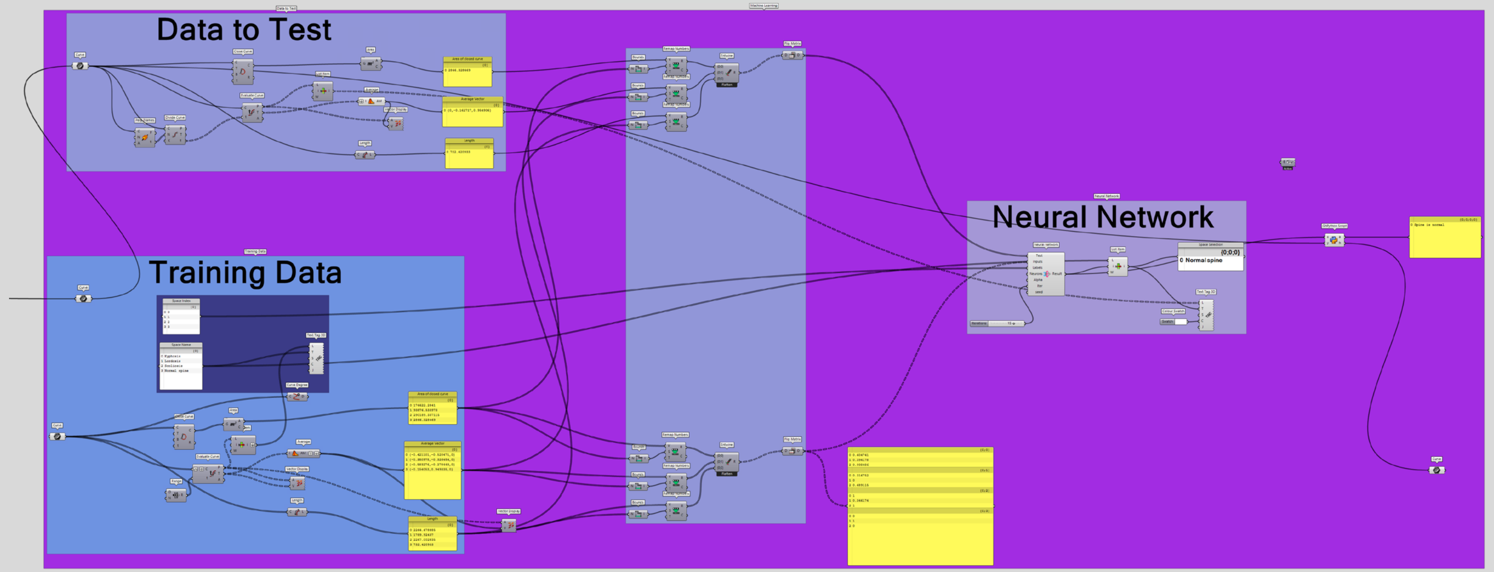


Image 26a| Machine learning component which characterizes input spine taking into account more criteria for more precise decision outcome.

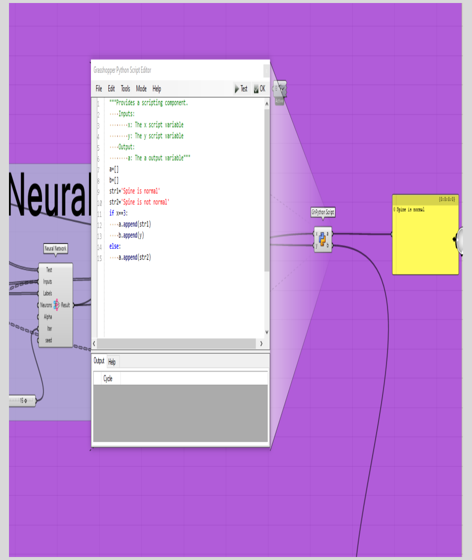


Image 26b|Python script with conditional statements.

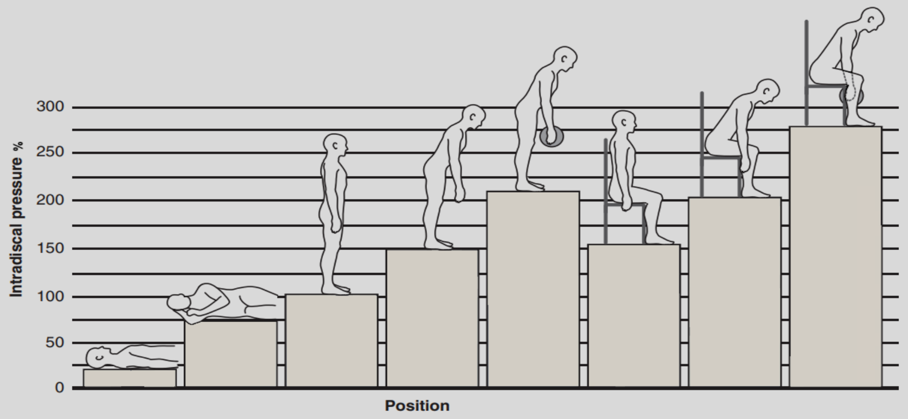


Image 27| [19] Intradiscal pressure percentage of each position.

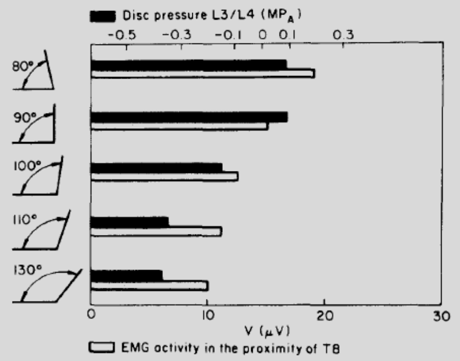


Table 3| [2] Disc pressure and electromyography (EMG) of back muscles in relation to different inclinations of the backrest.

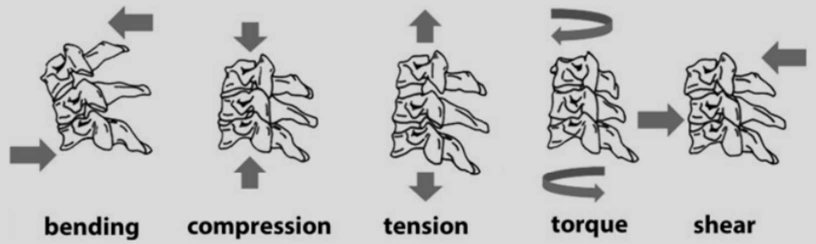


Image 28| [12] Possible loading of the vertebrae.

The next stages focus on the composition of the seatings where three (3) stances are created with the same designing principles.The first analysis creates a seat similar to supine position, then a position similar to semi Fowler's position and finally a perching position (image 8, 9 & 10), a stance between sitting and standing. In stage 6 (image 30), three angles will be adjusted in particular ranges for the required ergonomic outcome. First the angle between the trunk & thigh (T-T), will take values from 120° to 135 °. After the angle between the thigh and the calf, (knee angle), will take values from 130° to 145 °. Finally, the neck/head angle , will take values from 0 ° to 24 °.

In stage 7 (image 32) seating composition will take place where the user decides the form of the final outcome. Form of the three furniture is finalized and in stage 8 (images 33 & 35) a fem analysis is conducted to observe and inspect the right distribution of the moments (images 36 & 37) and material's durability (wood).

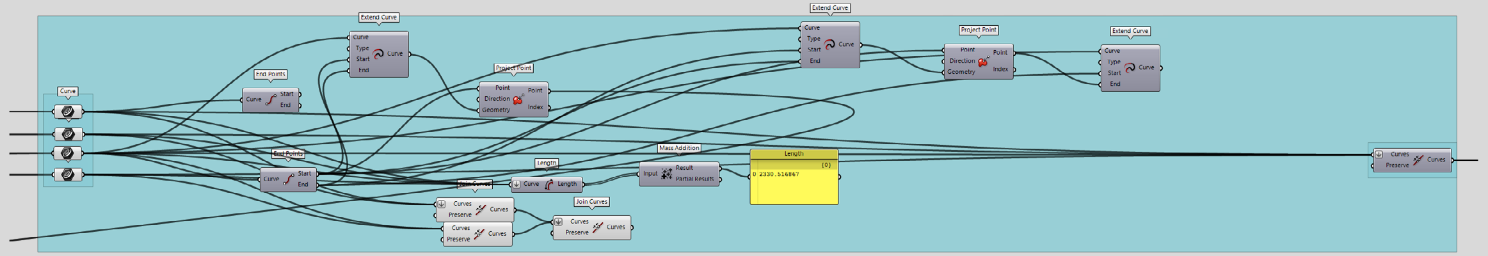


Image 29|Basic curves of the furniture composition.

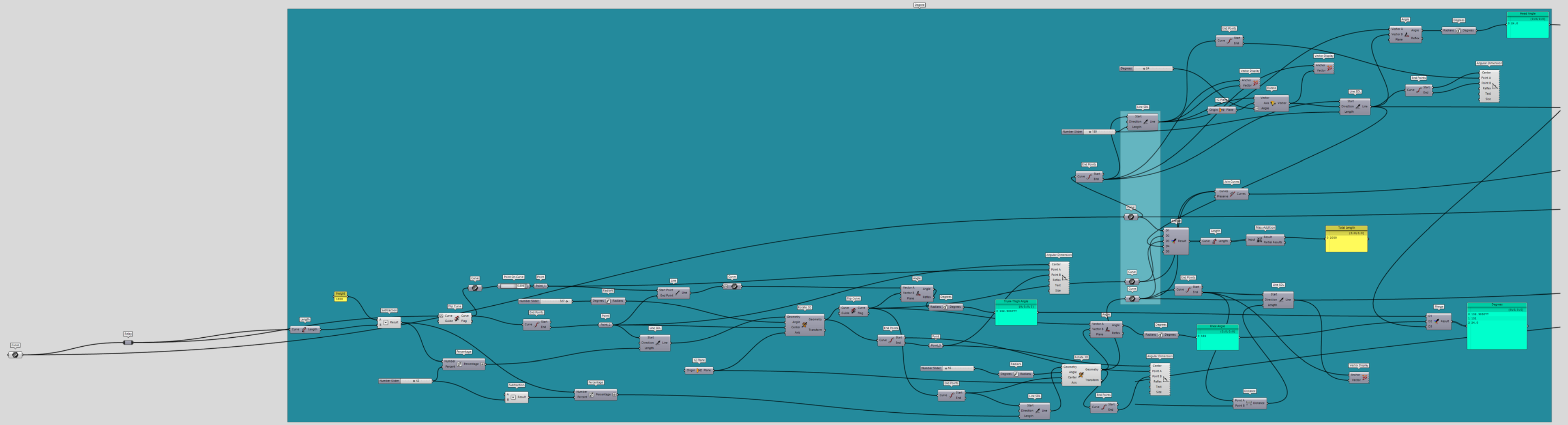


Image 30|Setting range of trunk-thigh,knee & neck angle.

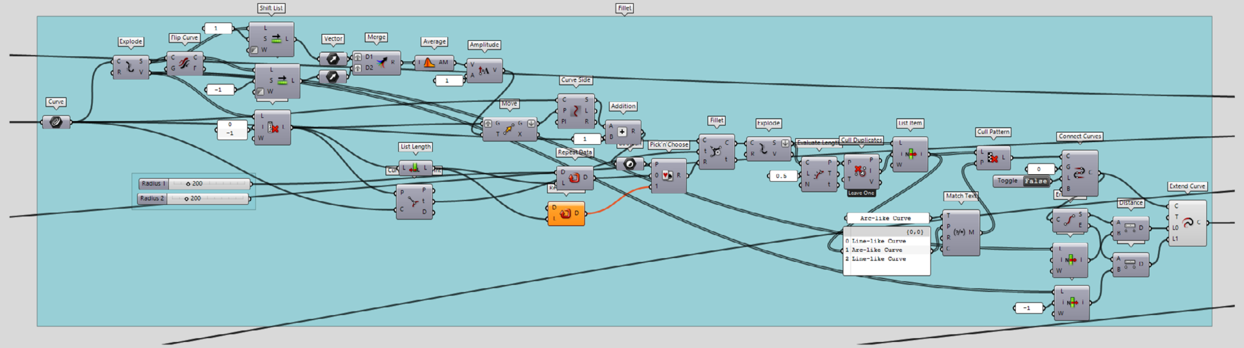


Image 31|Fillet of composition curves.

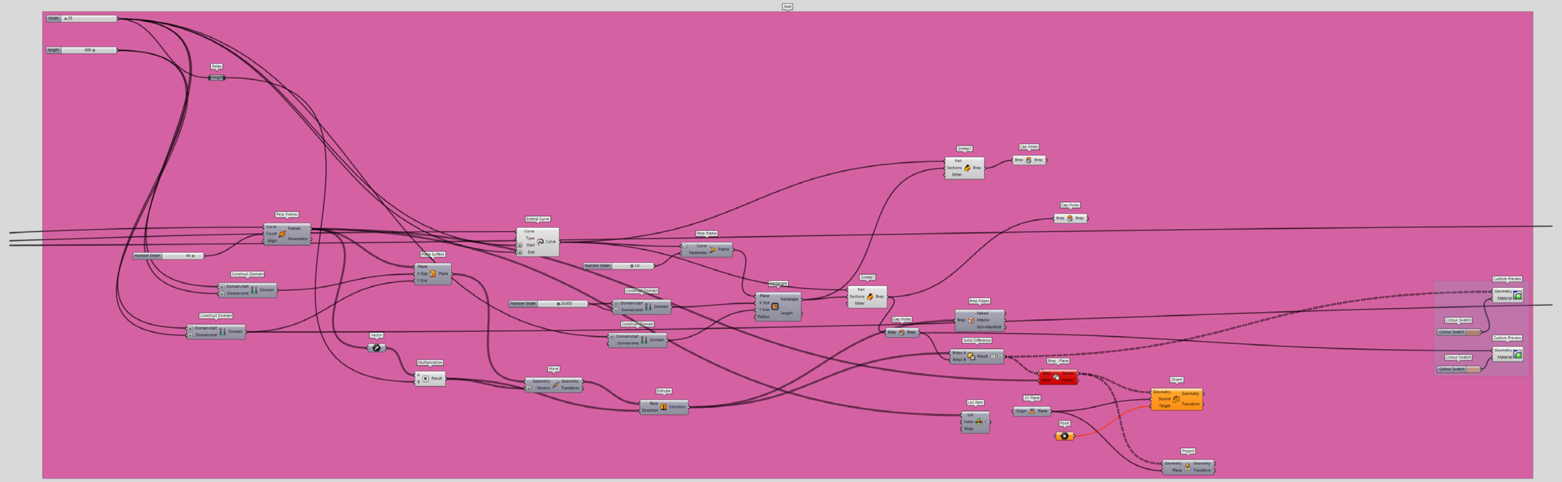


Image 32|Setting the geometry of the furniture.

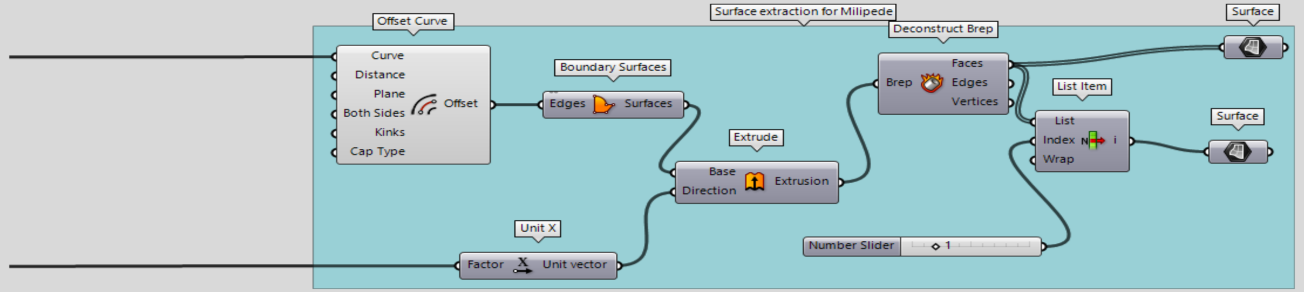
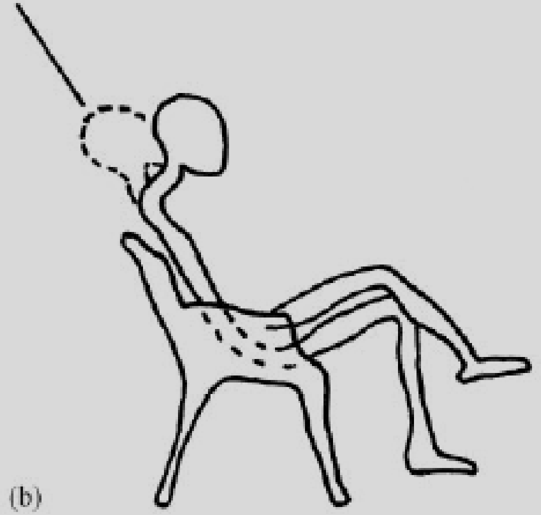
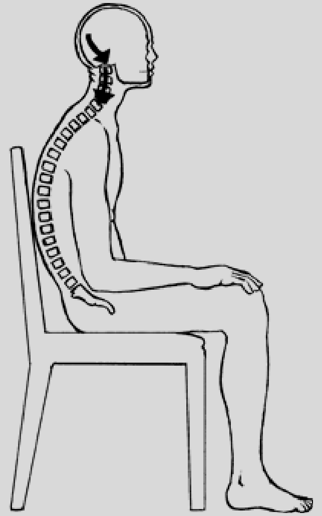


Image 33| Extraction of the final surface for Milipede FEM analysis.

In image 34 (a & b), is a chair from the AT&T lobby in New York City in 1988. The seated man is slumping creating a C shape spine. This happens because if he followed the geometry of the chair then he would place a tremendous stress on to his neck. So, he chooses to sit in a position where the stress is less. This results in bringing his head forward and flexing his spine (image 34c).[3]

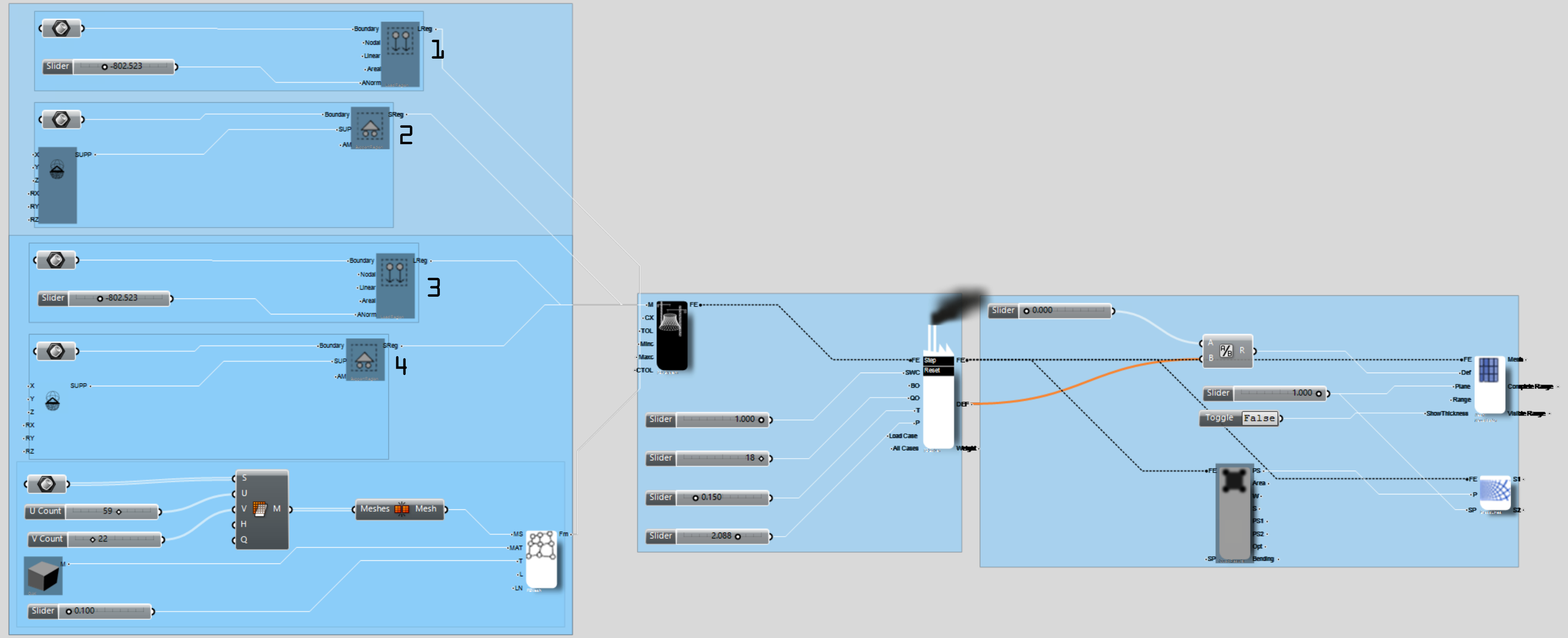




In a drawing by Don Jacot (image 34c) it is obvious that the right angle seated posture encourages slumping, and in order to see while slumped, the head rotates back in relation to the top vertebra (c1 atlas), exerting a downward pressure on the spine.[3]

Image 34 (a&b)| [3] |The chair itself causes back problems.

Image 34c |[3]



MATERIAL: OAK, E=10GPA, N=0.2 & P=713,801KG/M^3

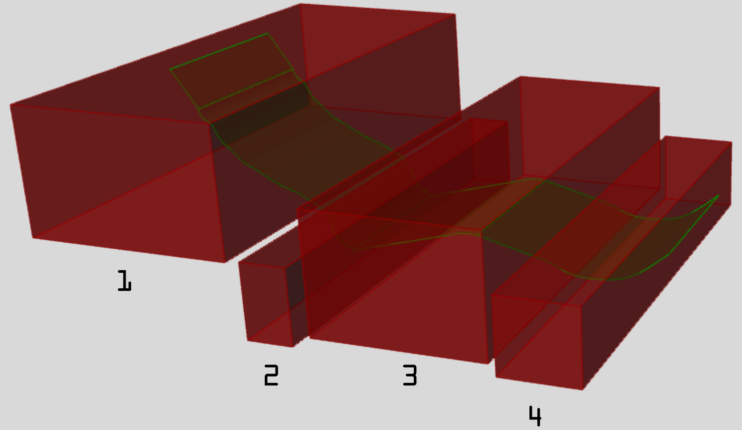


Image 35|Milipede Fem components for each furniture with loads, supports & materials.

Script of the Designing Procedure

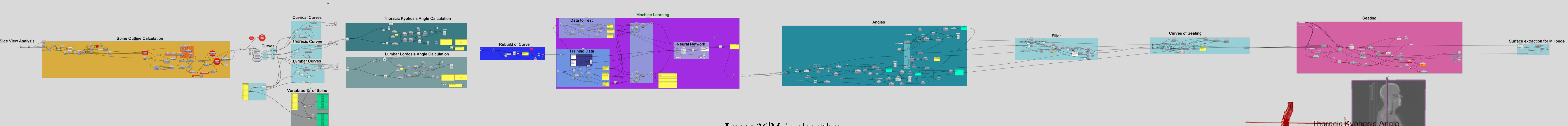
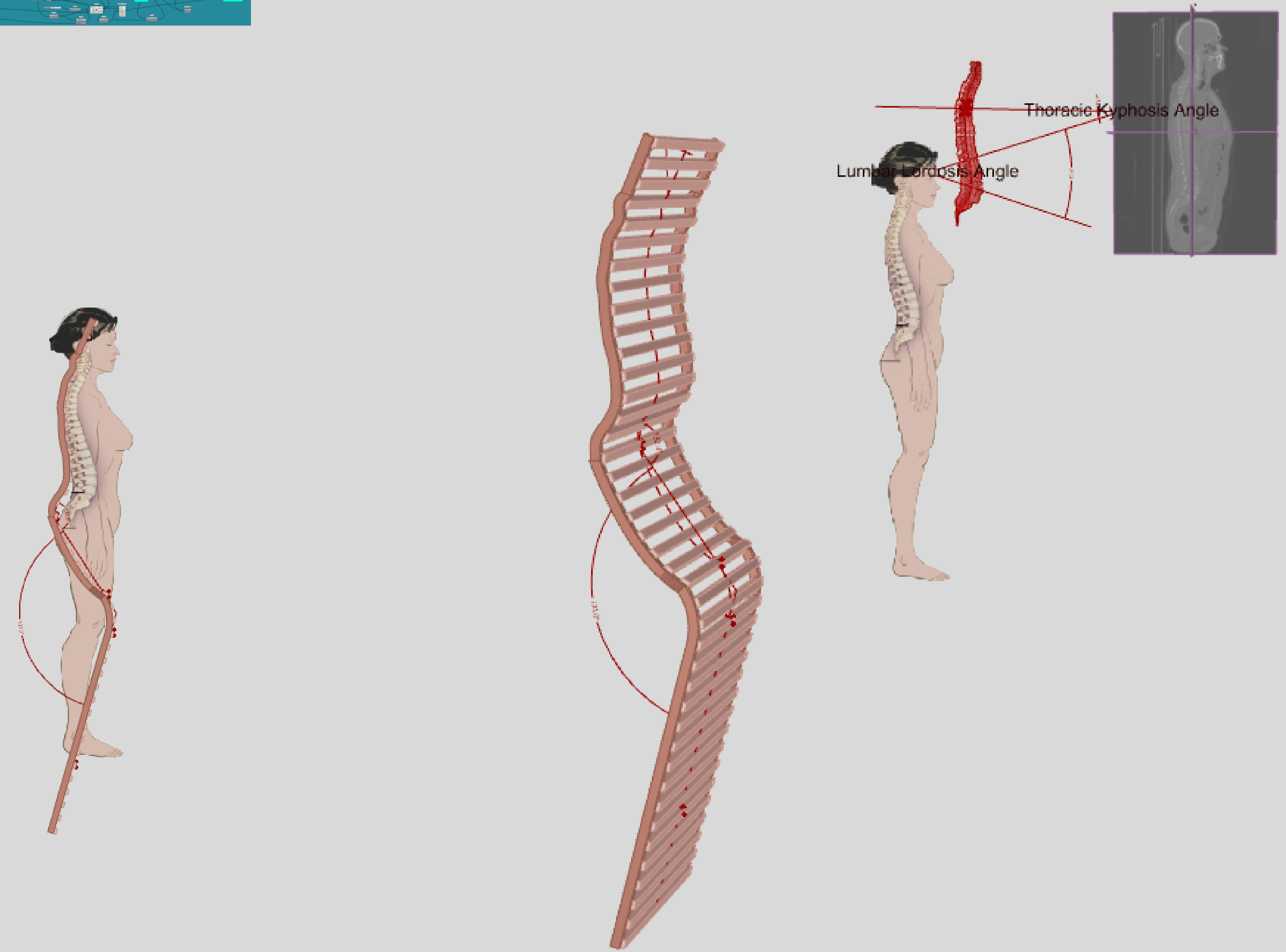


Image 36|Main algorithm.



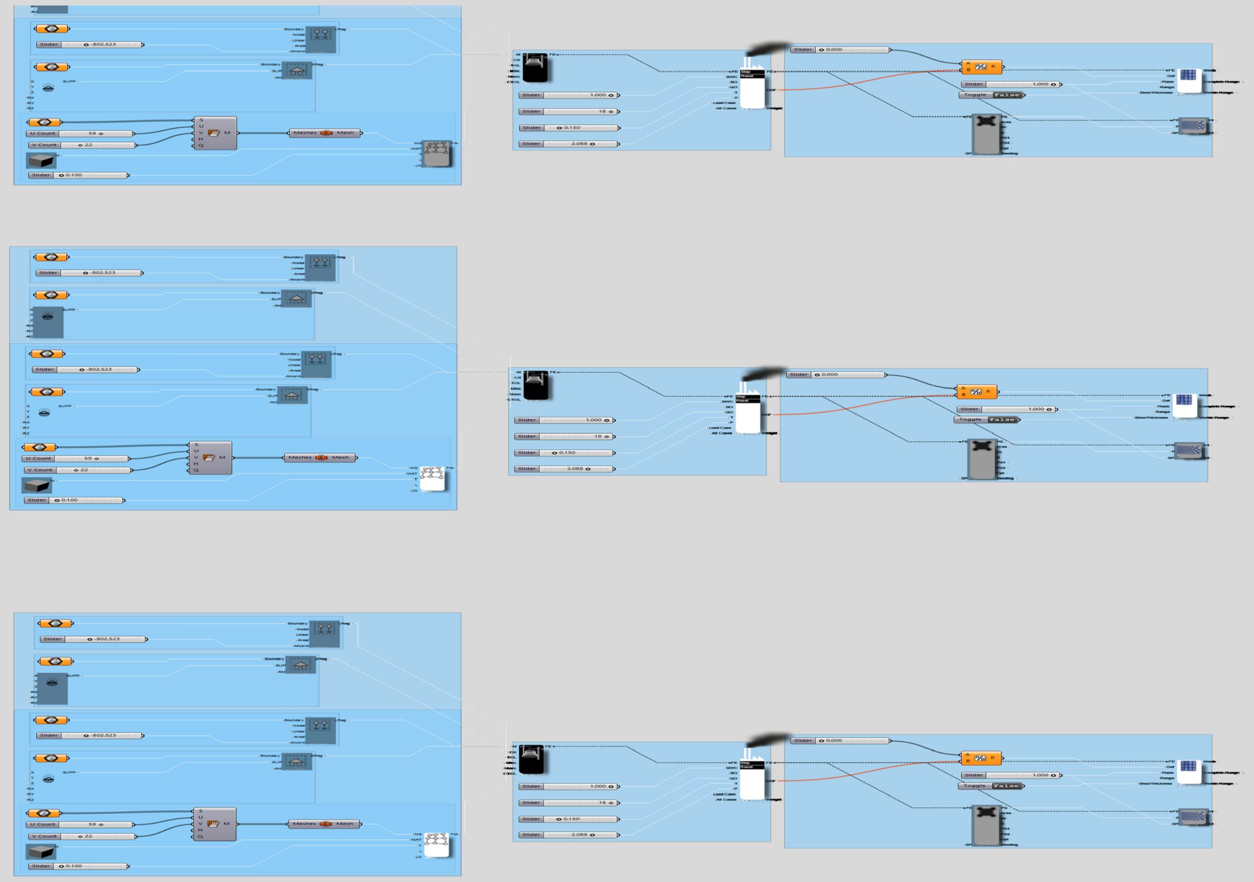


Image 37a|Calculation of Moments via milipede components.

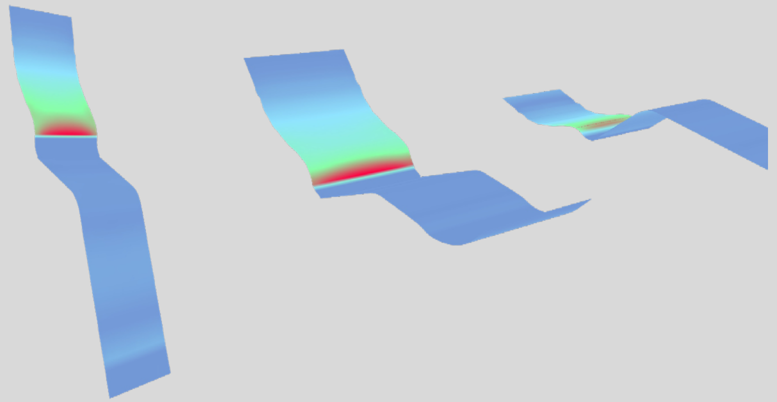


Image 37b|Moments Distribution.

Furniture of the 20th Century

Image 38|Gerrit Thomas Rietveld chair (1918-1923).

Most people might assume that the famous Reitveld (image 38) chair is uncomfortable, but it can be more comfortable than a modern chair, because of its planes serve the structure of the body, rather than its surface sensations.[4]

Le Corbusier's chaise longue (image 39) is also good because of its planar surfaces, and the open angle between trunk and thigh, but it is no longer a chair, strictly speaking.[4]

Image 39| Le Corbusiers chaise longue (1928).

Image 40| Barcelona Chair by Ludwig Mies (1929).

Barcelona chairs (image 40), became a classic of 20th century furniture design, it was made by the German designers Ludwig Mies van der Rohe and Lilly Reich in 1929 for the king and queen of Spain to sit in. It hit the mass market in the '50s.

The basic designing "mistakes" of many famous mid century modern chairs are: The backrest is too far from the edge of the seat so this causes the legs to stick out straight. Also, the seating is too deep & too soft.

Image 41| Gio Ponti chair (1956).

Image 42| Gravity balans chair rocker by Peter Opsvik (1983).

Stu McGill, who has studied spine mechanics for 30 years at the University of Waterloo in Ontario, Canada, says the problem with soft chairs and particularly the ones that are too deep is that they cause people to slouch or slump. Furthermore, when you slouch, you do something bad to your spine, you bend it into C shape, that puts more stress on the spinal discs.

Peter Opsvik, who designed the Balans chair, created the rocker Balans "Tripos" chair (image 42) ergonomic chairs are usually better than most side chairs, but they are not perfect. They share with ordinary chairs the drawbacks of the right angle seated posture. The best ergonomic chairs available today are actually perches.[4]

Image 43| Capisco chair by Peter Opsvik (1975).

Image 44| Variable balans designed by Peter Opsvik (1979).

The Variable Balans chair, known variously as the posture, kneeling, or computer chair (image 44), was designed to reduce the stress on both sitting and standing, it creates the same 135 degree leg-spine relationship that professionals use to conserve their own strength when providing stand-up work stations. However, it folds the legs merely in order to lower the body in space to be able to use standard height tables and desks, resting on the shins and losing proprioceptive feedback from the soles of the feet are two disadvantages of this compromise.[4]

Image 45| David Trubridge's Dandola (2004).

Urban Furniture

Image 46| Root bench in Seoul.

Image 47| Root bench in Seoul.

"Good public space is required for the social and psychological health of modern communities"[59]. In view of the above, it is reasonable to say that seating furniture in open spaces play an important role in the psychosocial balance of a society.

Image 48| Childrens playground design.

Image 49| Streetlife's Surf Isles.

Root bench (images 46 & 47), is the winning proposal in Hangarg Art Competition is designed by Korean architect Yong Ju Lee with a diameter of 30m , placed in grass in fully balance with nature. The art piece designed by computer algorithm presents dynamicity from a three-dimensional geometry. It also functions perfectly as furniture with three different heights: a child's chair (250mm), an adult's chair (450mm) and a table (750mm). The circle shaped bench blends and organically spreads across Hangang Park.[63]

Image 50| Streetlife's Surf Isles.

Hardscape Akershuskaia (image 52), was built in the port of Oslo and built in 2016 by Pushak Architecture. Wooden benches and boxes are used for relaxing and playing. This public park is consisted of sitting areas, slopes for reclining and a playground. Furthermore, old boardwalk boards have been re-used for flooring, and the construction is made with corten steel.

Image 51| Streetlife's Surf Isles.

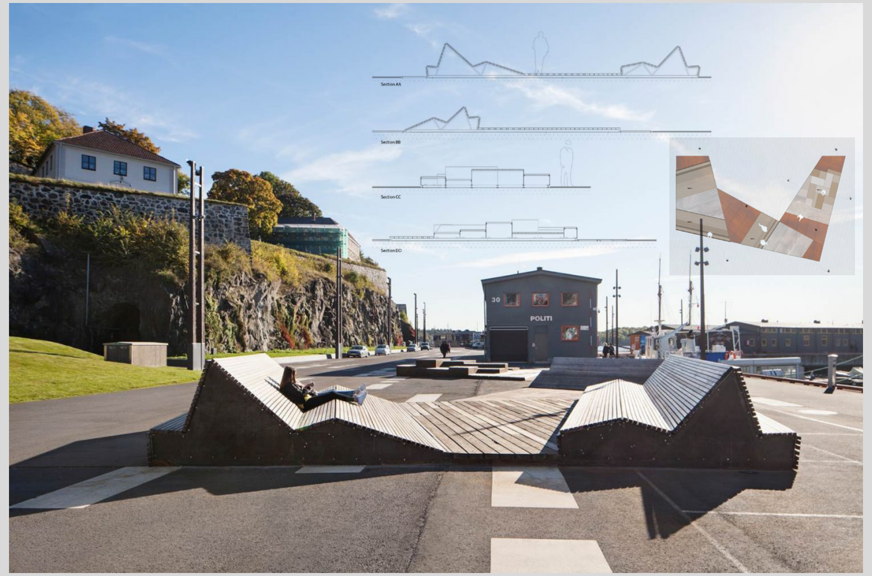


Image 52| Hardscape Akershuskaia in Oslo, Norway.

The Ecodistrict site (image 53) , in Hammarby Sjostad was initially intended for an Olympic Village, but when Sweden lost the bid for the 2004 Olympics, they continued with the brownfield redevelopment of this former industrial area. Now it is a sustainable residential neighborhood.

Image 53| Ecodistrict in Sweden.

Image 54,55| Public Space and Public Surface at Iowa State University developed a temporary public installation from concept to construction.

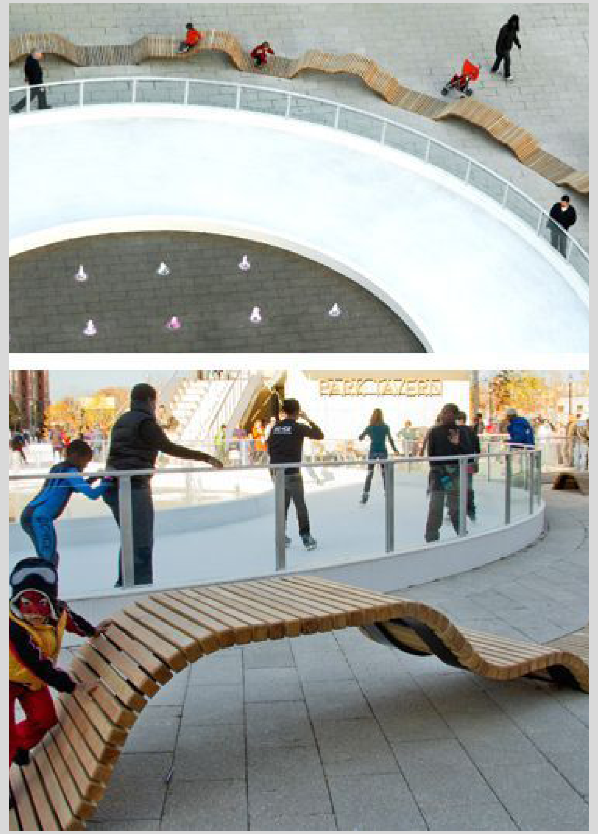
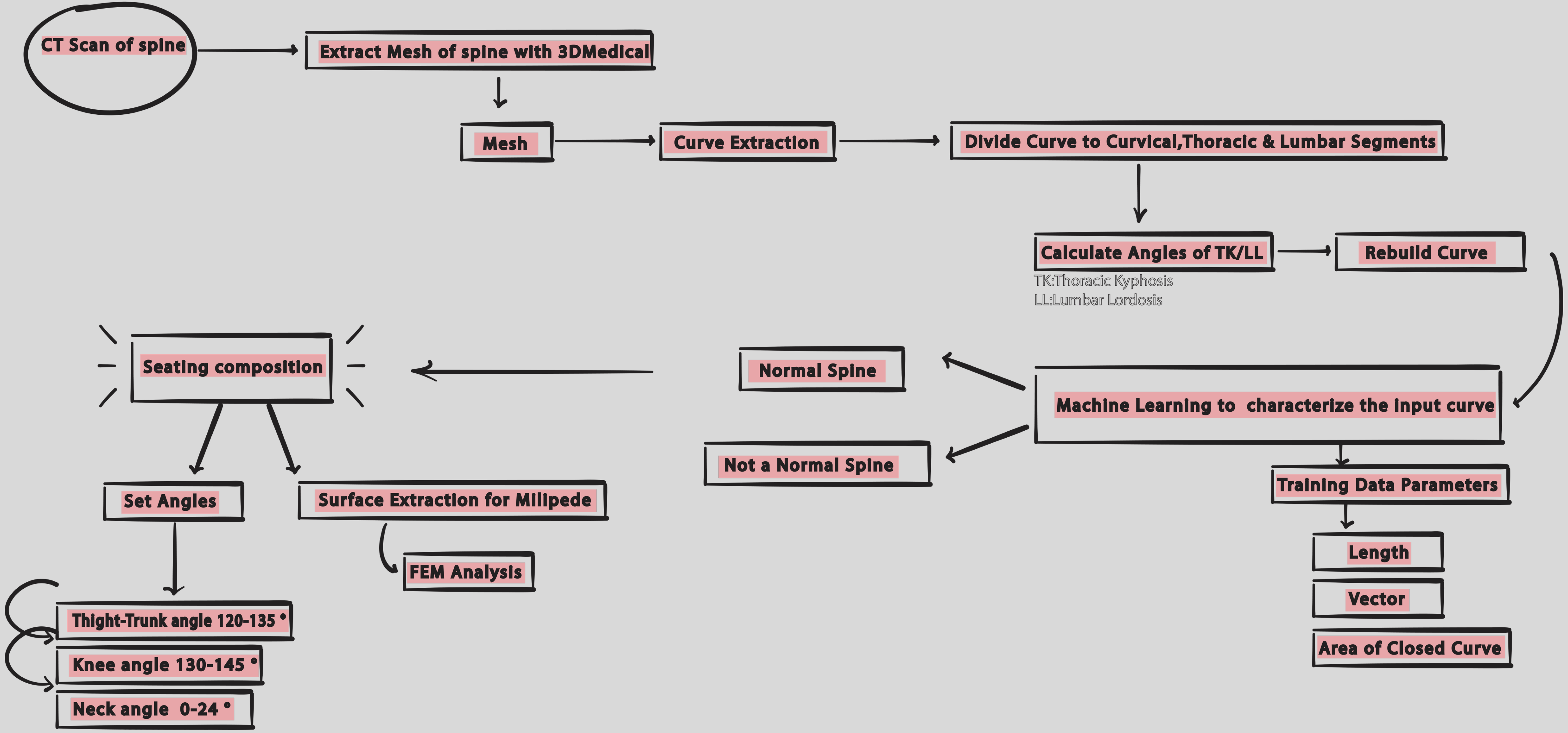
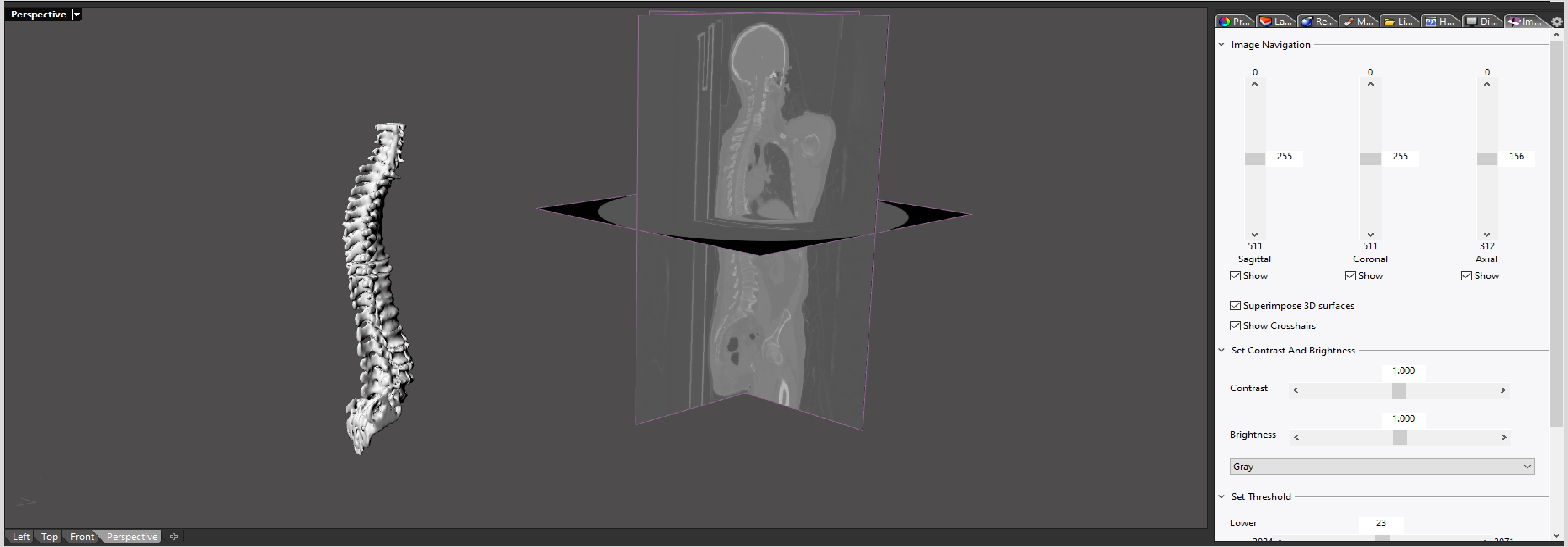


Image 56|Washington Canal Park.

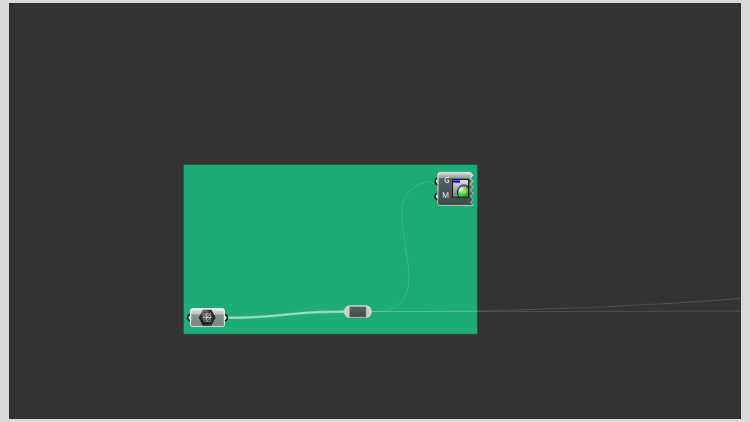
Schematic Explanation



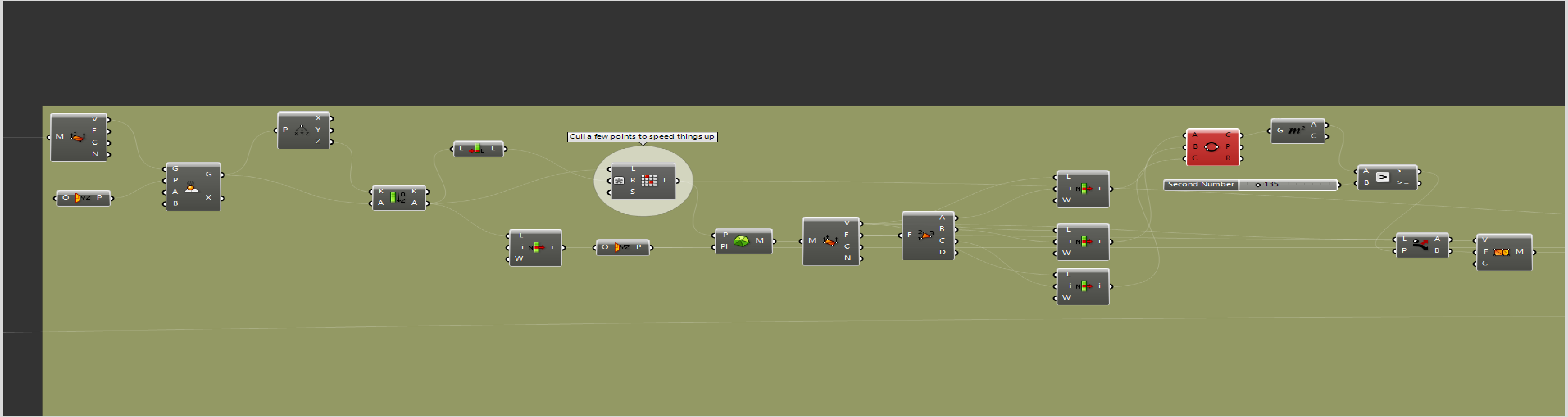
Thorough Explanation of Backend



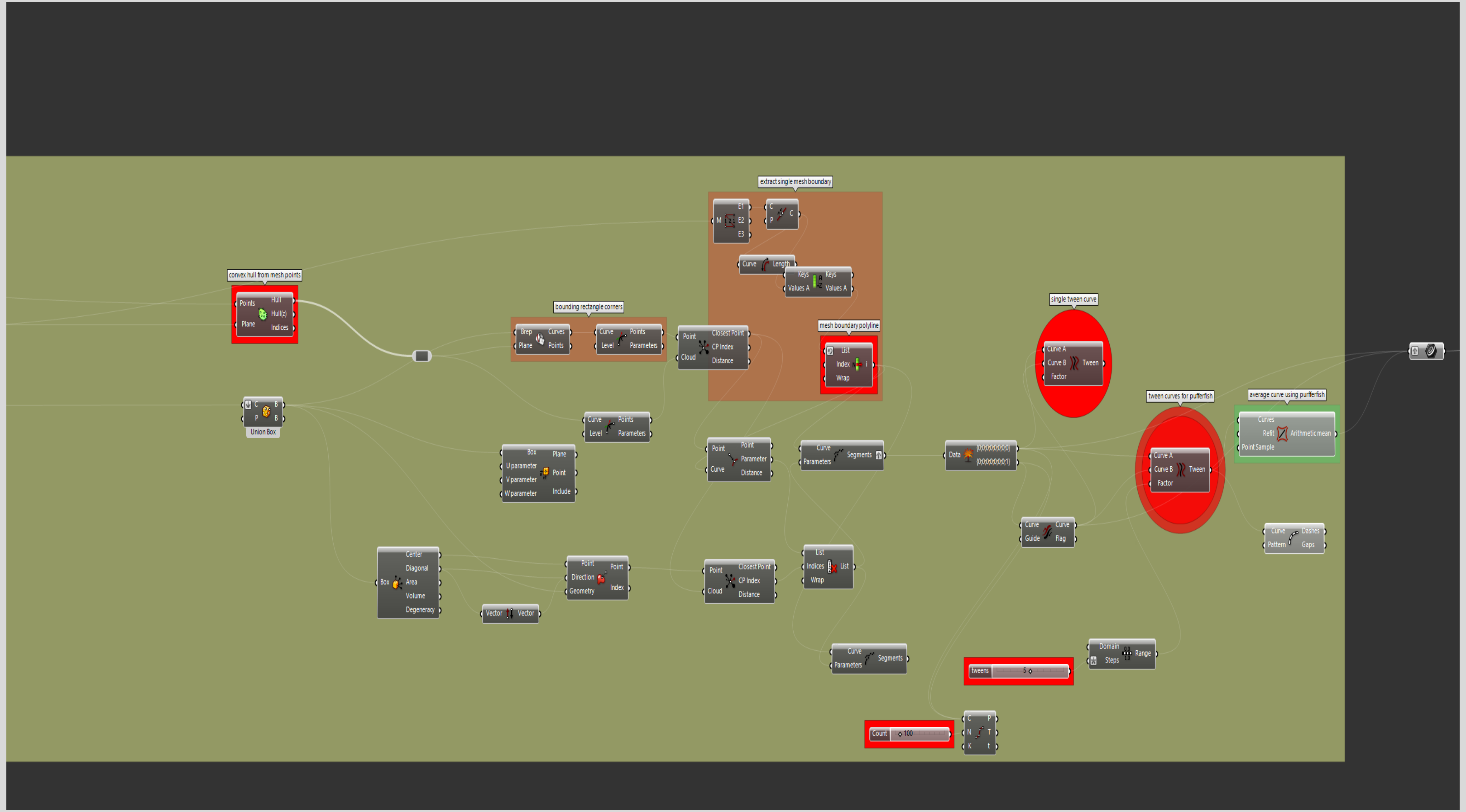
Mesh is constructed via Medical-3d, plug in for Rhinoceros after importation of ct scan file.



Mesh(side view analysis) is imported in grasshopper environment via param for meshes

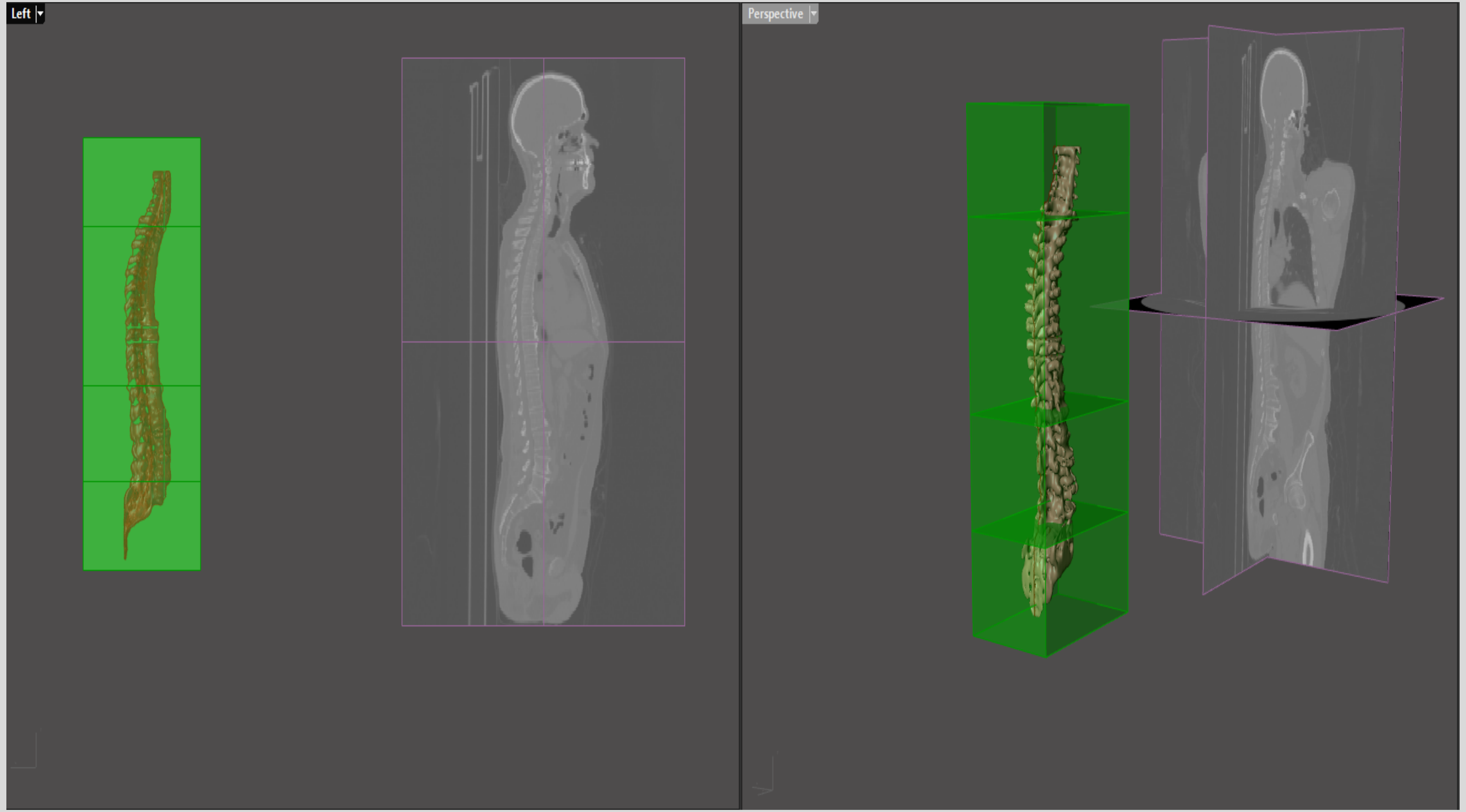


Calculation of the boundary of spine mesh geometry. Mesh is deconstructed, points are projected in yz plane, points being sorted and calculation of boundary is completed by the 10% of the points for faster calculation. Delaunay triangulation of points, then deconstruct of delaunay mesh , and contruction of new mesh from scratch.

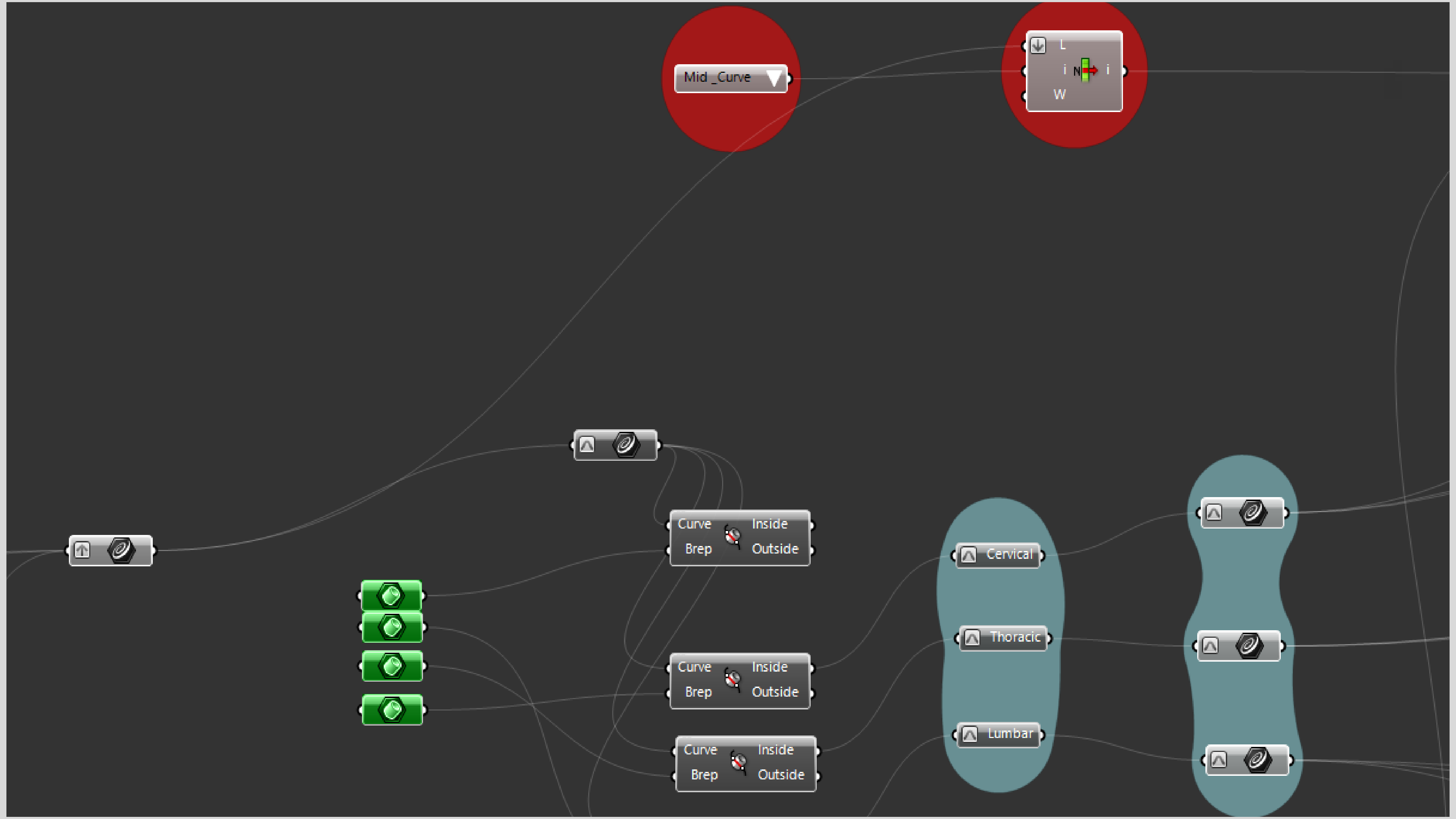


Convex hull is used to calculate the outline curve of spine & the average curve of it.

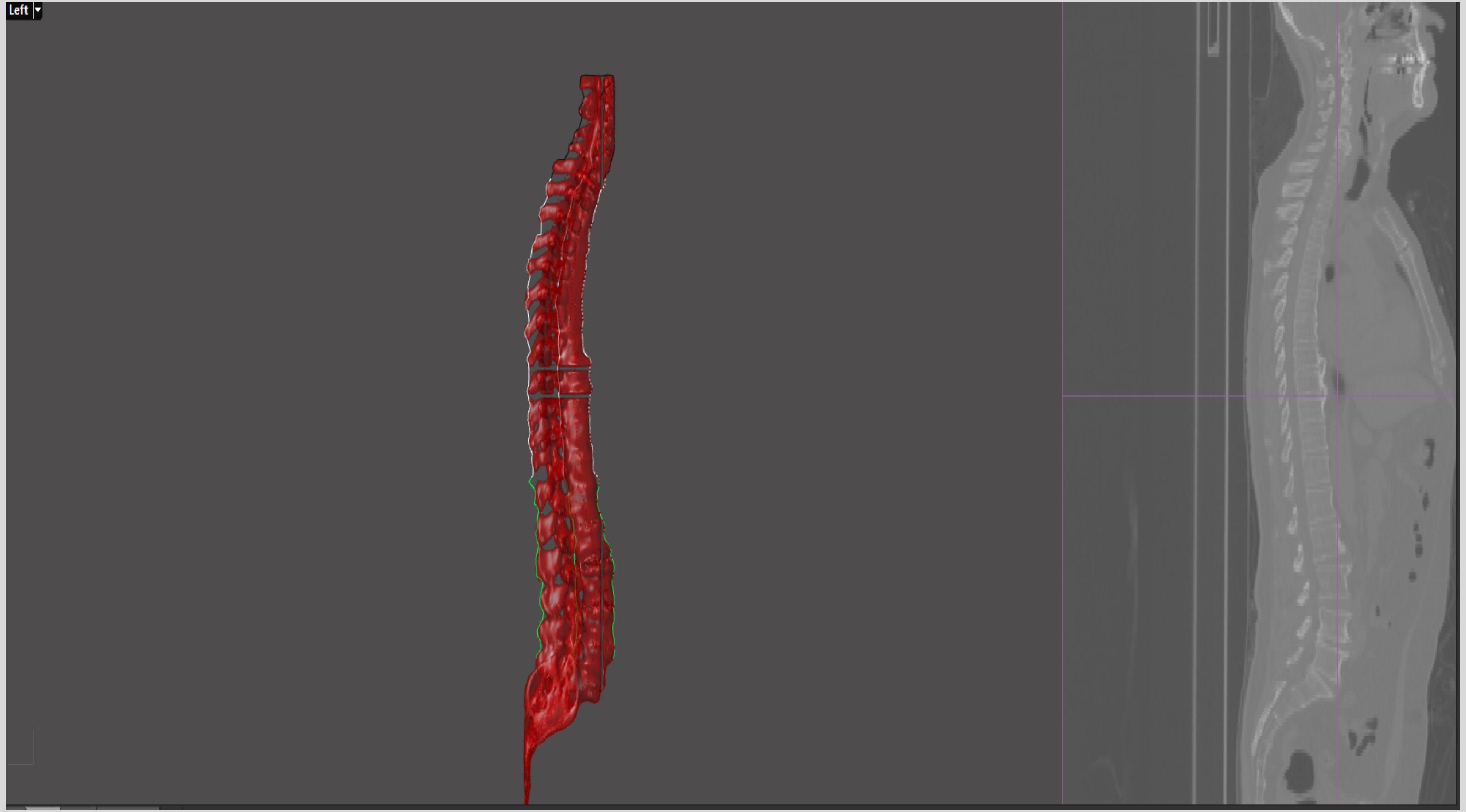
Side view calculation of outline & average curve.



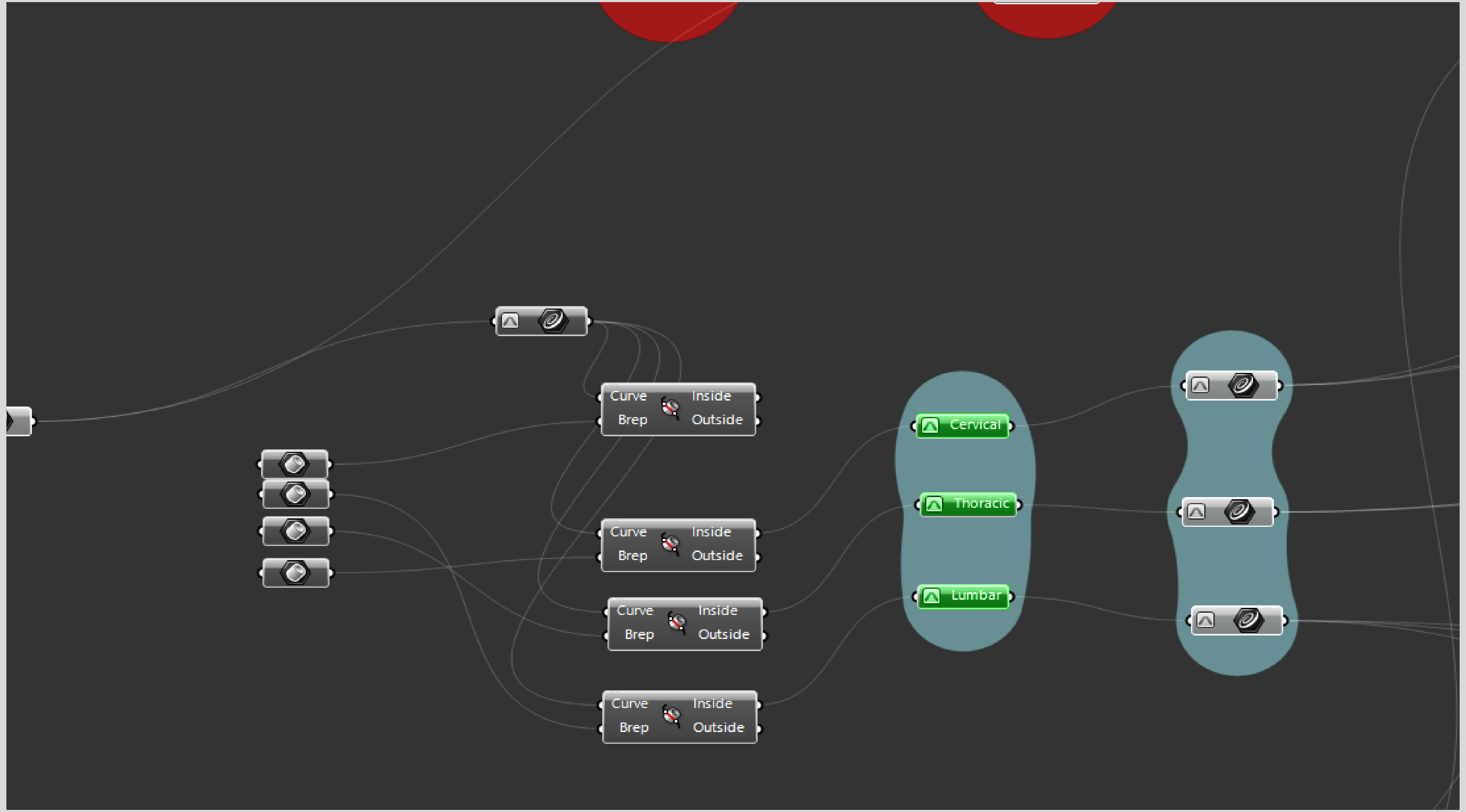
Four Breps are used to sort spine in parts (Curvical,Thoracic,Lumbar & Sacrum).



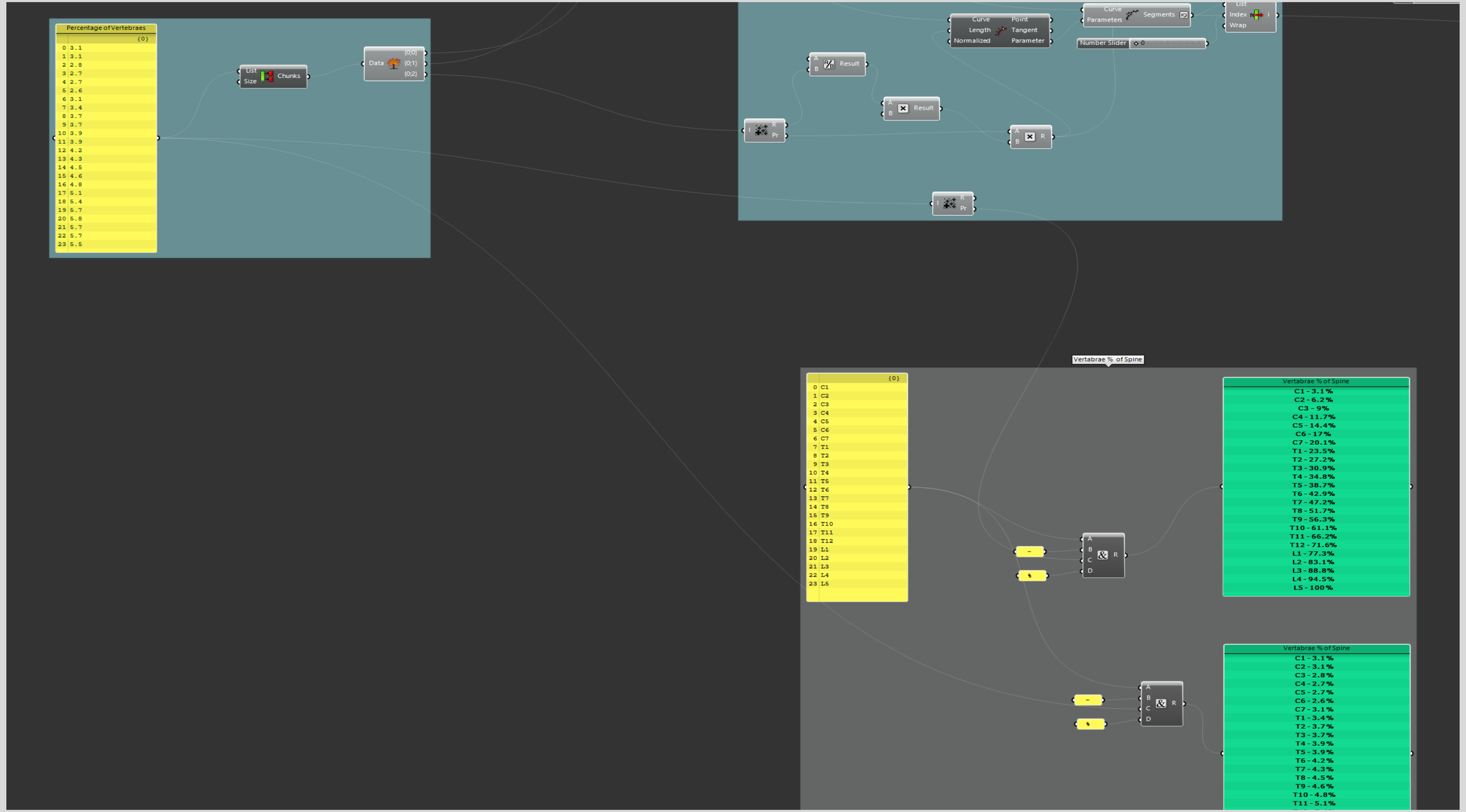
Breps set in params.



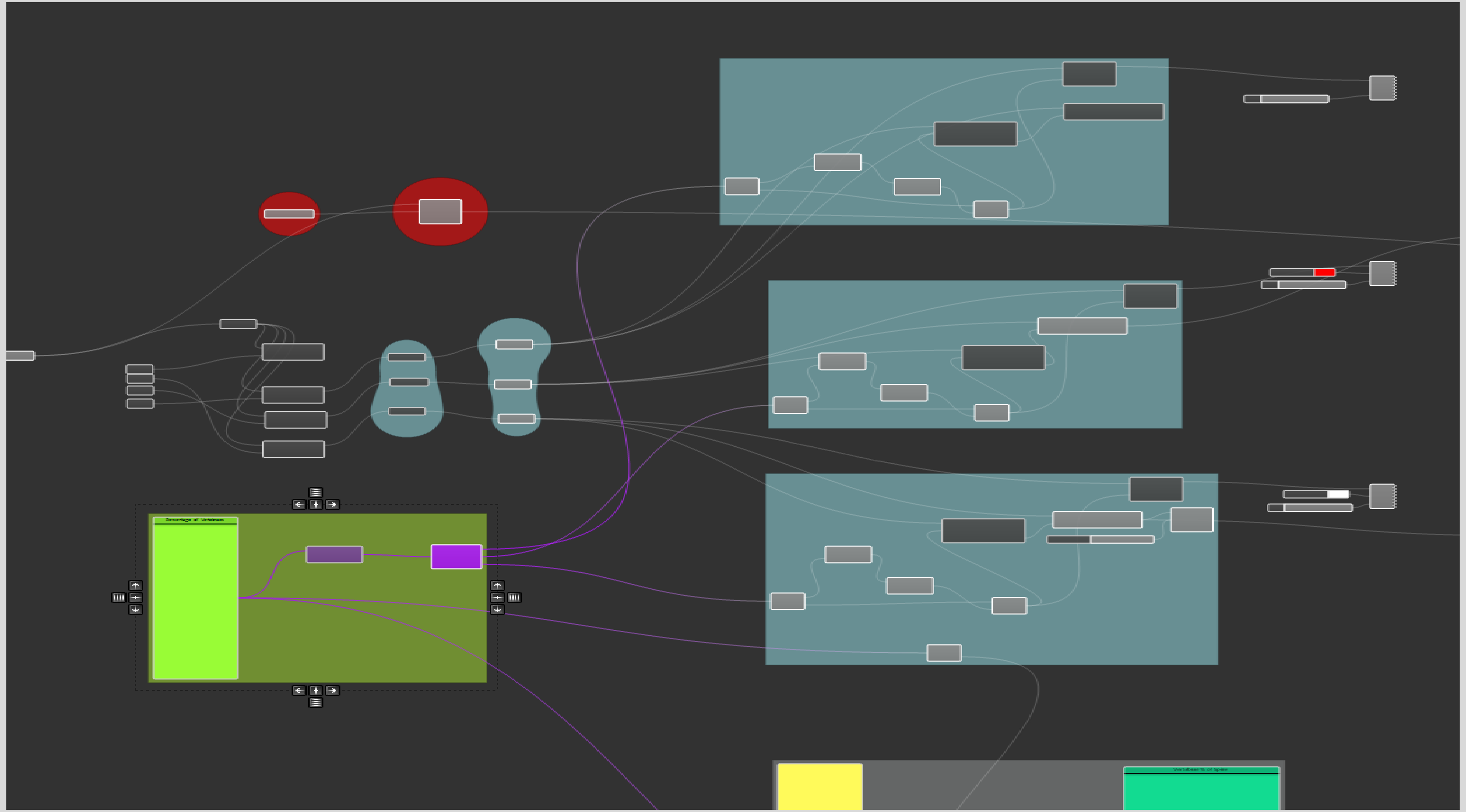
Curvical part of spine(Black outlines), Thoracic(White outlines) & Lumbar(Green outlines) are displayed above.



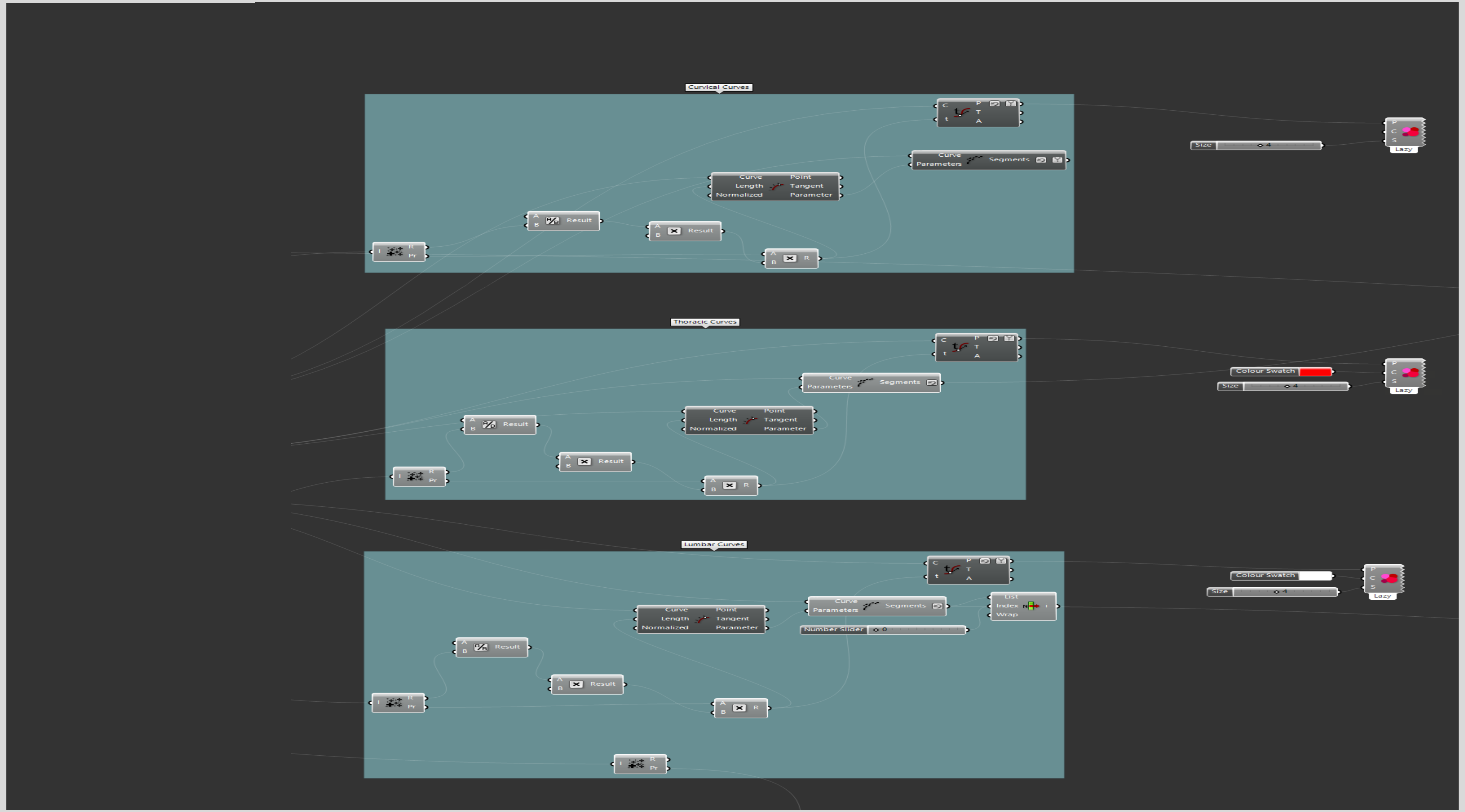
Curves are separated into parts.



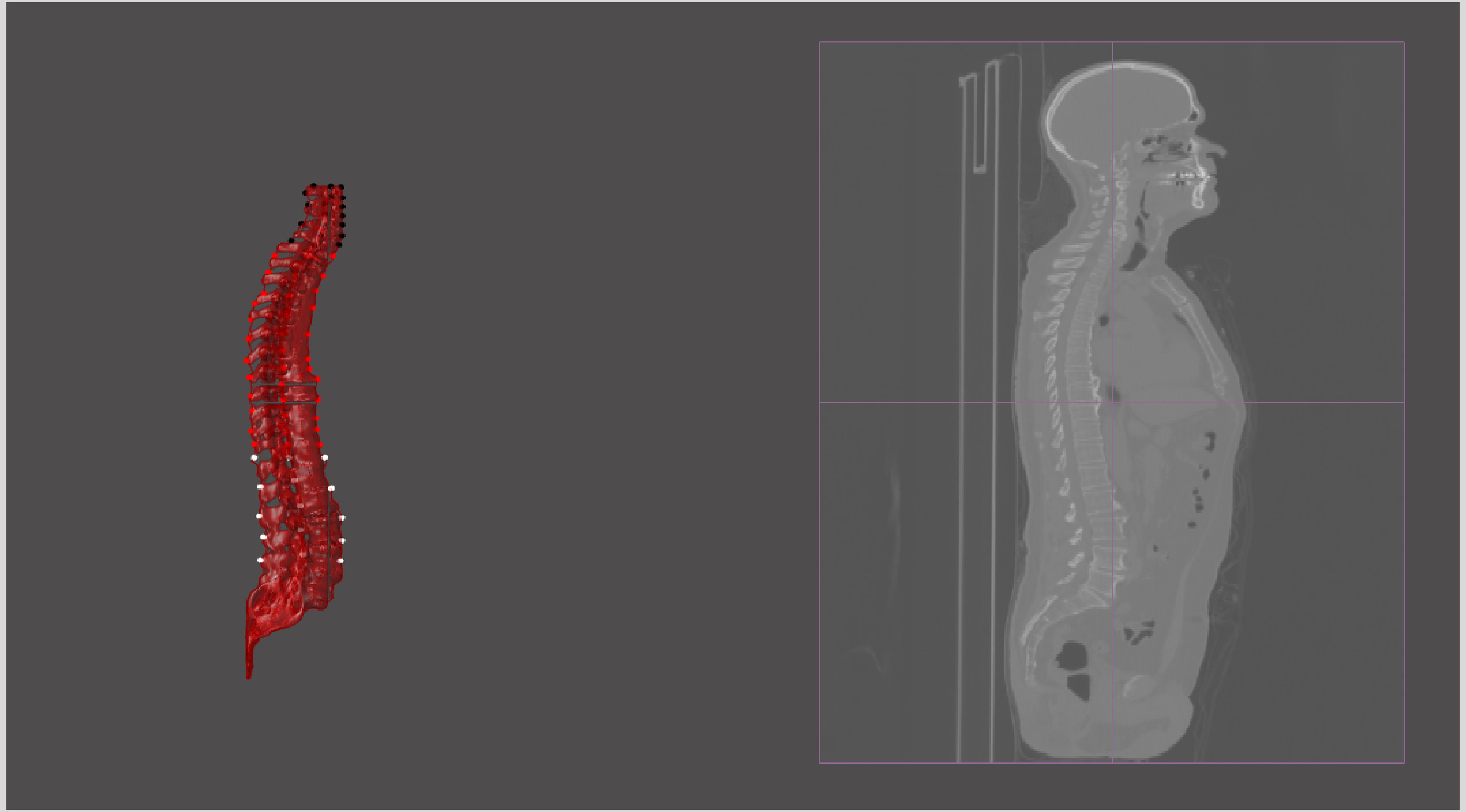
Thoracic & Lumbar parts of curve are divided into the corresponding vertabrae, according to Arvid Frostell, Ramil Hakim, Eric Peter Thelin, Per Mattsson and Mikael Svensson (Table 2).



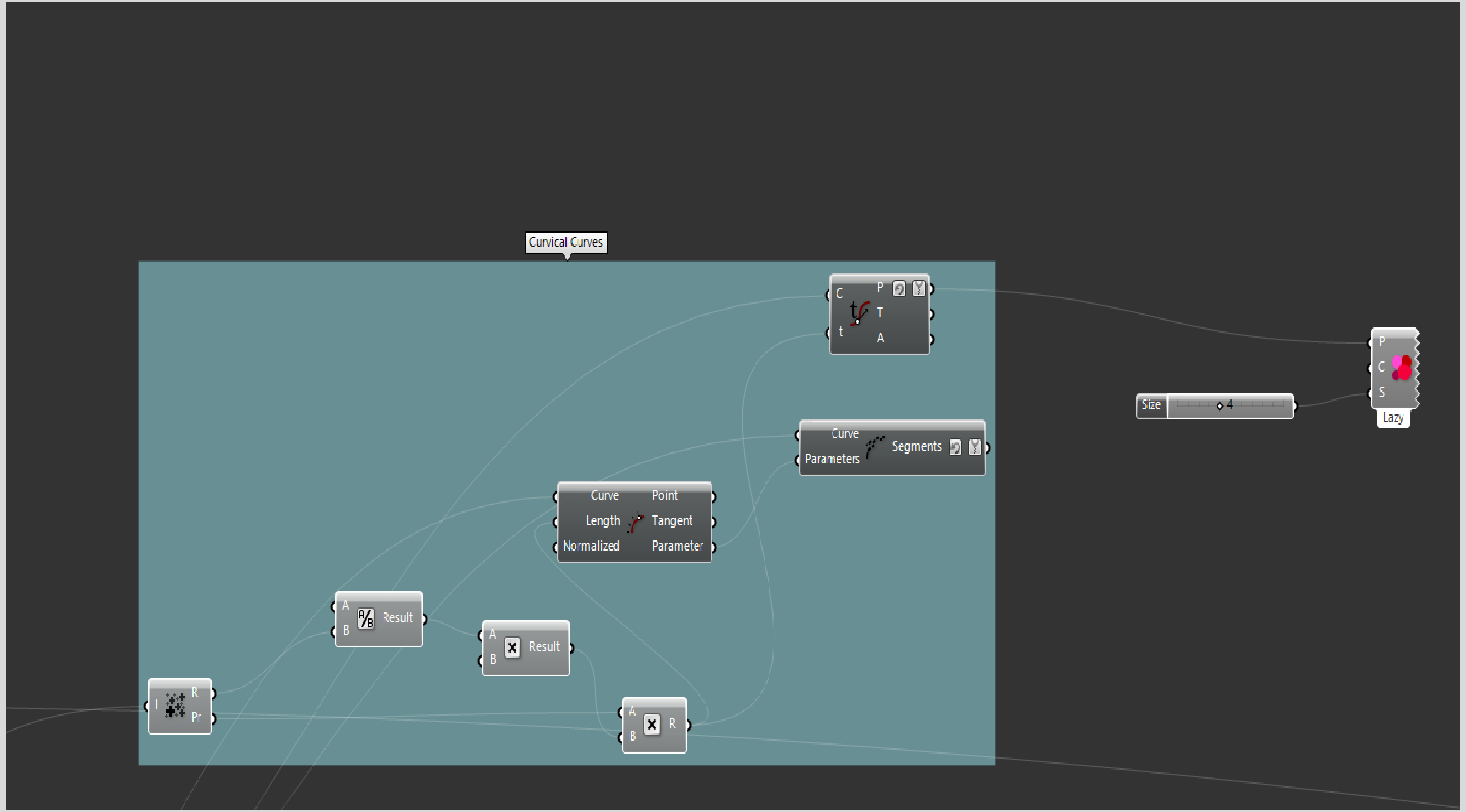
Curves are separated in vertabrae segments.



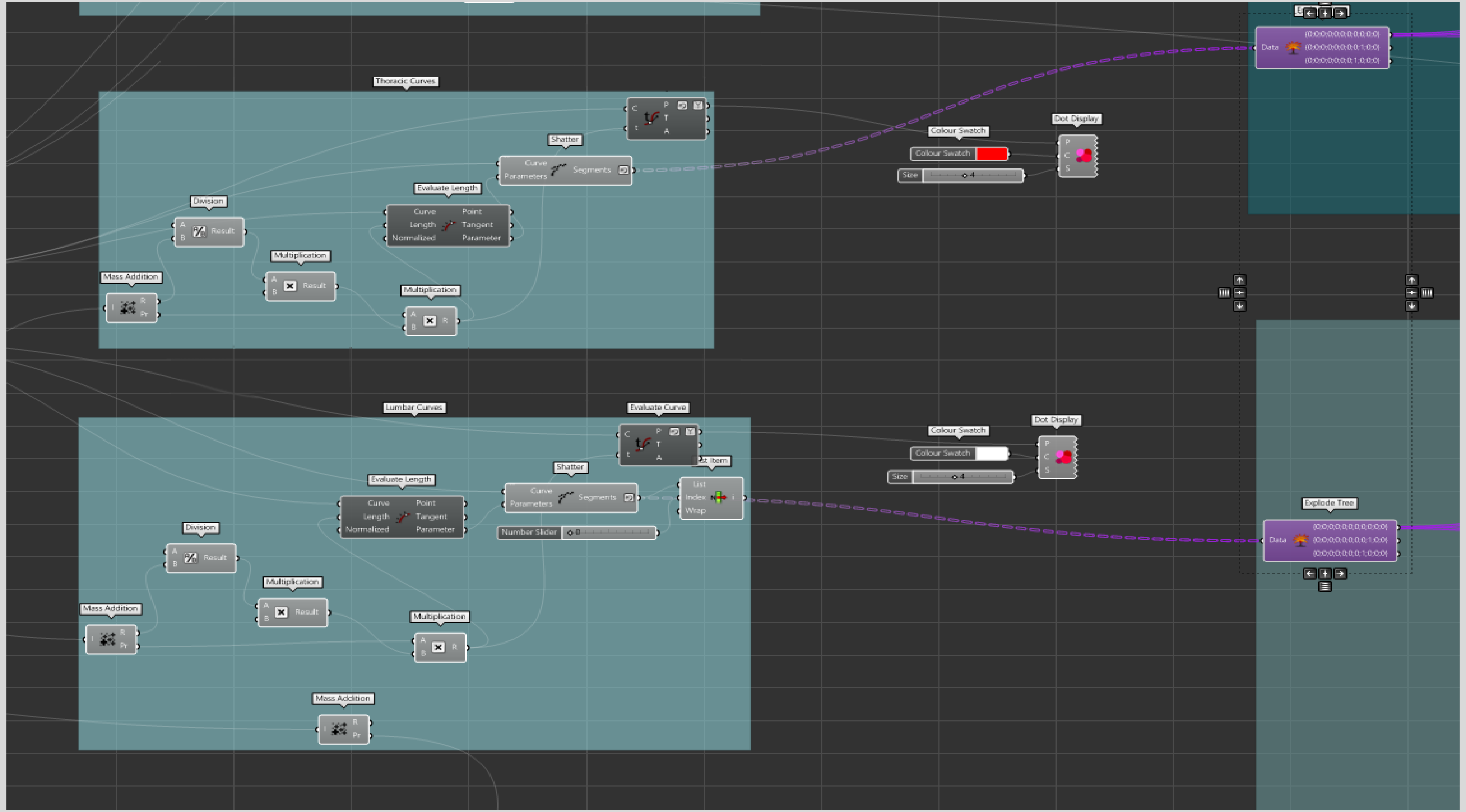
Vertebrae are calculated according to percentages of the mentioned study (Table 2).



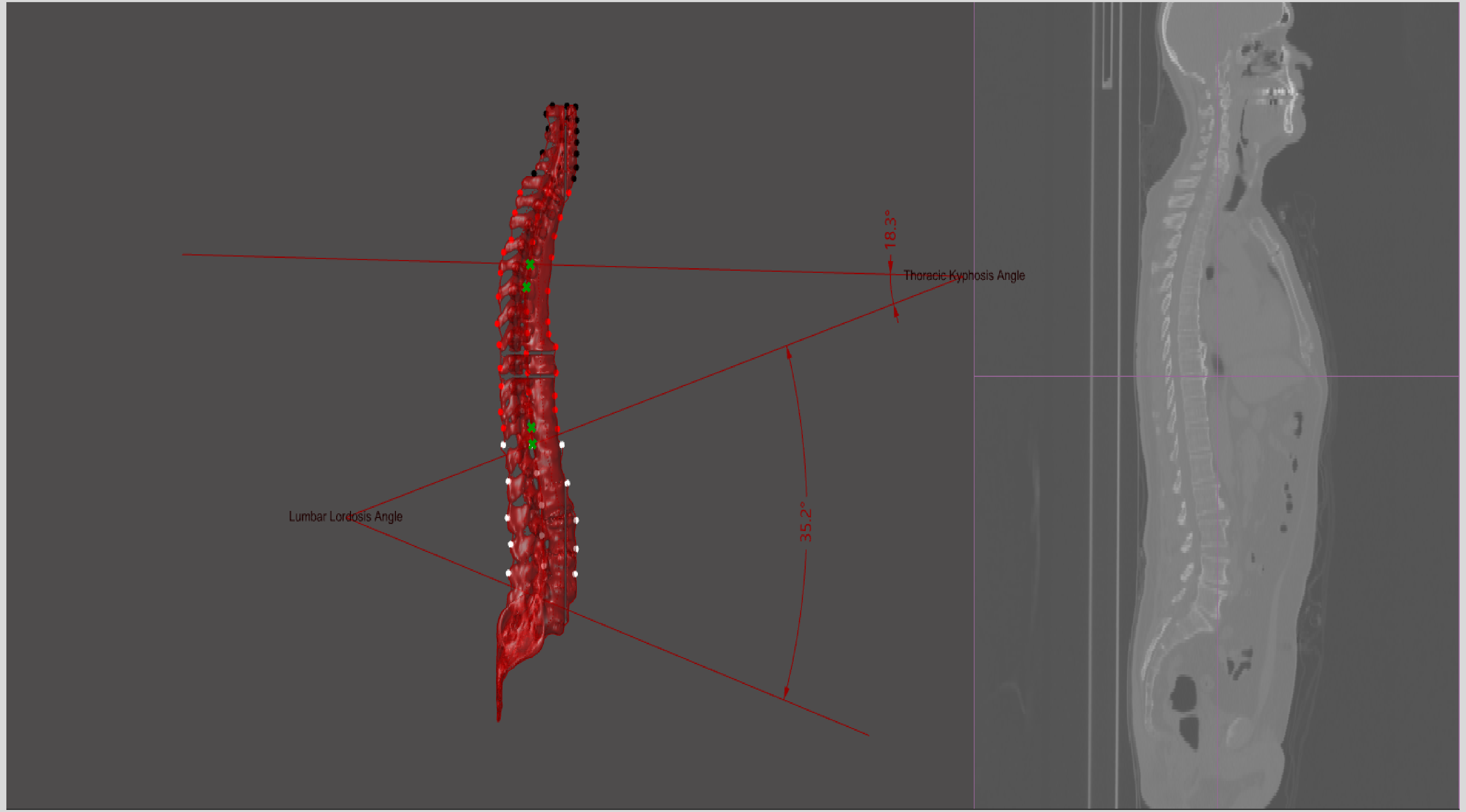
Vertebrae are visible with dot display.



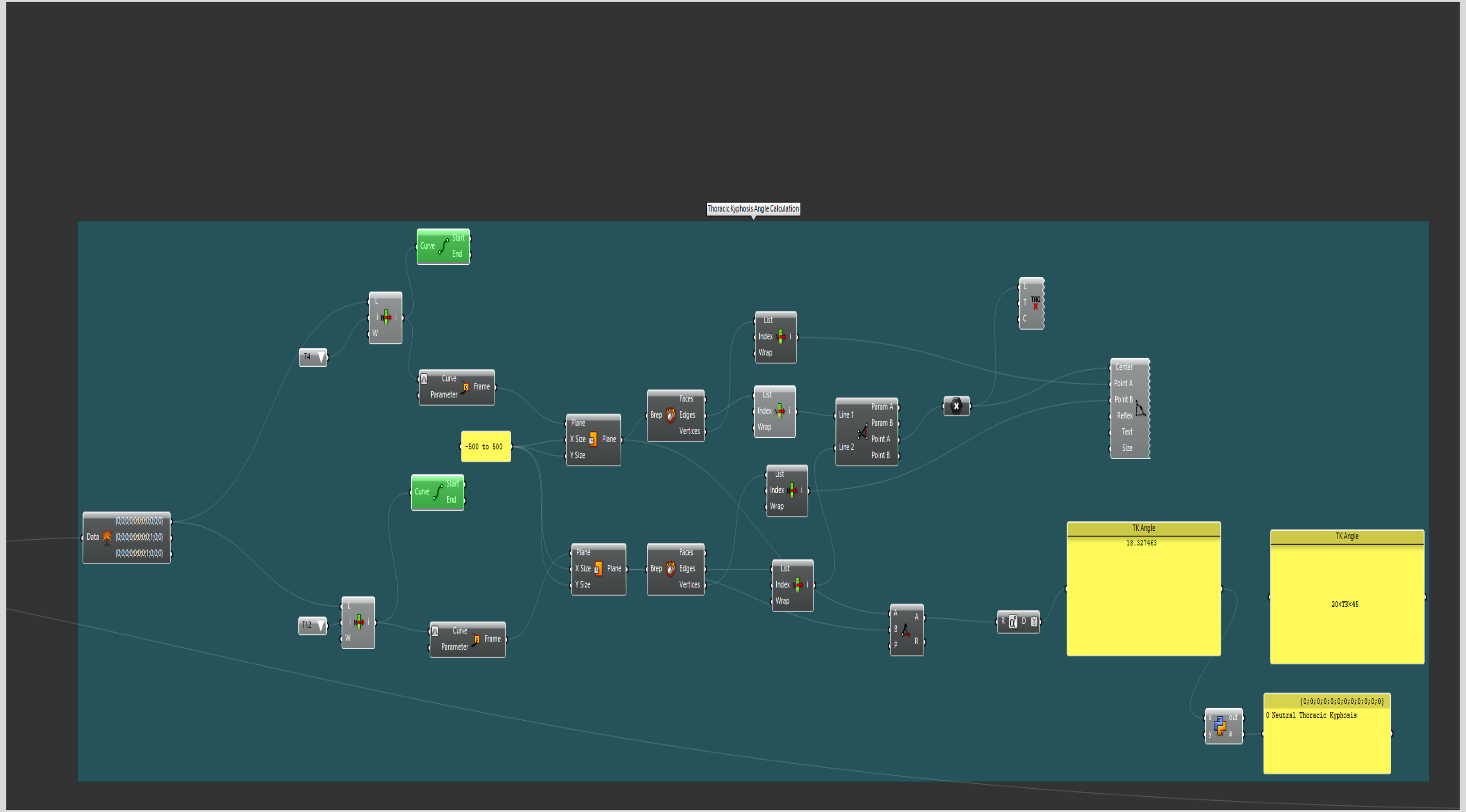
Curvical vertebrae calculation.



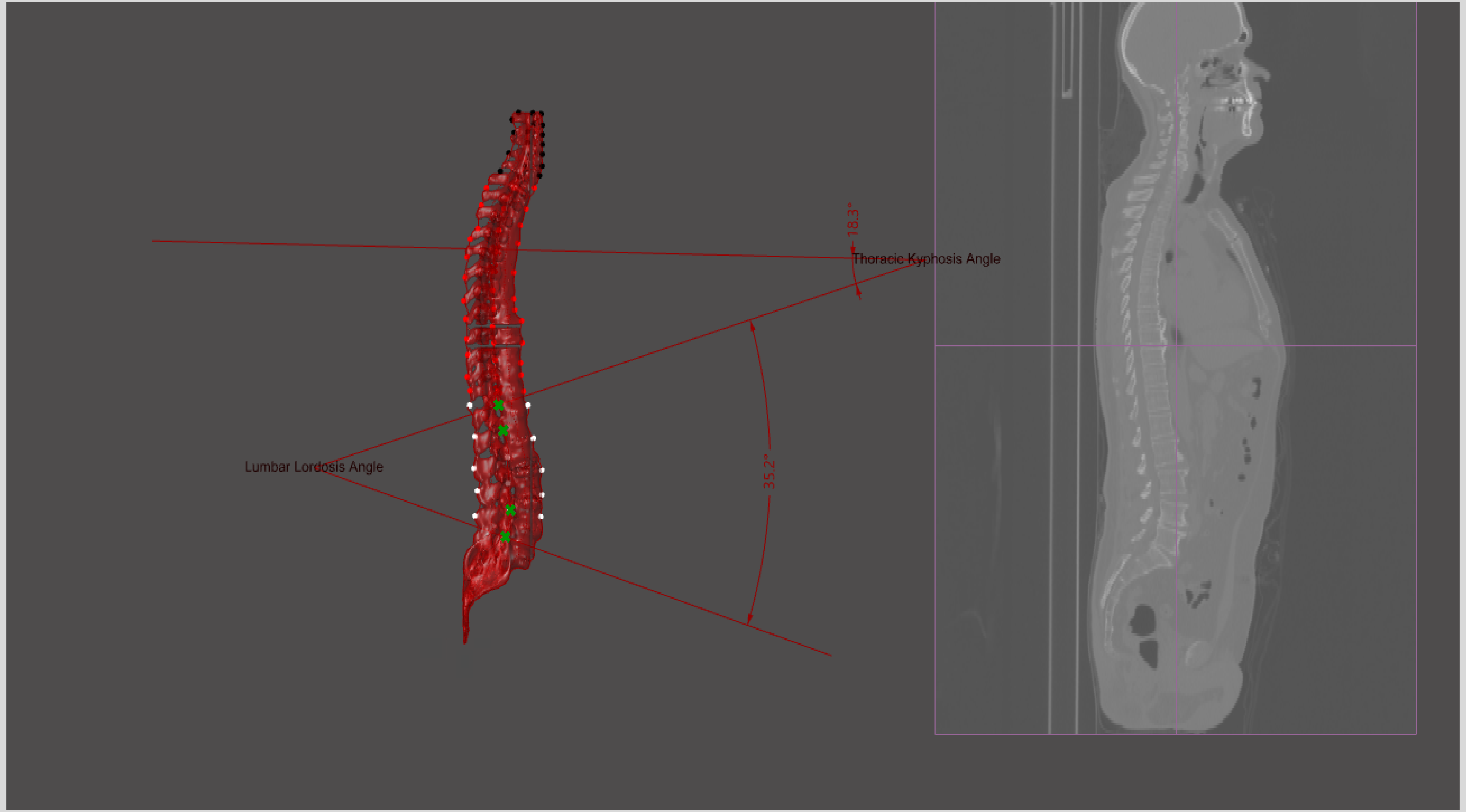
Thoracic & Lumbar vertebrae calculation.



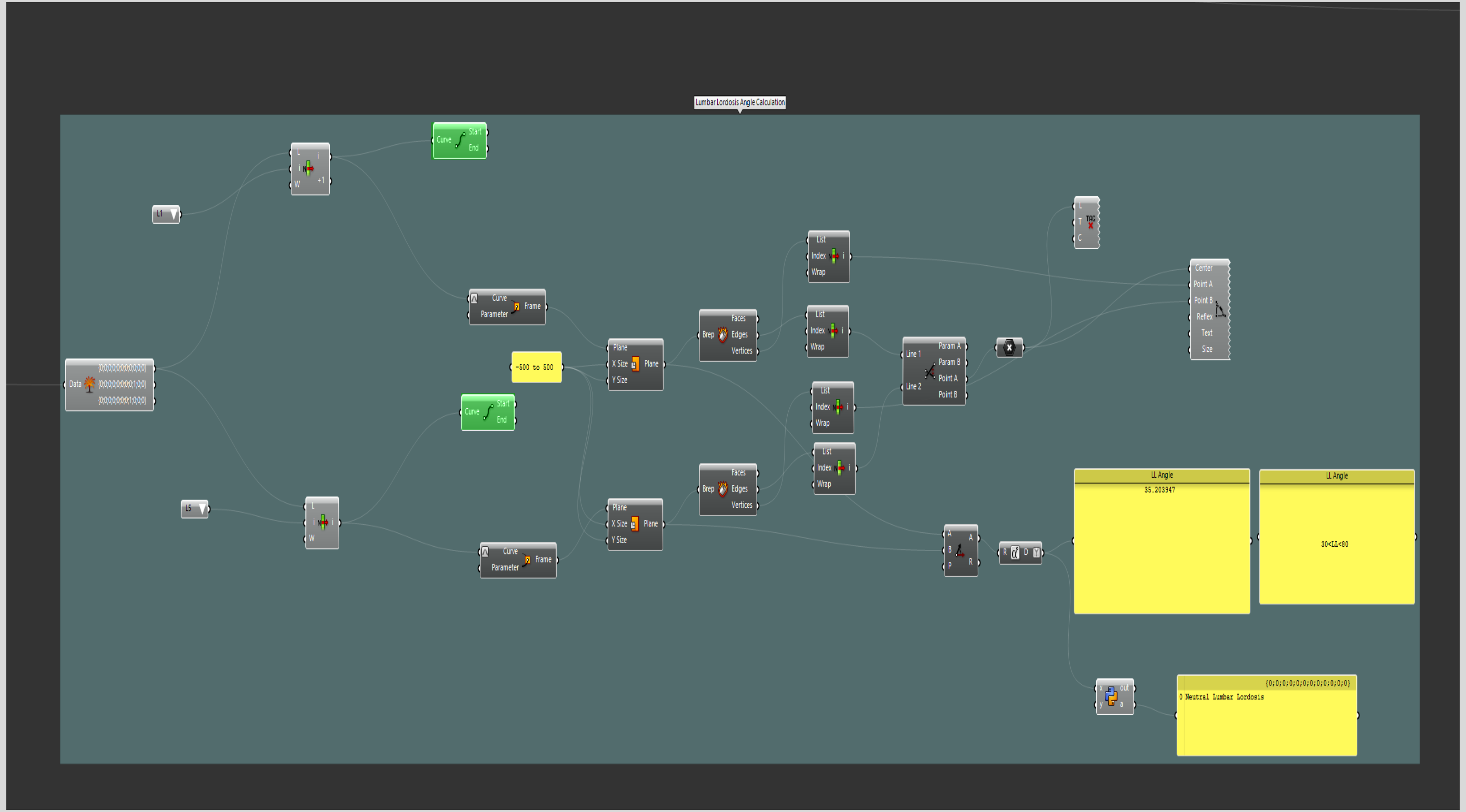
Thoracic Kyphosis angle (TK), is measured between T4-T12 vertebrae.



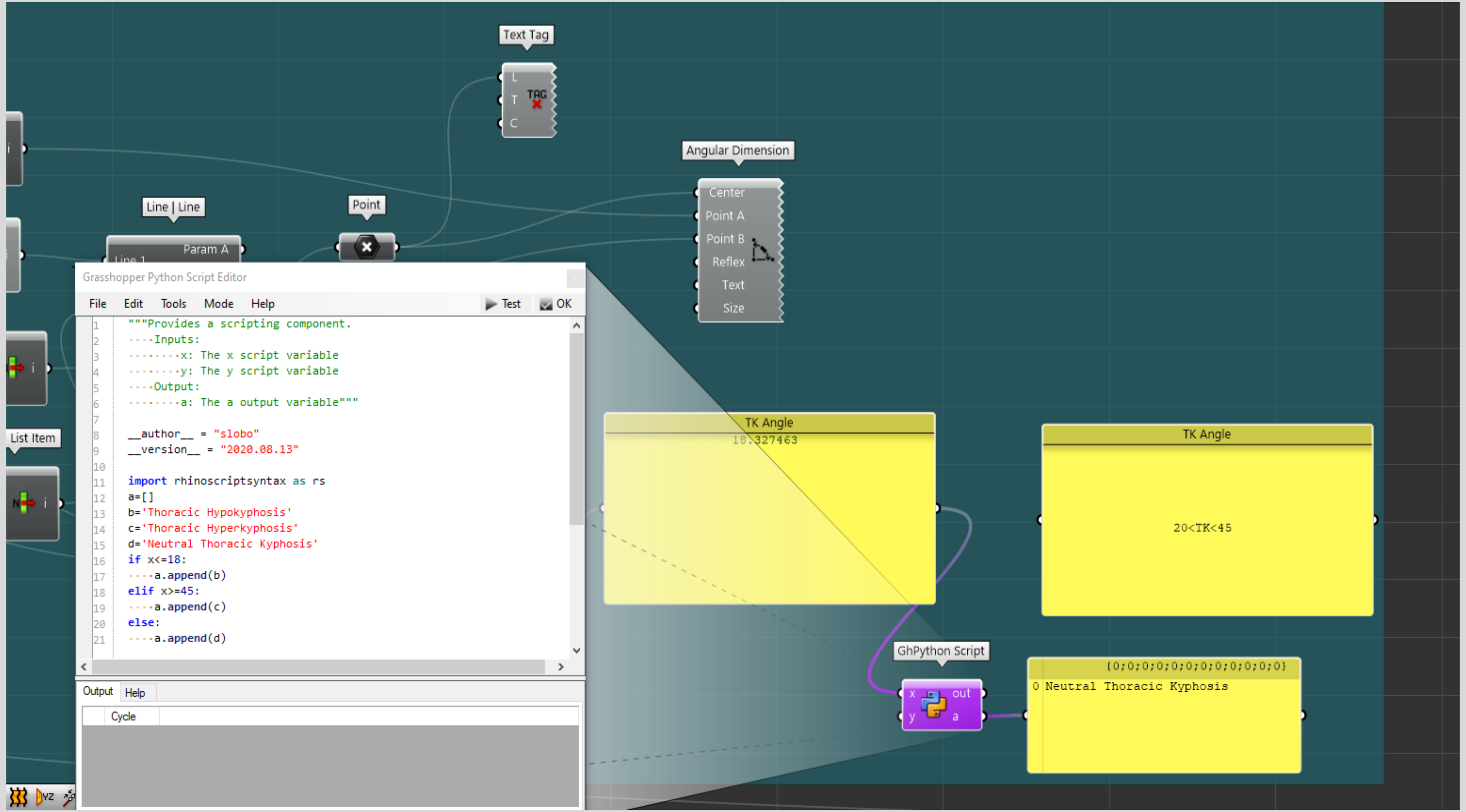
Calculation of thoracic kyphosis angle shows that is in range of a neutral TK angle.



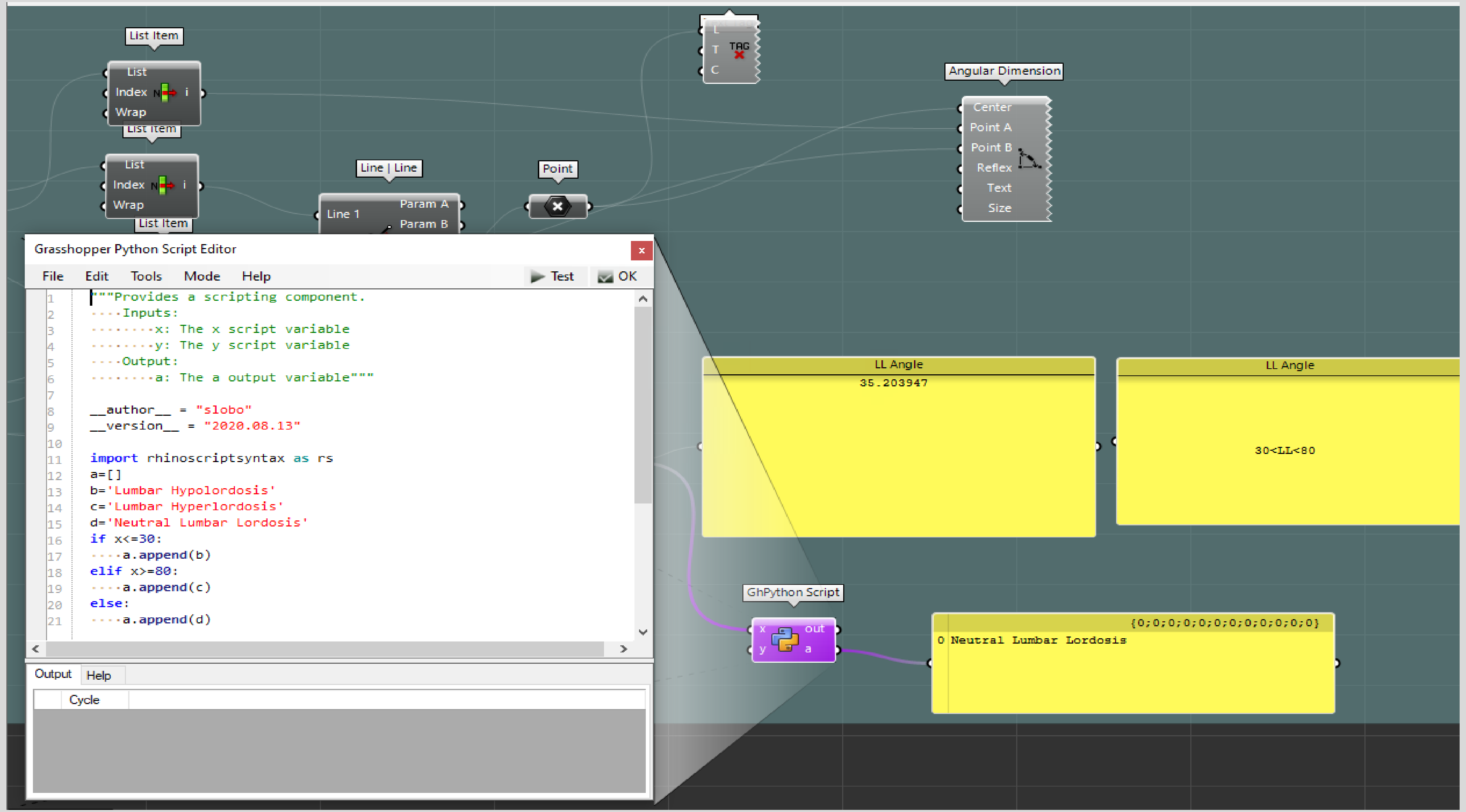
Lumbar Lordosis angle (LL), is measured between L1-L5 vertebrae.



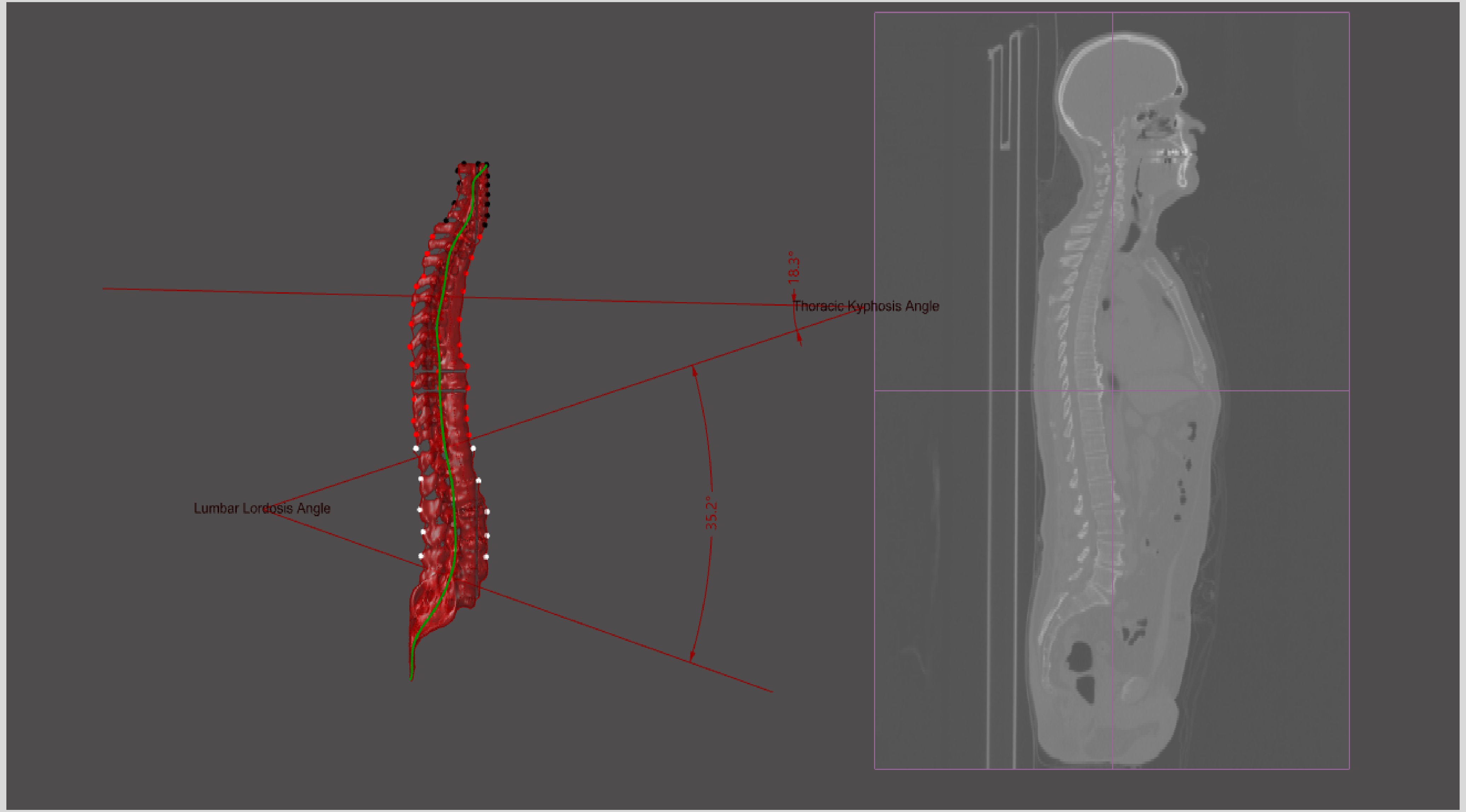
Calculation of lumbar lordosis angle shows that is in range of a neutral LL angle.



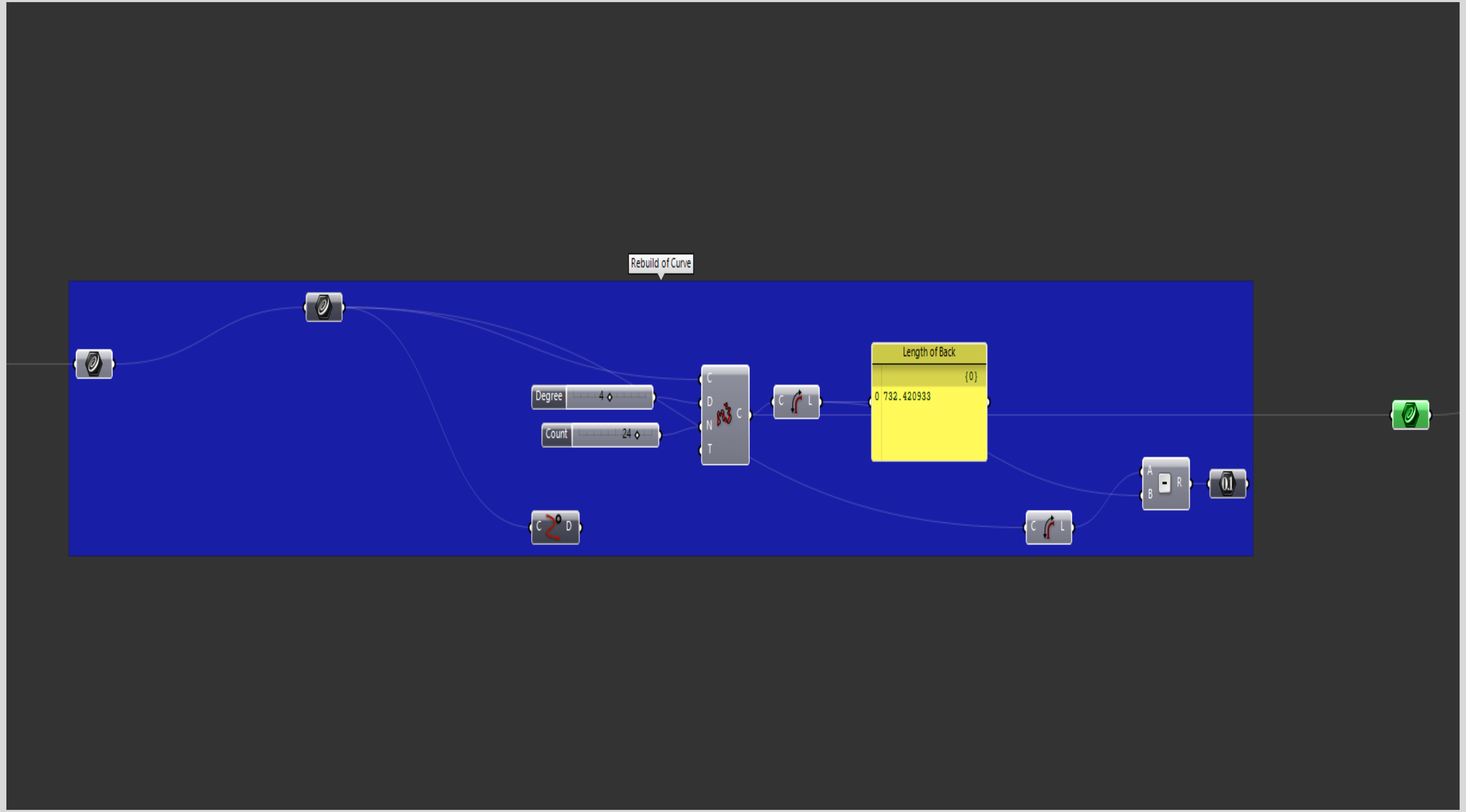
Python script for characterization of TK angle.



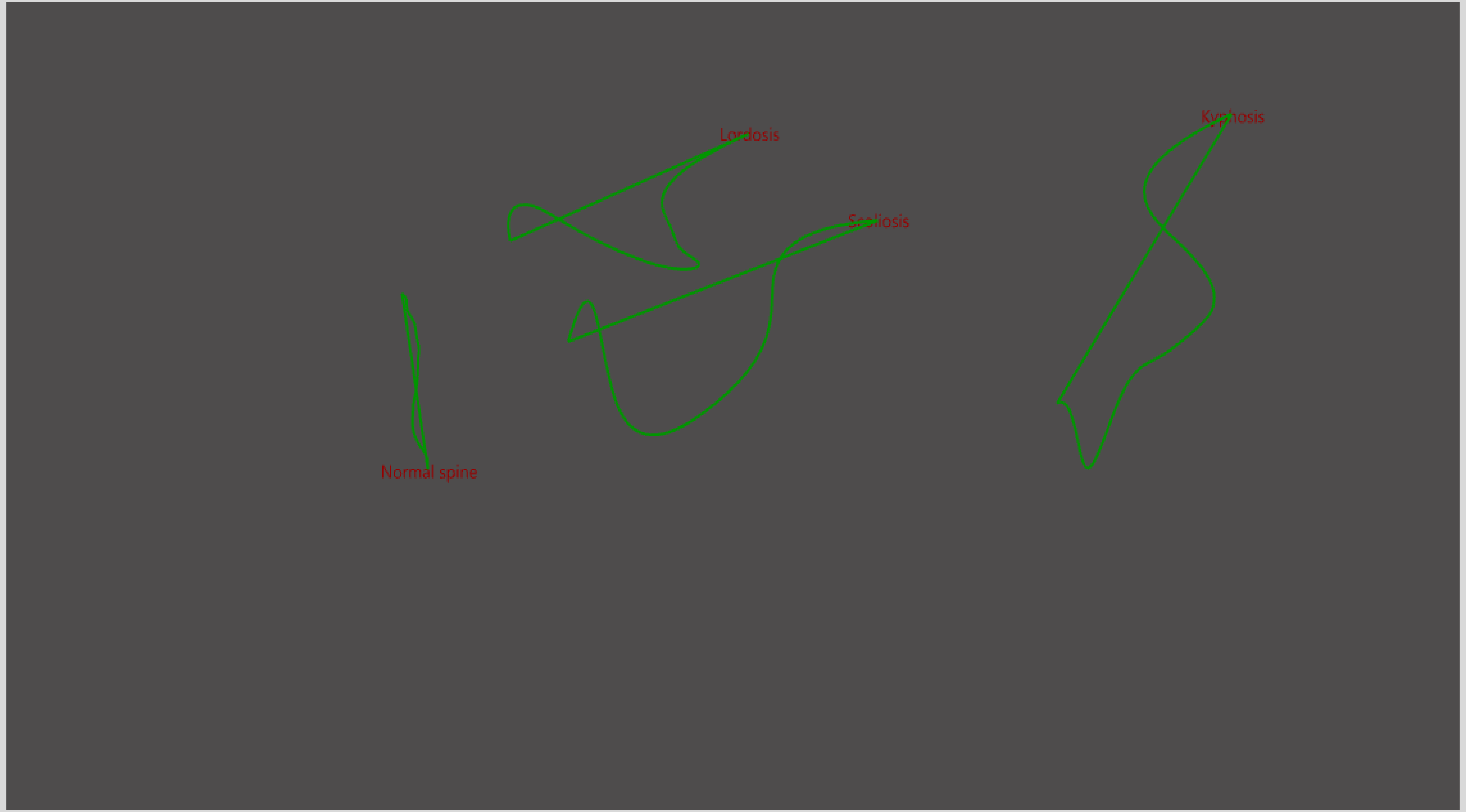
Python script for characterization of LL angle.



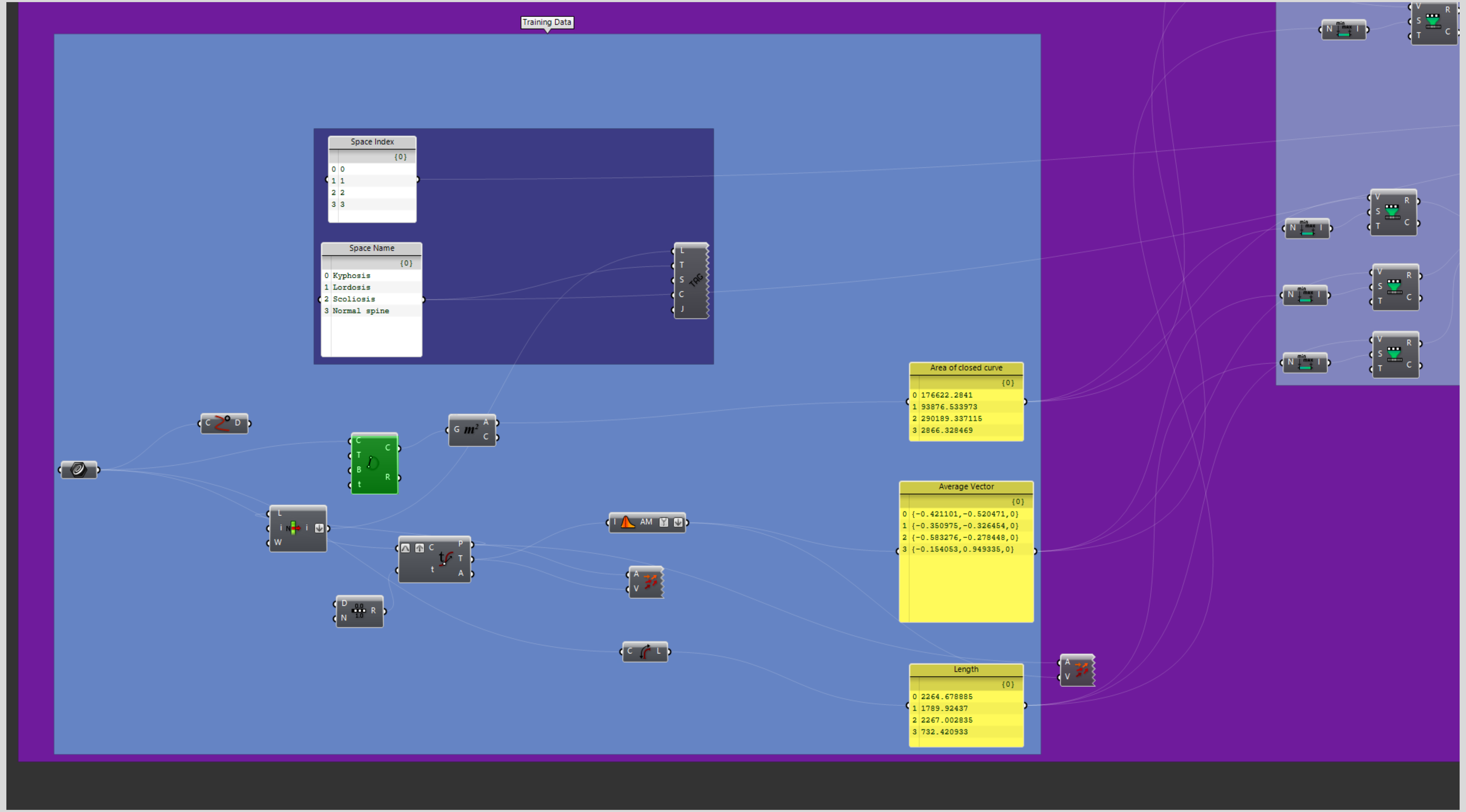
Average curvature of spine.



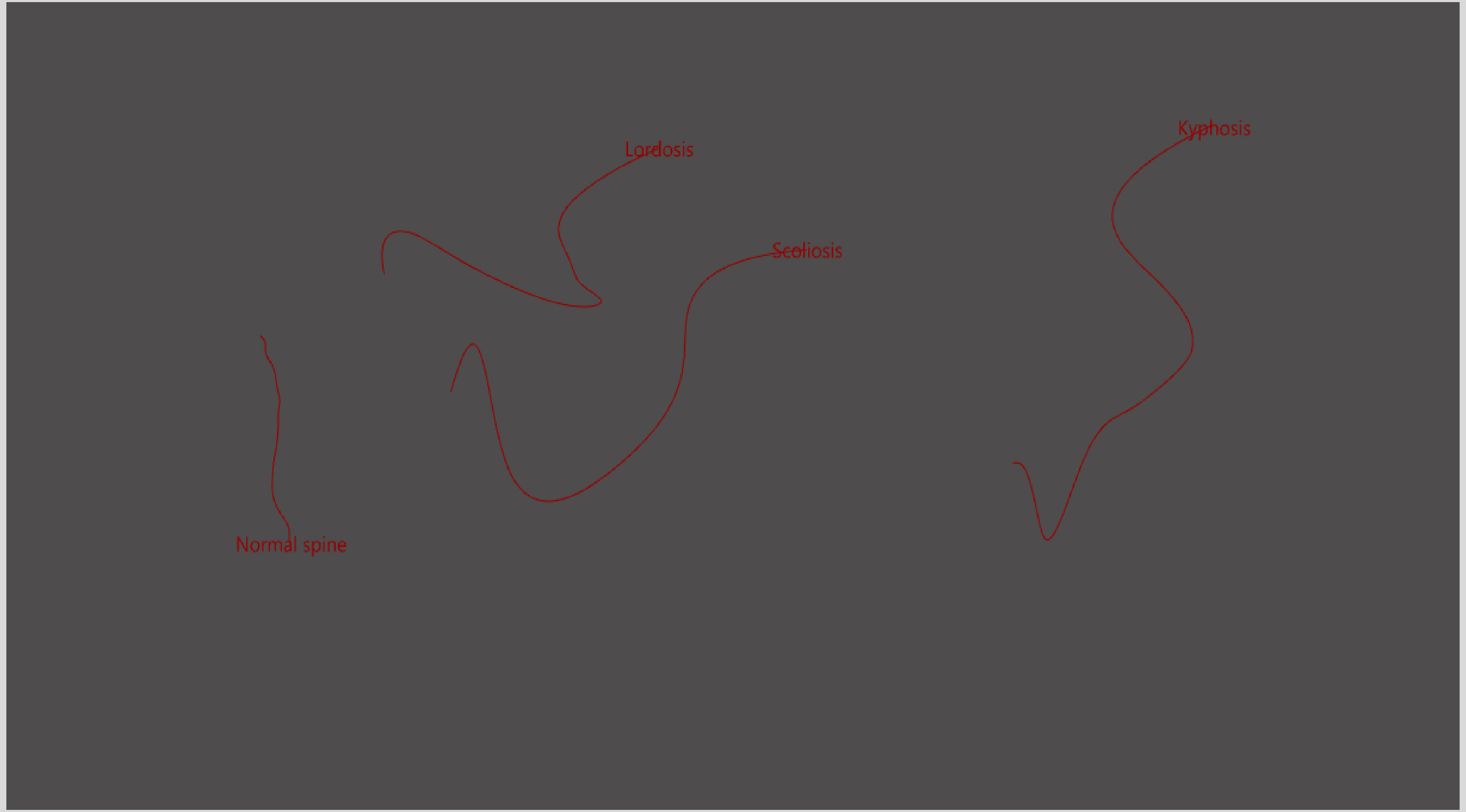
Curve is being rebuilded in a smoother 4th degree curve of 73 cm length(from C1 vertebra to the end of coccyx).



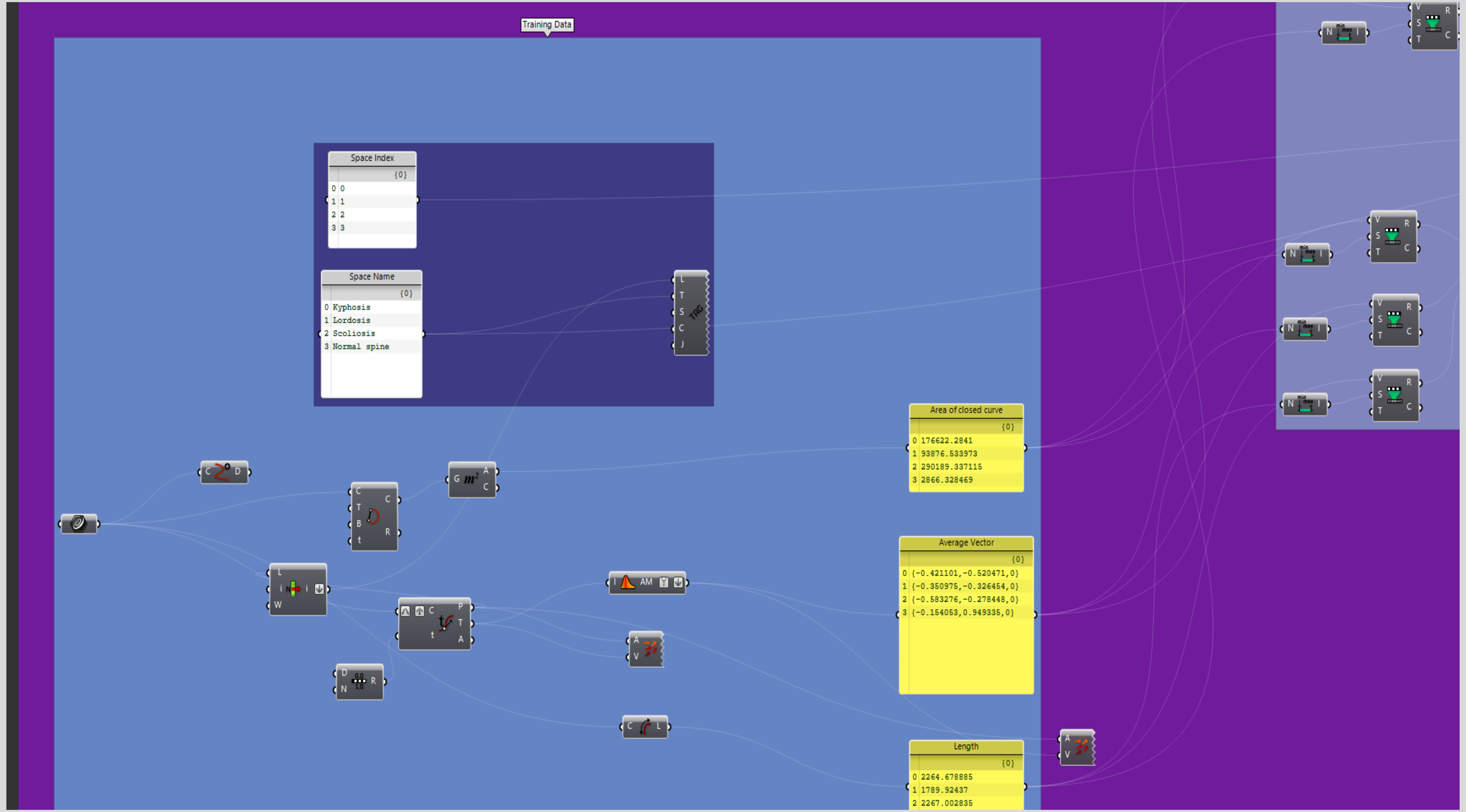
Model is trained to indetify a spine as normal or not. Indetification is based only in side view analysis so scoliosis wasn't considered. Also normal spine is trained with the input geometry so the result will be verified, if it is tested. Lordotic,Kyphotic or Scoliotic curves above are not results of any calculations because the focus of the study is not that part.

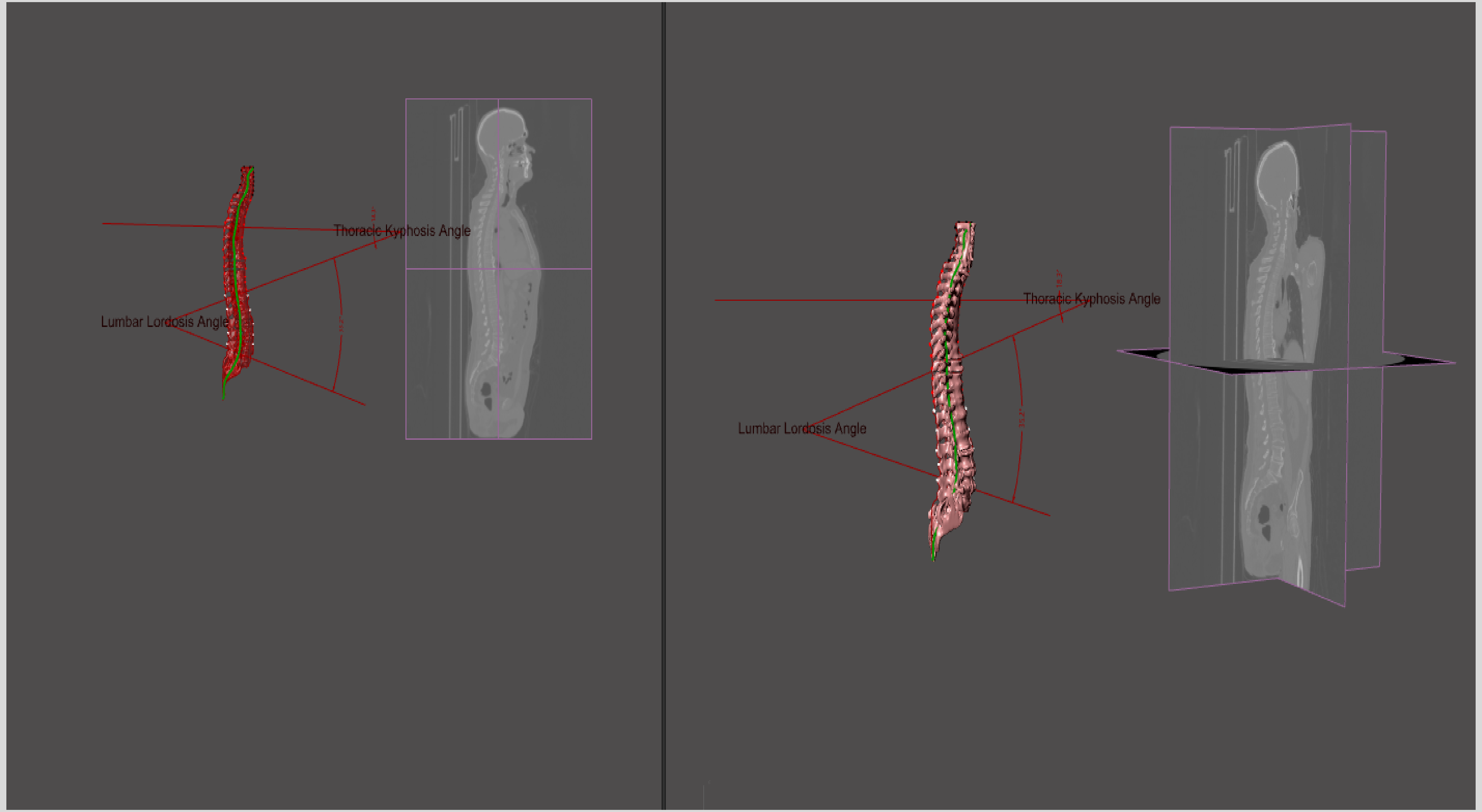


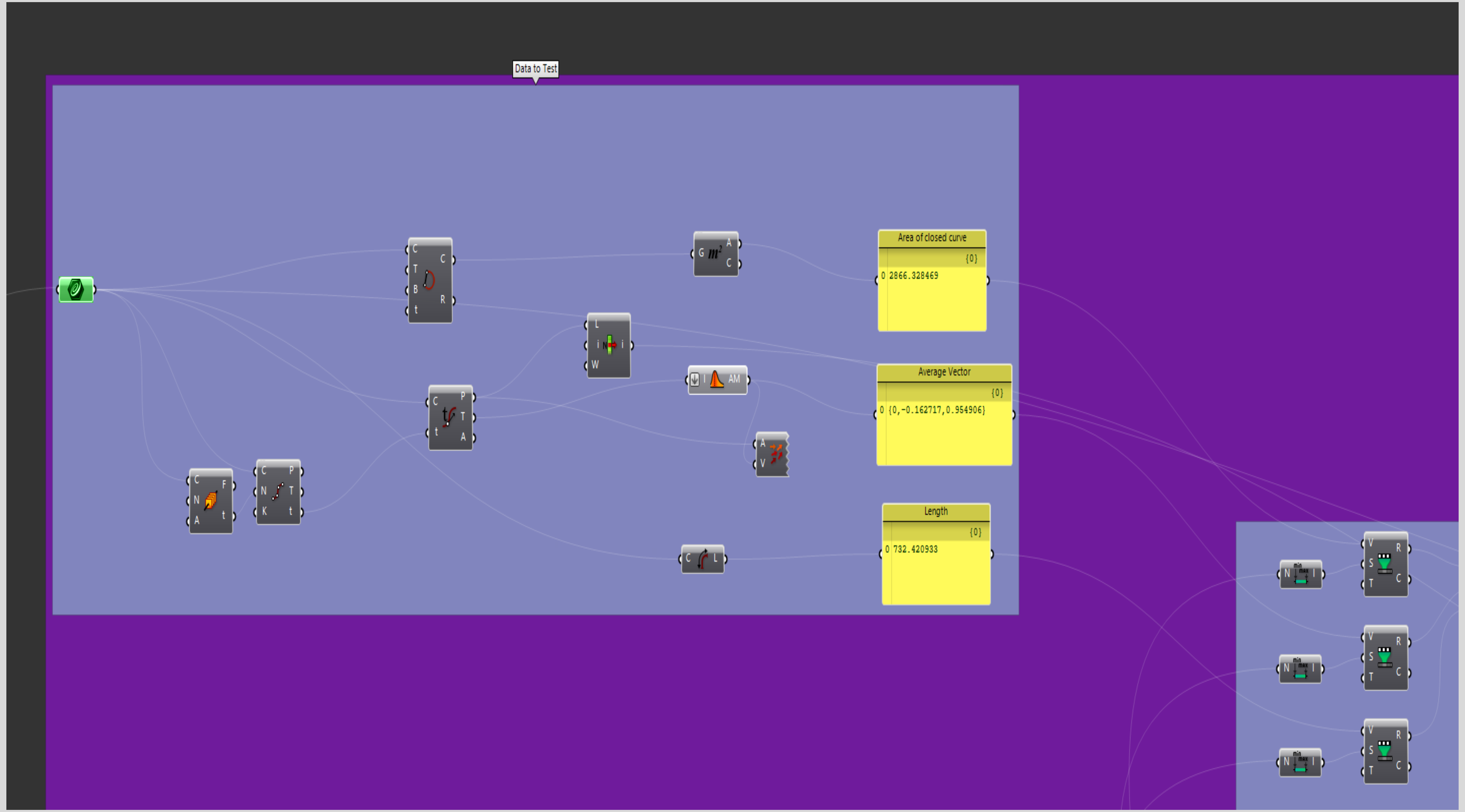
Model is trained with factors such as length, vector and area of the closed curve.



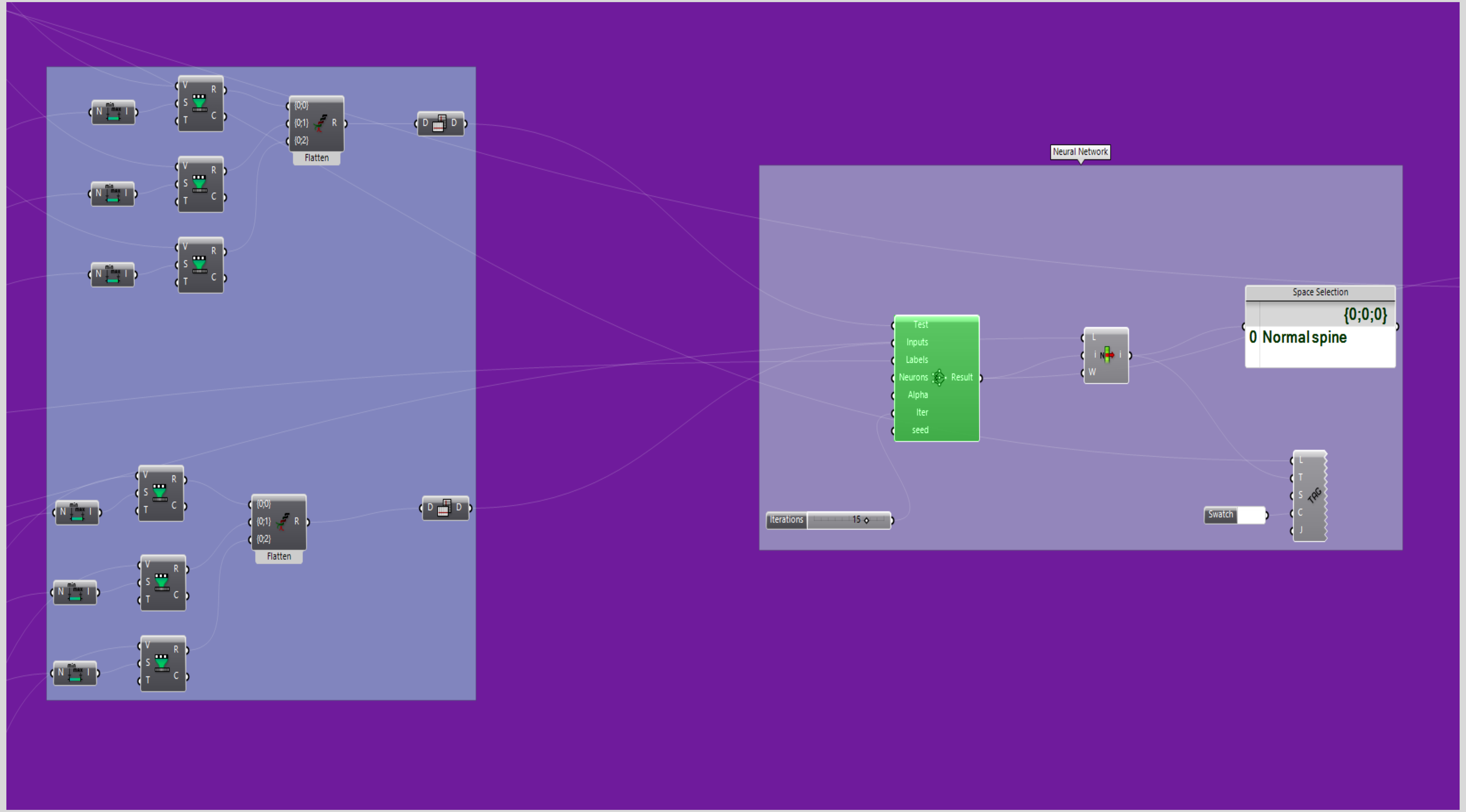
As it is mentioned in the structure of backend part, machine learning is taken into account as an evaluation tool which would be essential in a mass production.



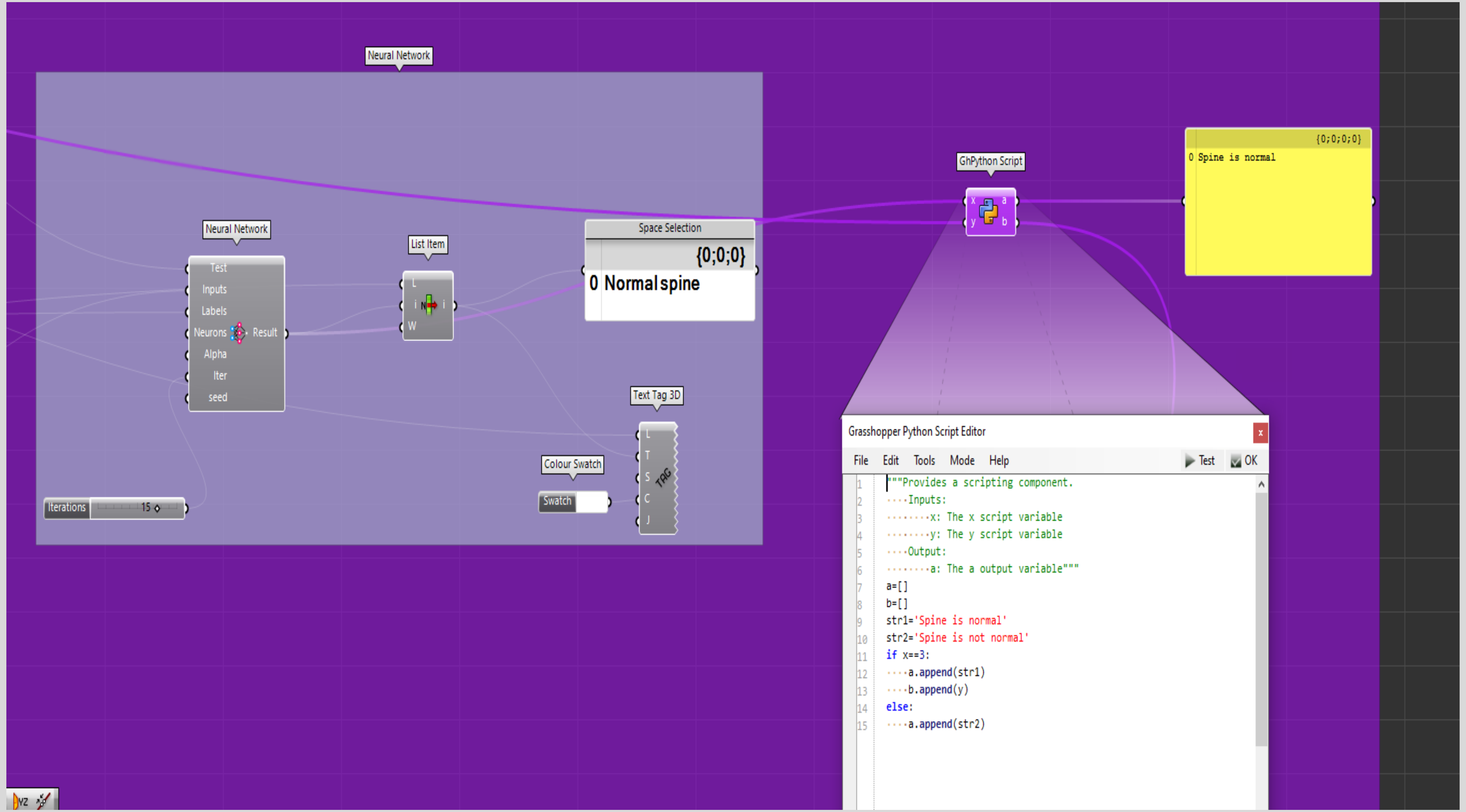




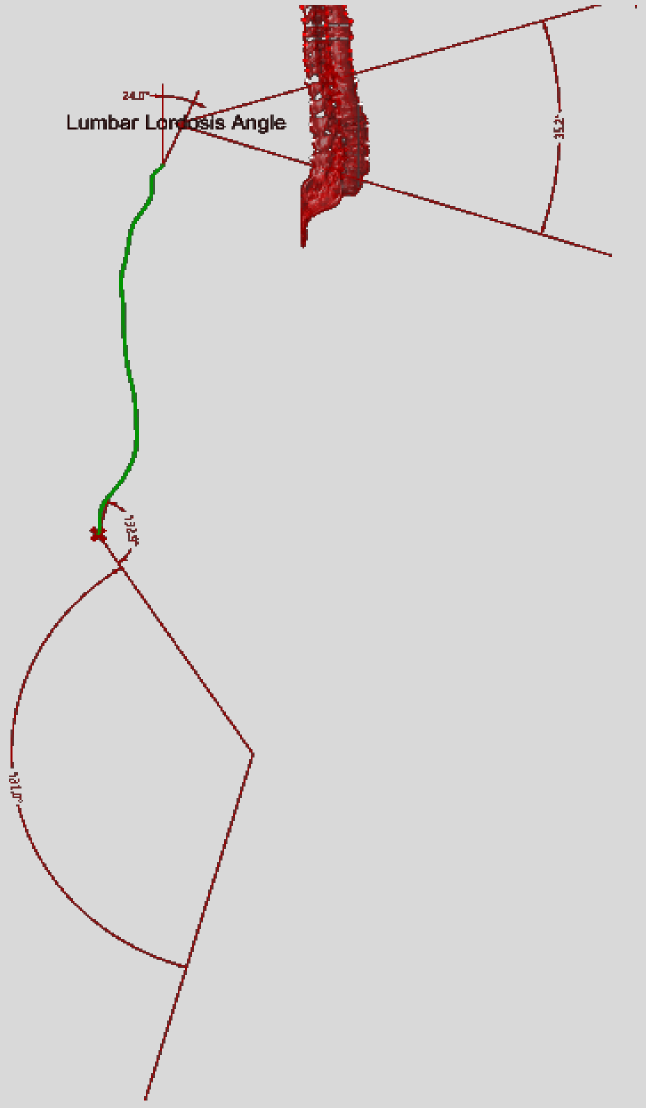
Average curvature is inserted to be tested & characterised.

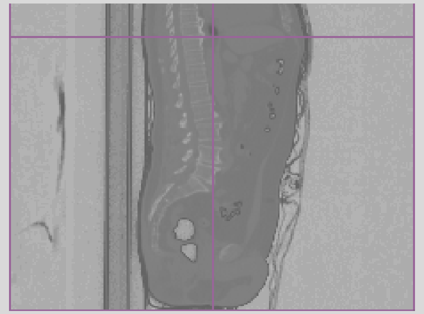


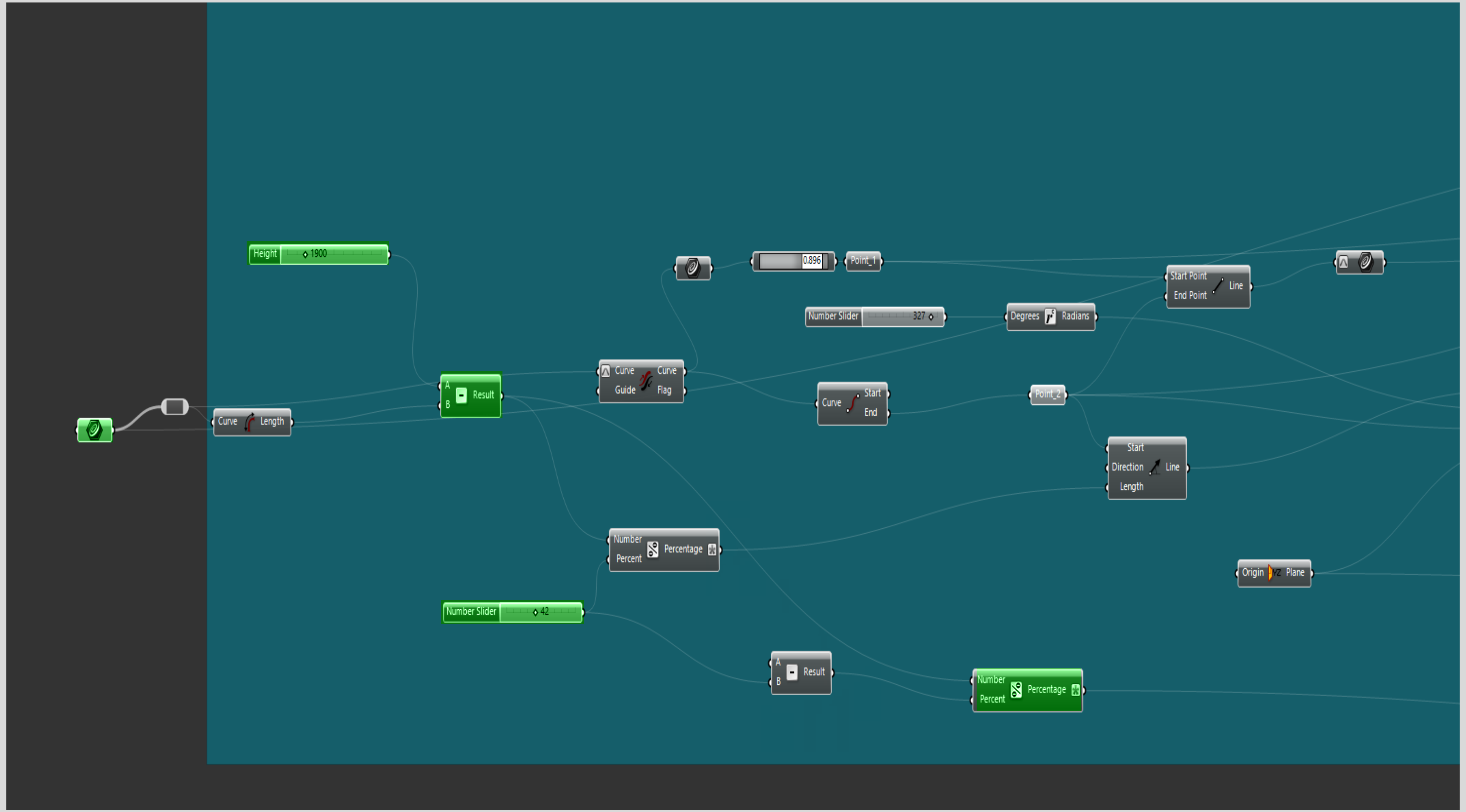
Neural Network shows inserted spine (curvature) is characterised as Normal.



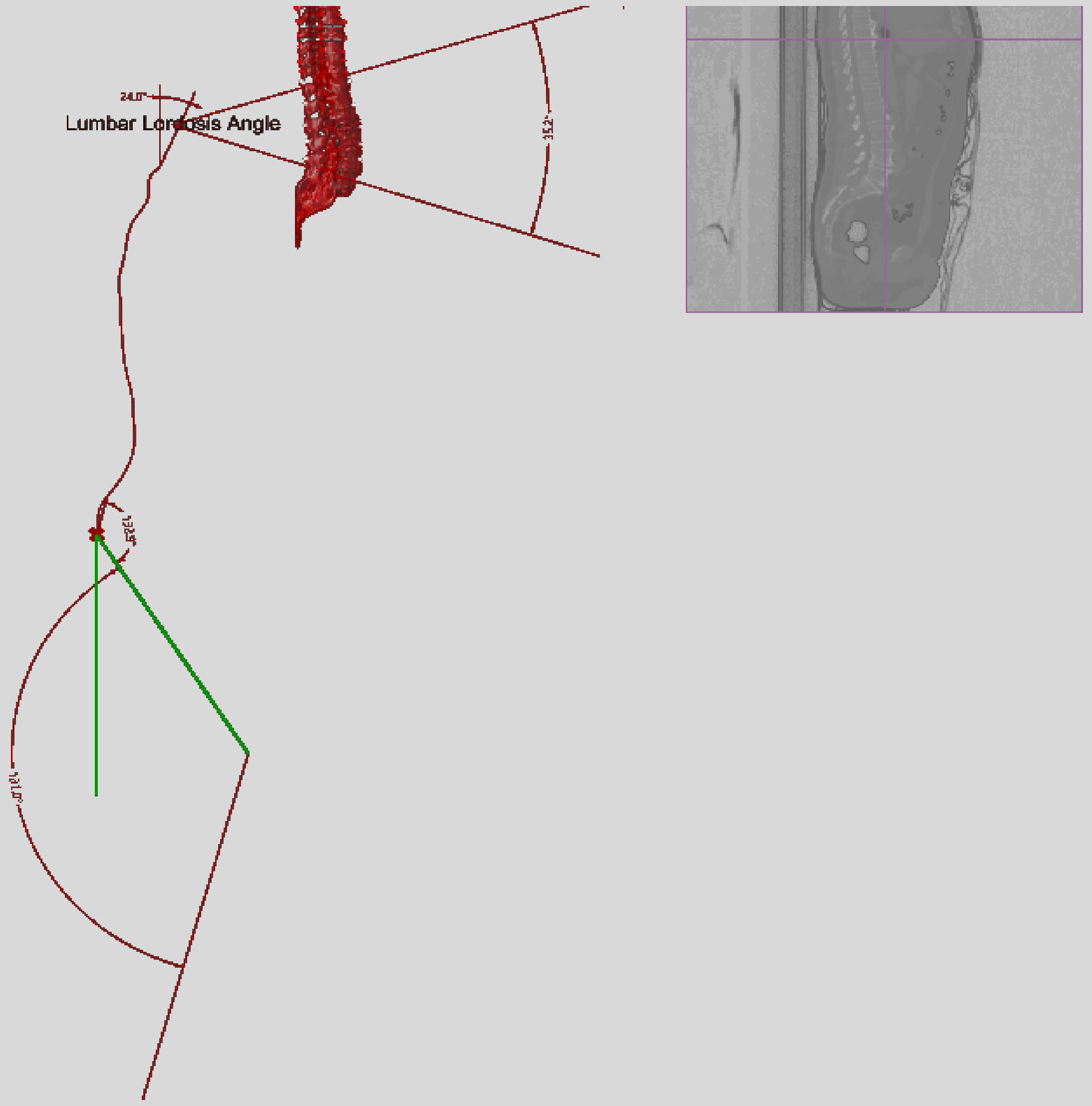
Python script for characterization of the spine.



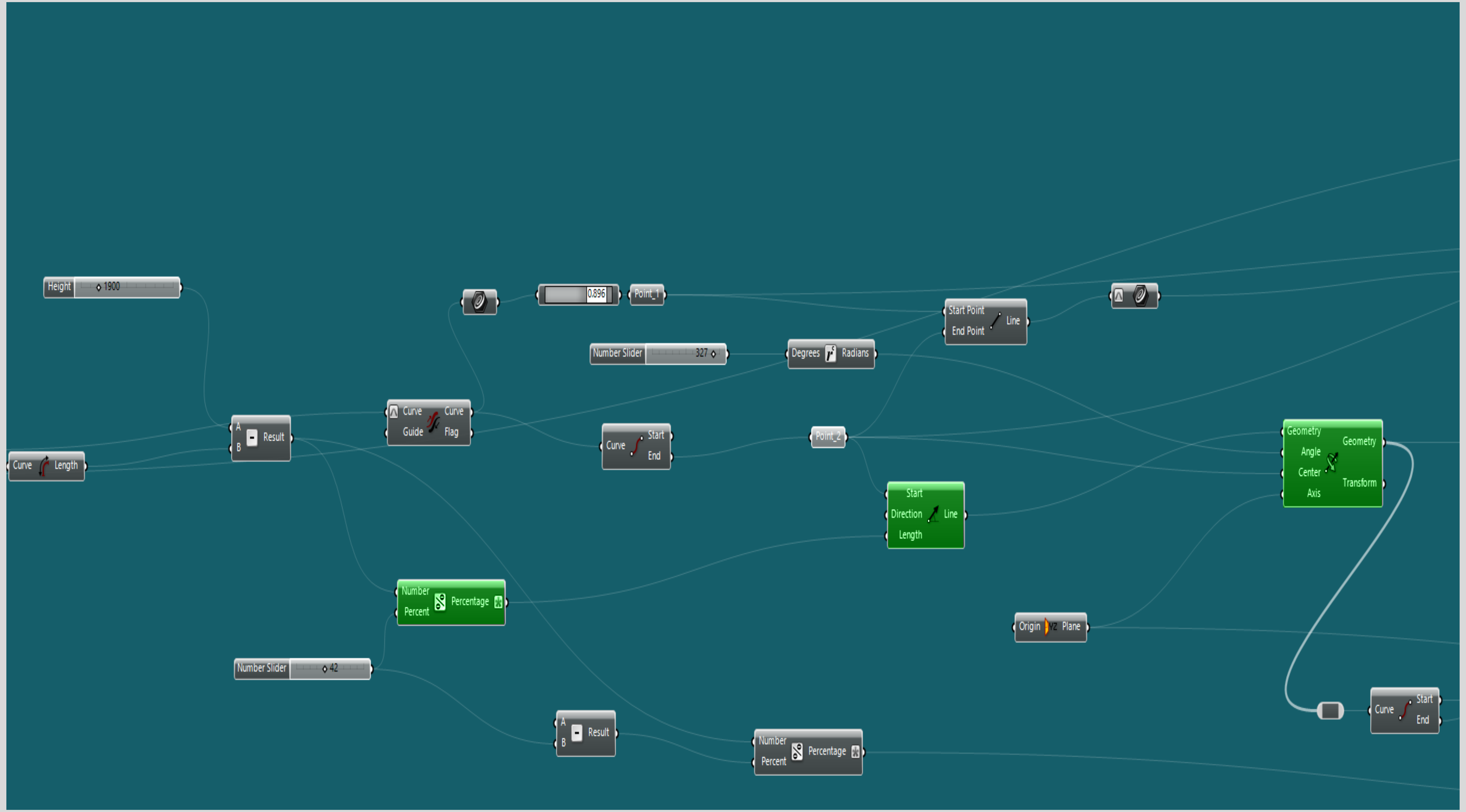




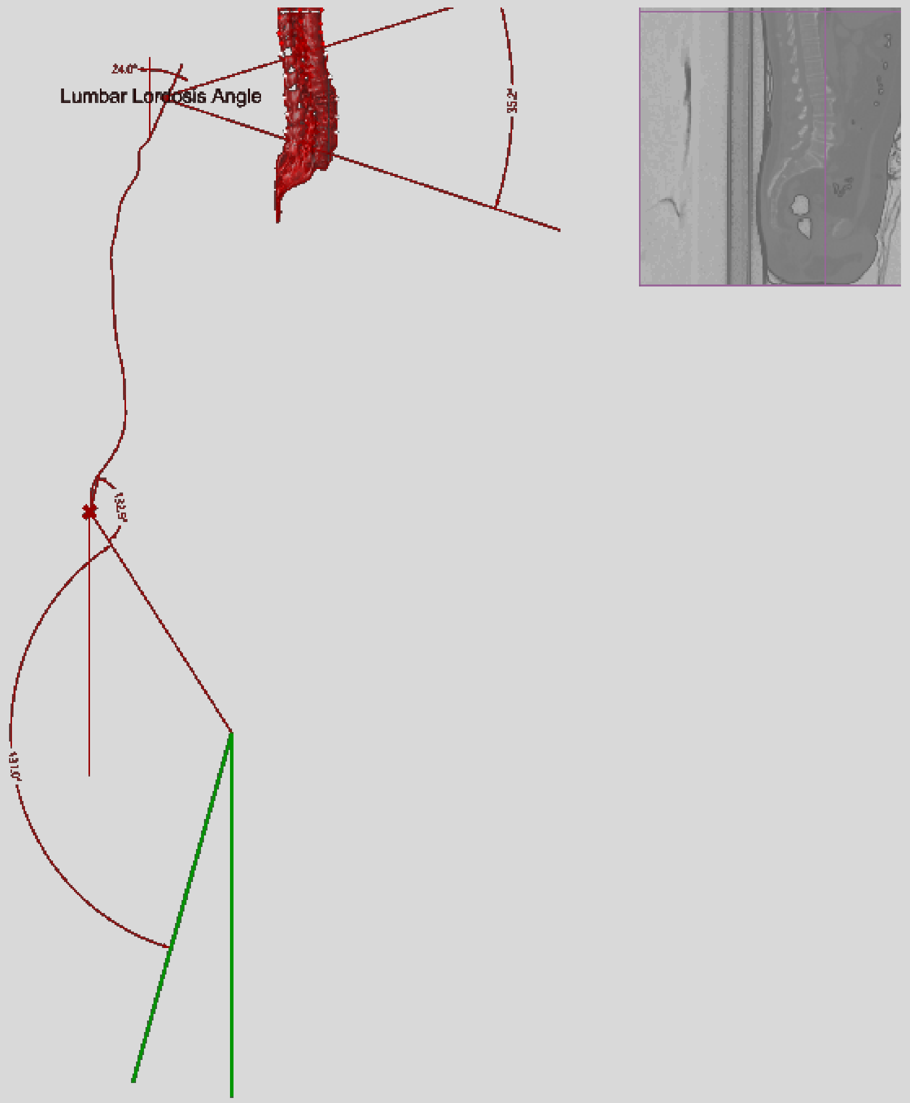
Height parameter is considered for 1.9m , and 73cm is the length of the spine. The 42% of the remainder is the part between trunk-knees & 58% the part between knees and ankles.



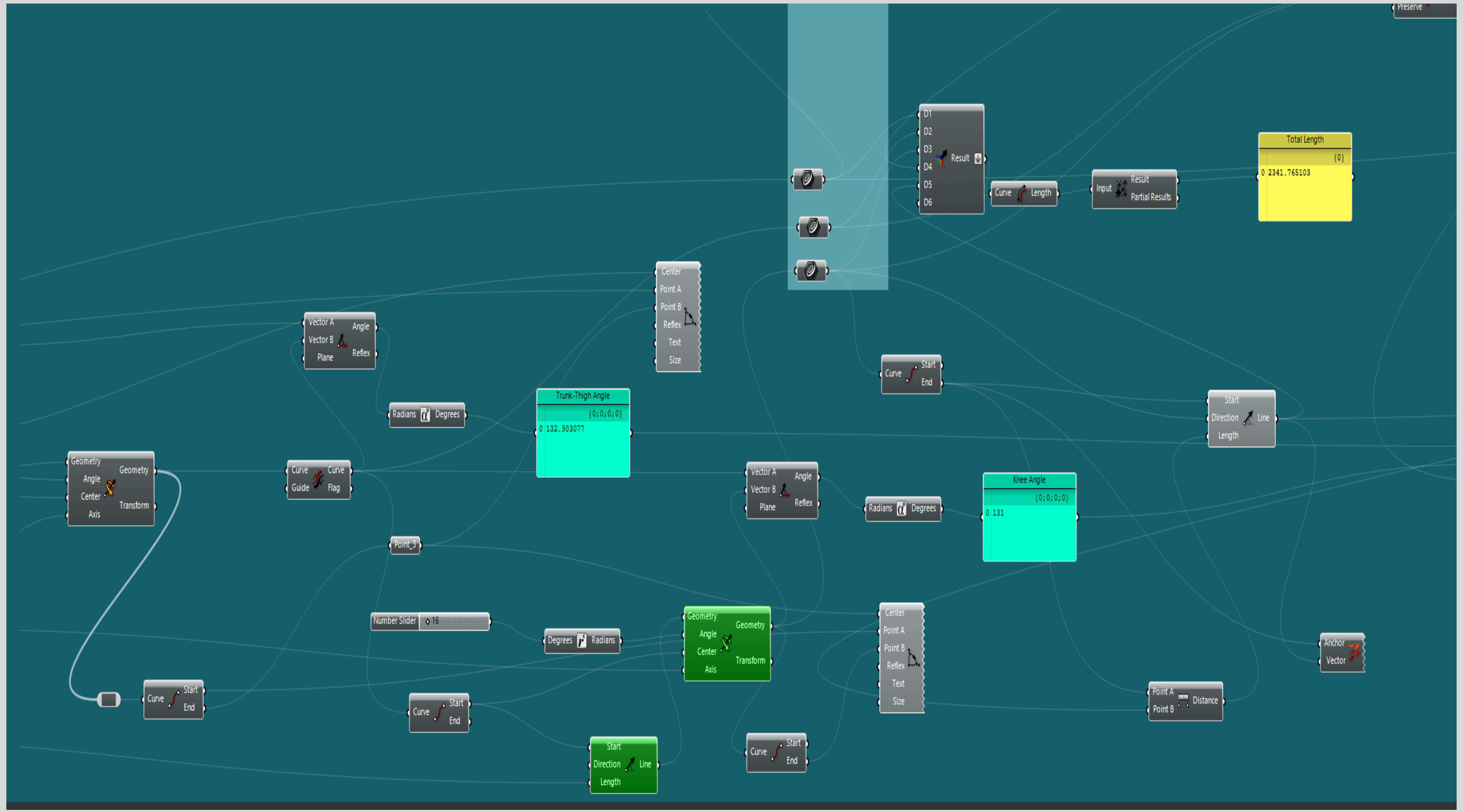
Part between trunk-knees is displayed.



Angle between trunk-knees is set to 132 degrees.

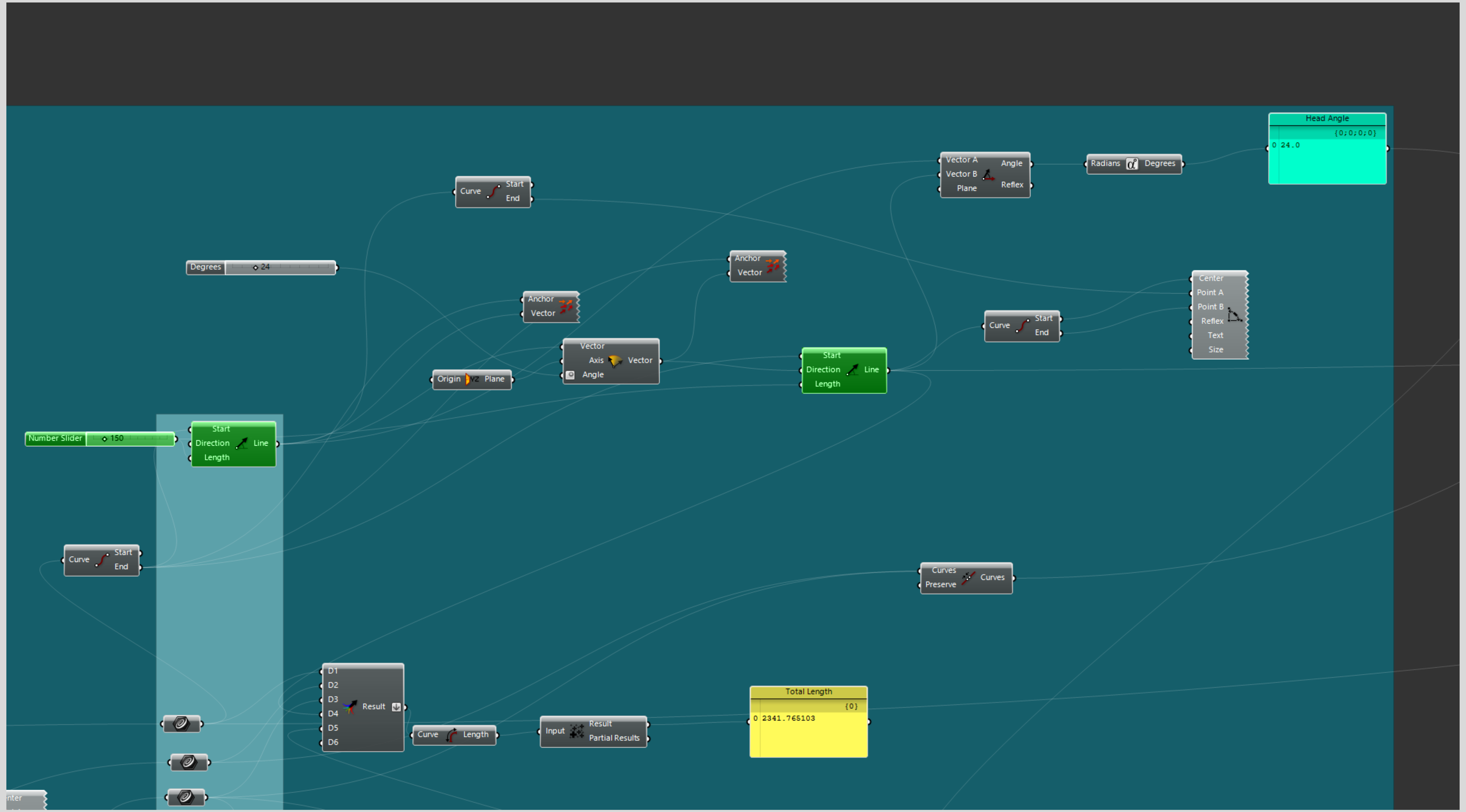


Part between knees-angles is displayed.

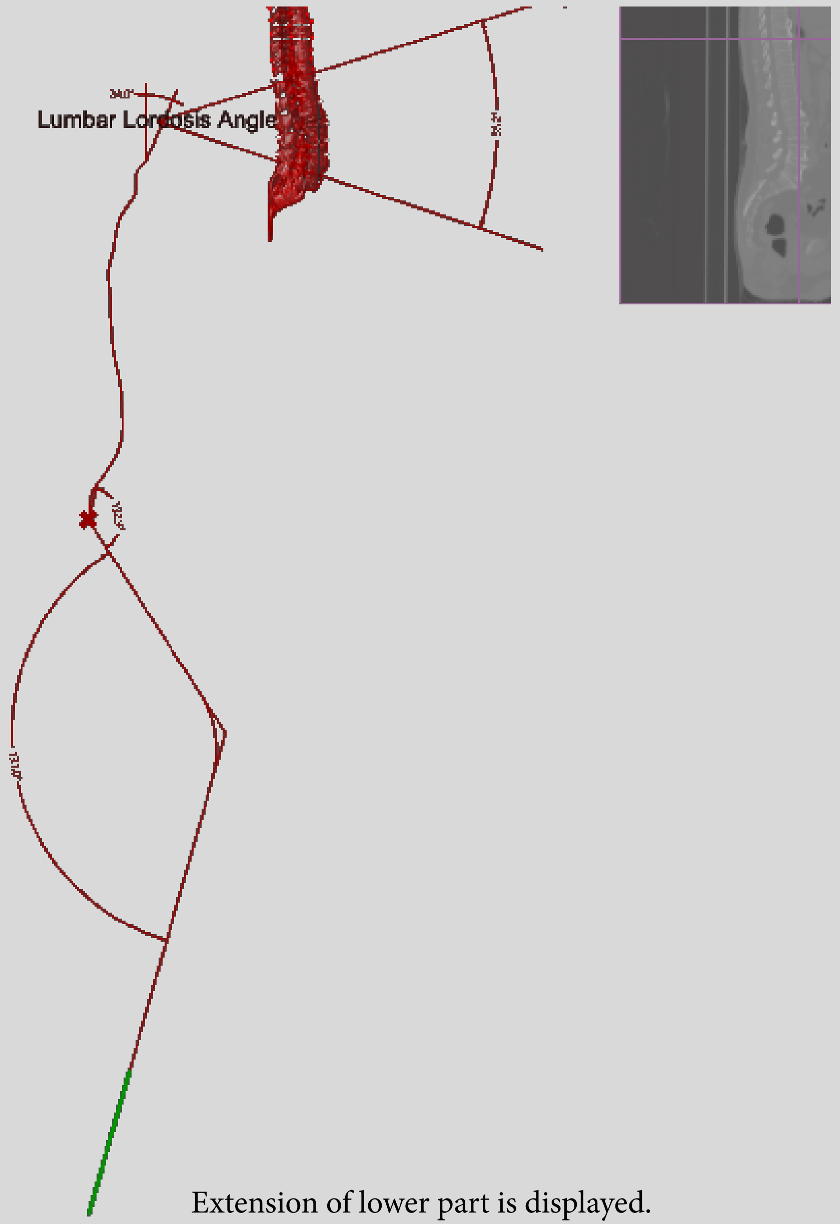


Knee angle is set to 131 degrees.

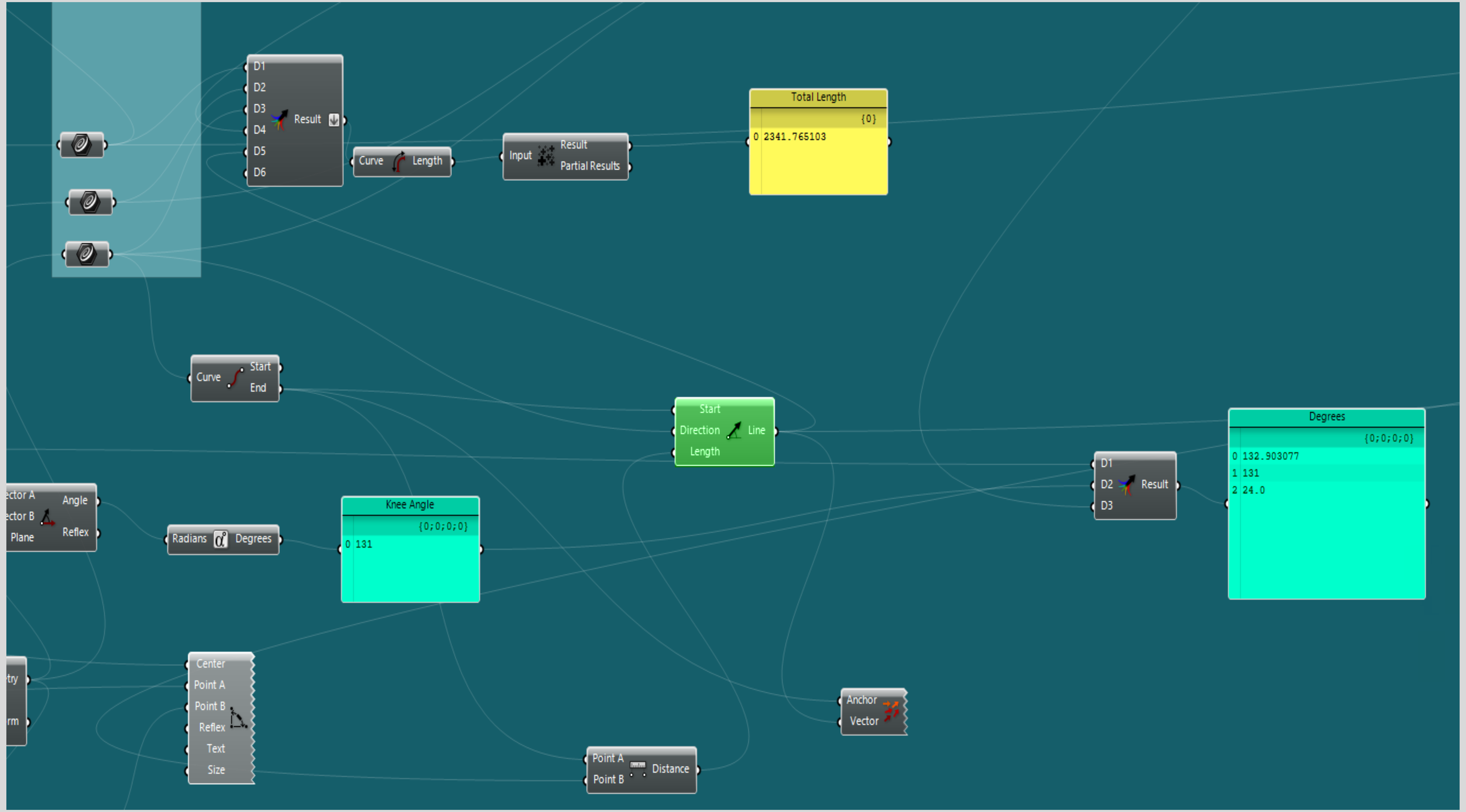
Upper part is displayed.



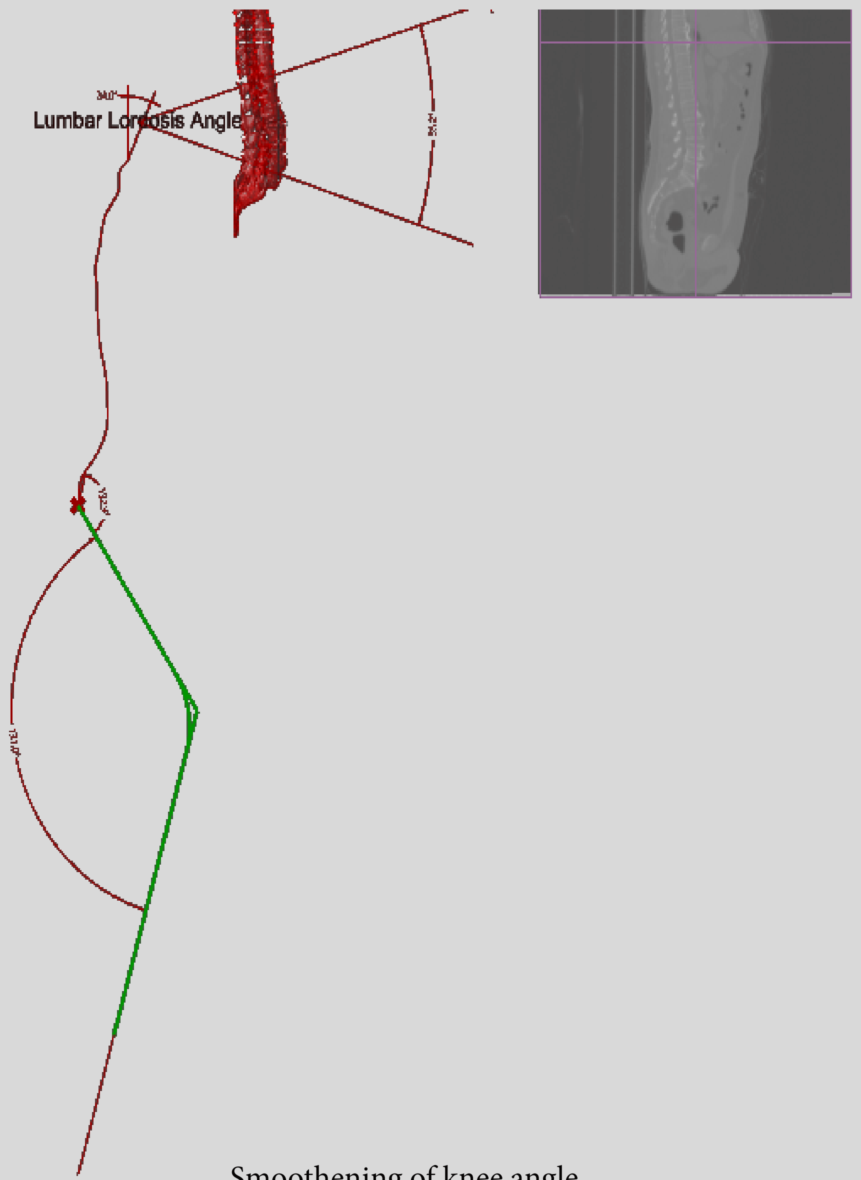
Head-neck angle is set to 24 degrees.



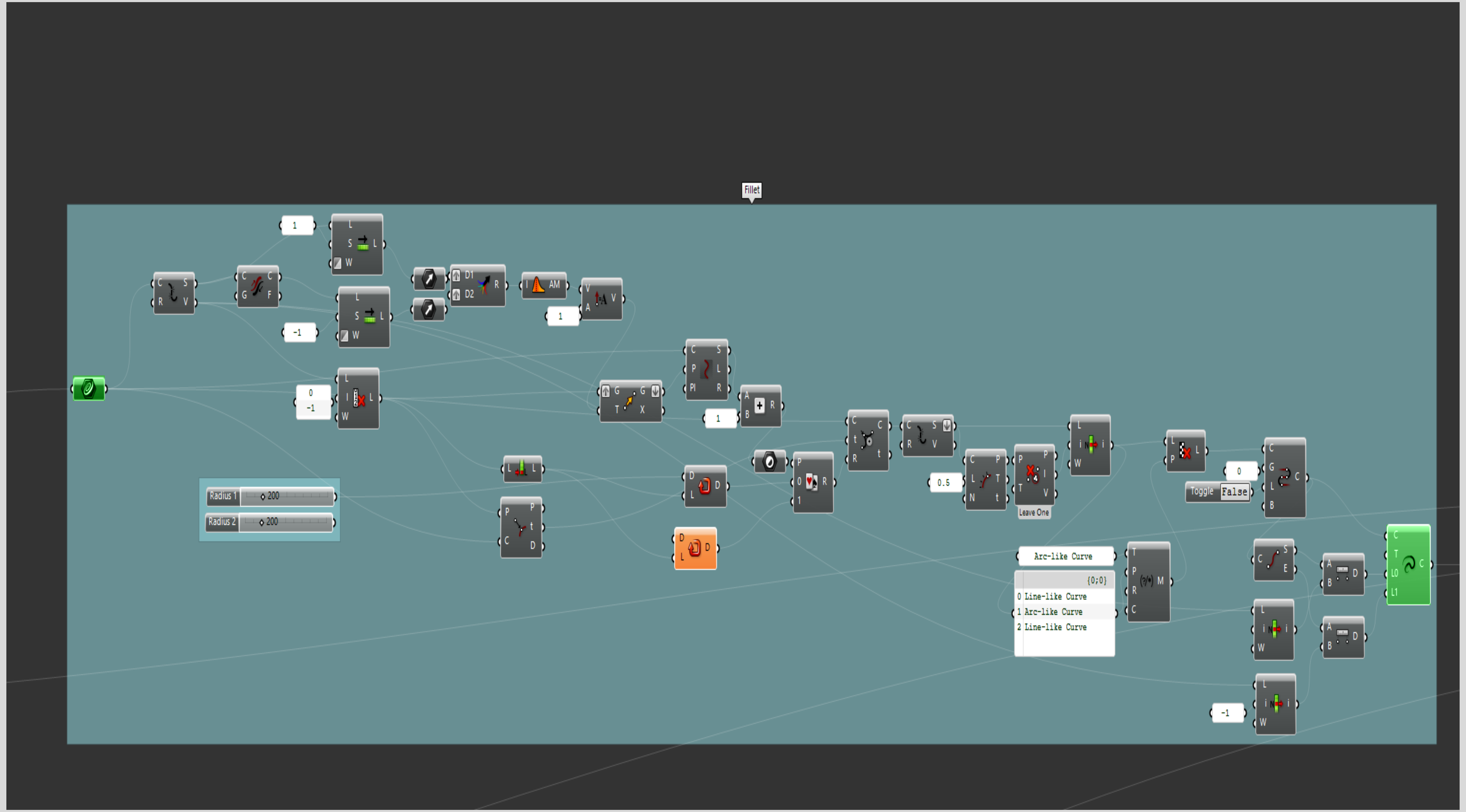
Extension of lower part is displayed.

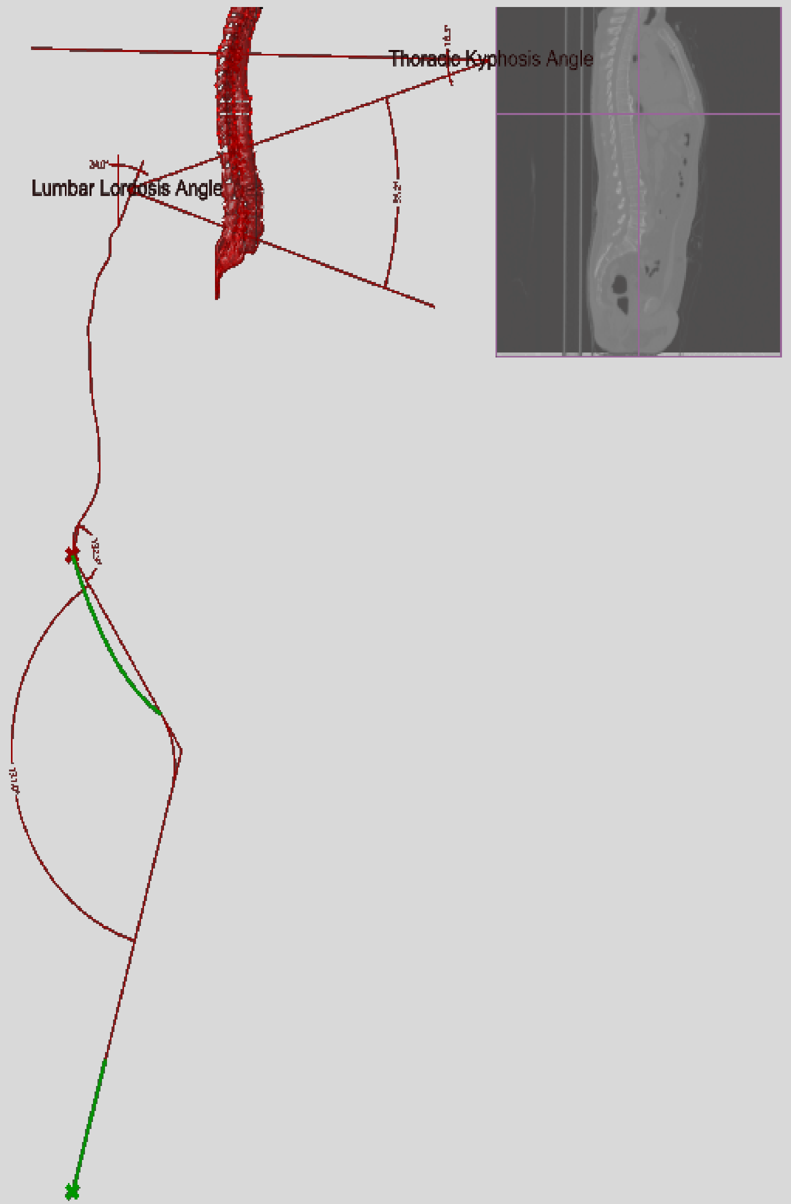


Total length: neck, spine, trunk-thigh, knee-ankle parts & extension in summary.

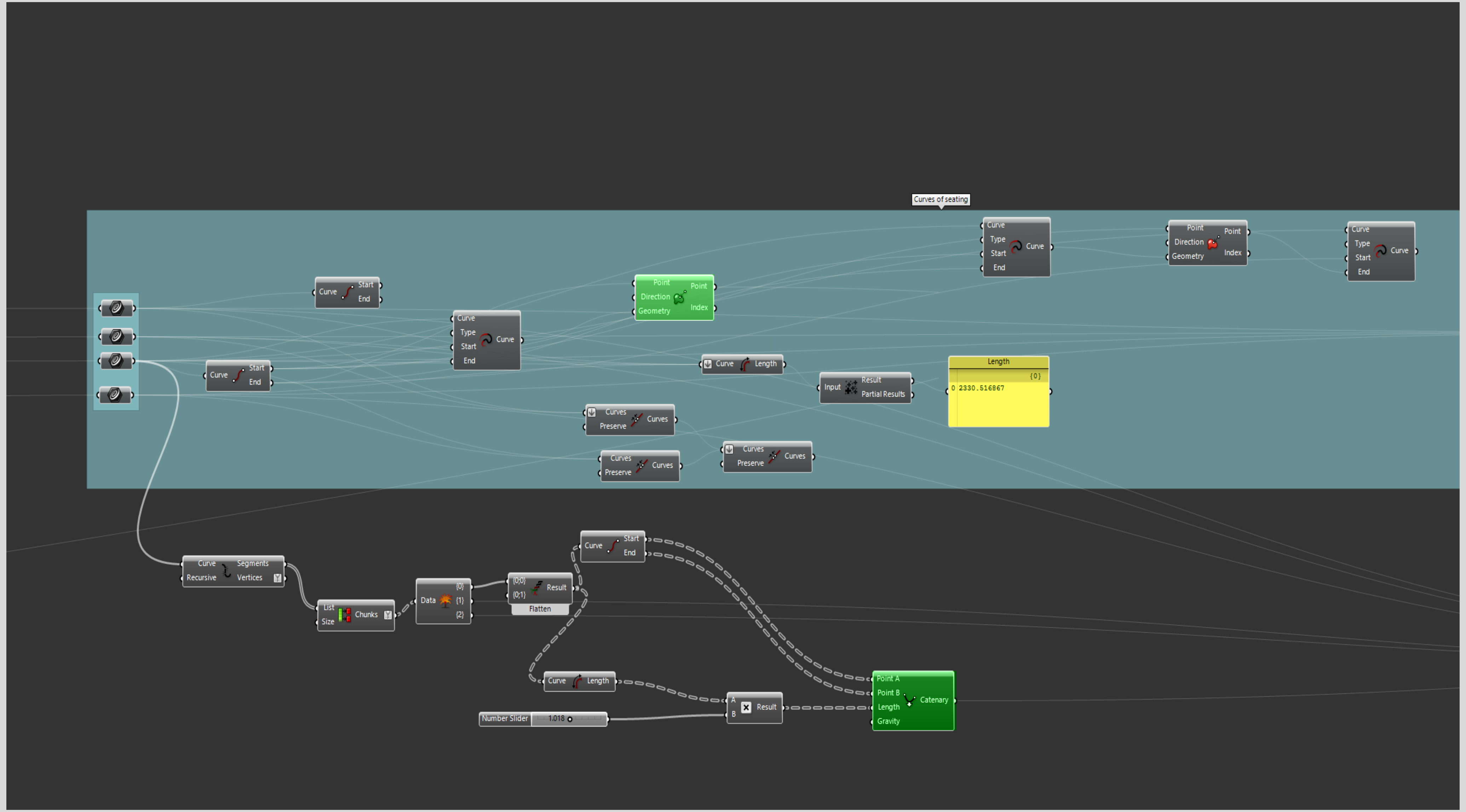


Smoothening of knee angle.

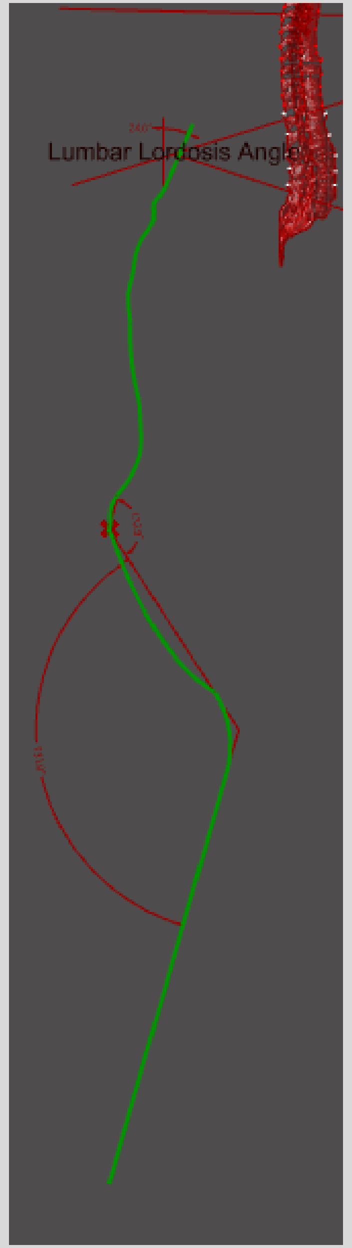


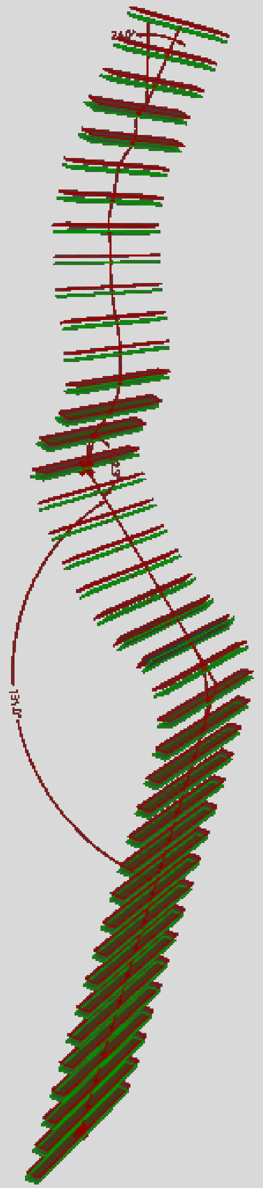


Part between trunk-thighs with a more curvy form.

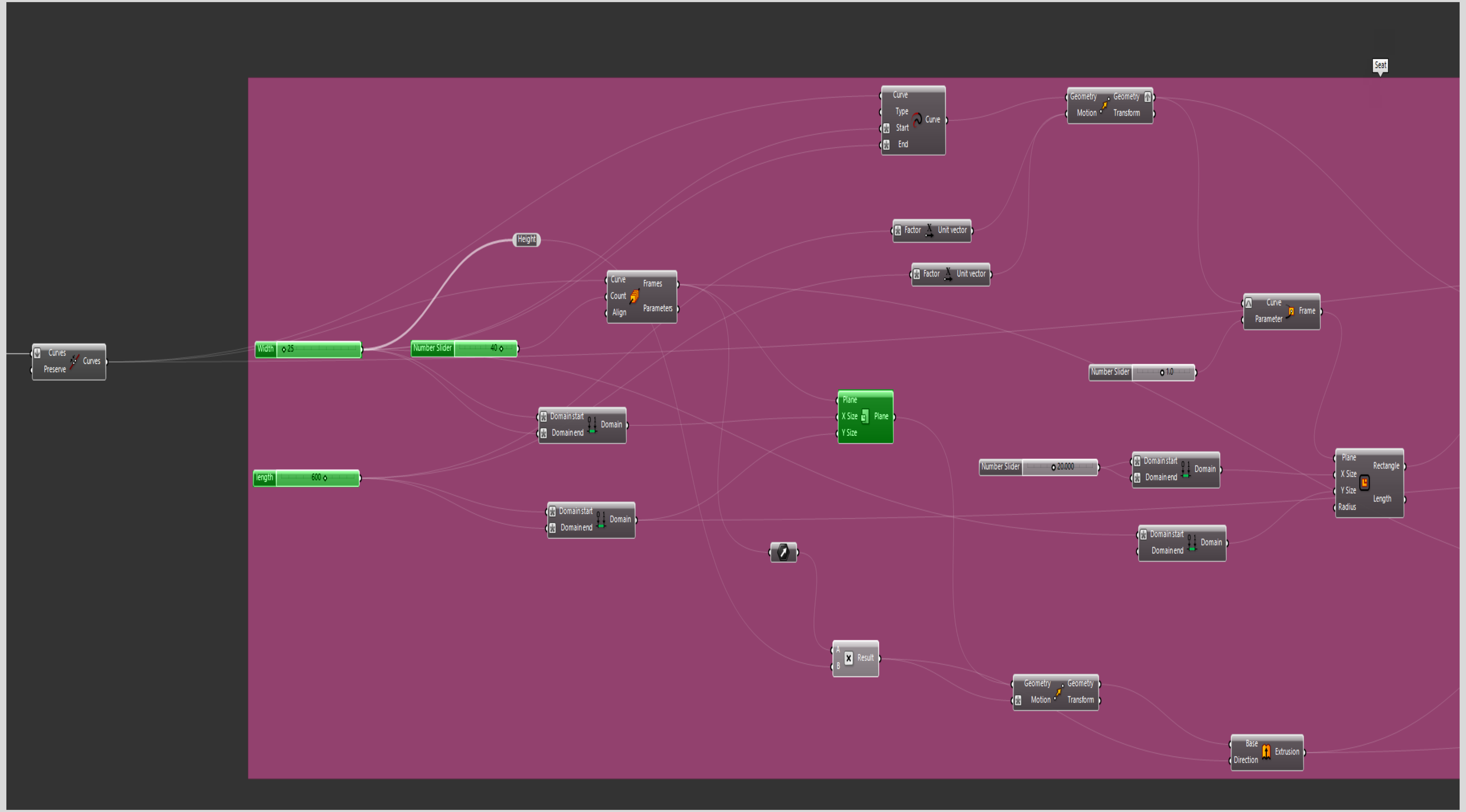


Catenary component to increase curvature.

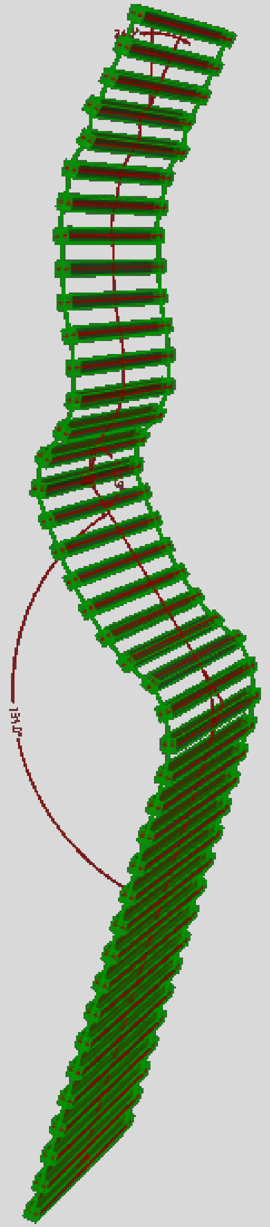


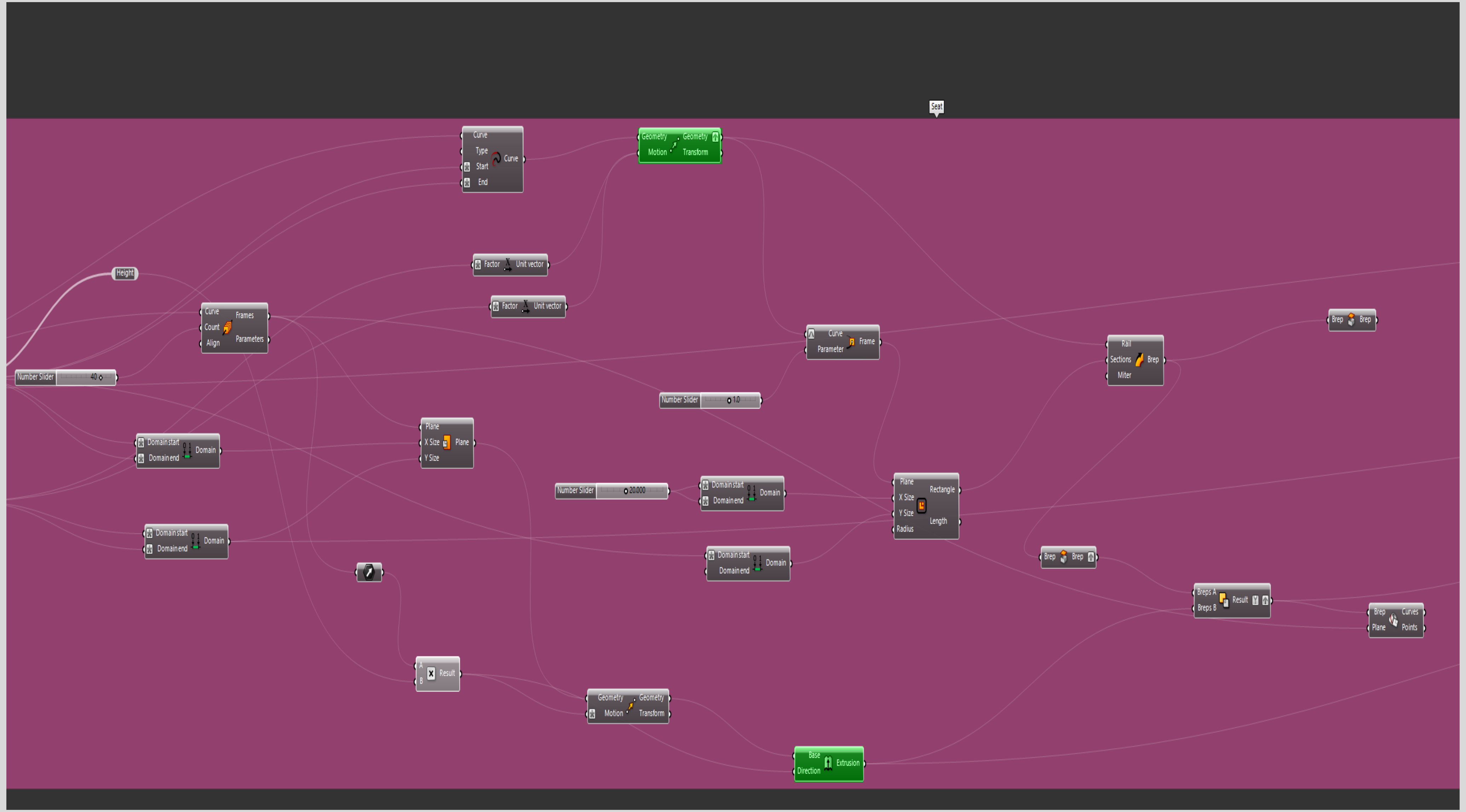


Updated curve used for seating geometry.

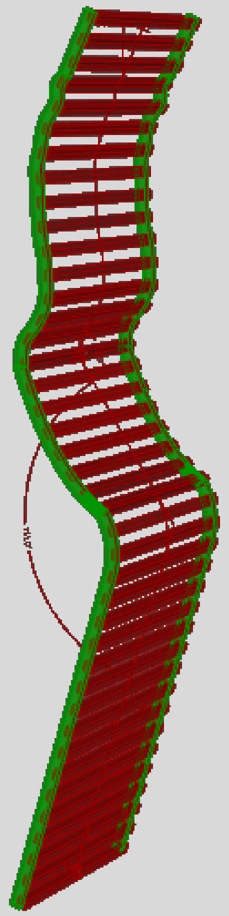


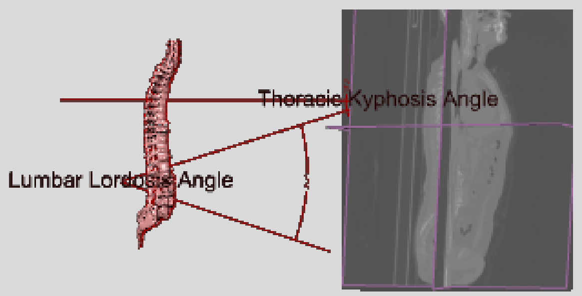
40 Pieces are constructed with 60cm length & 2,5cm width.

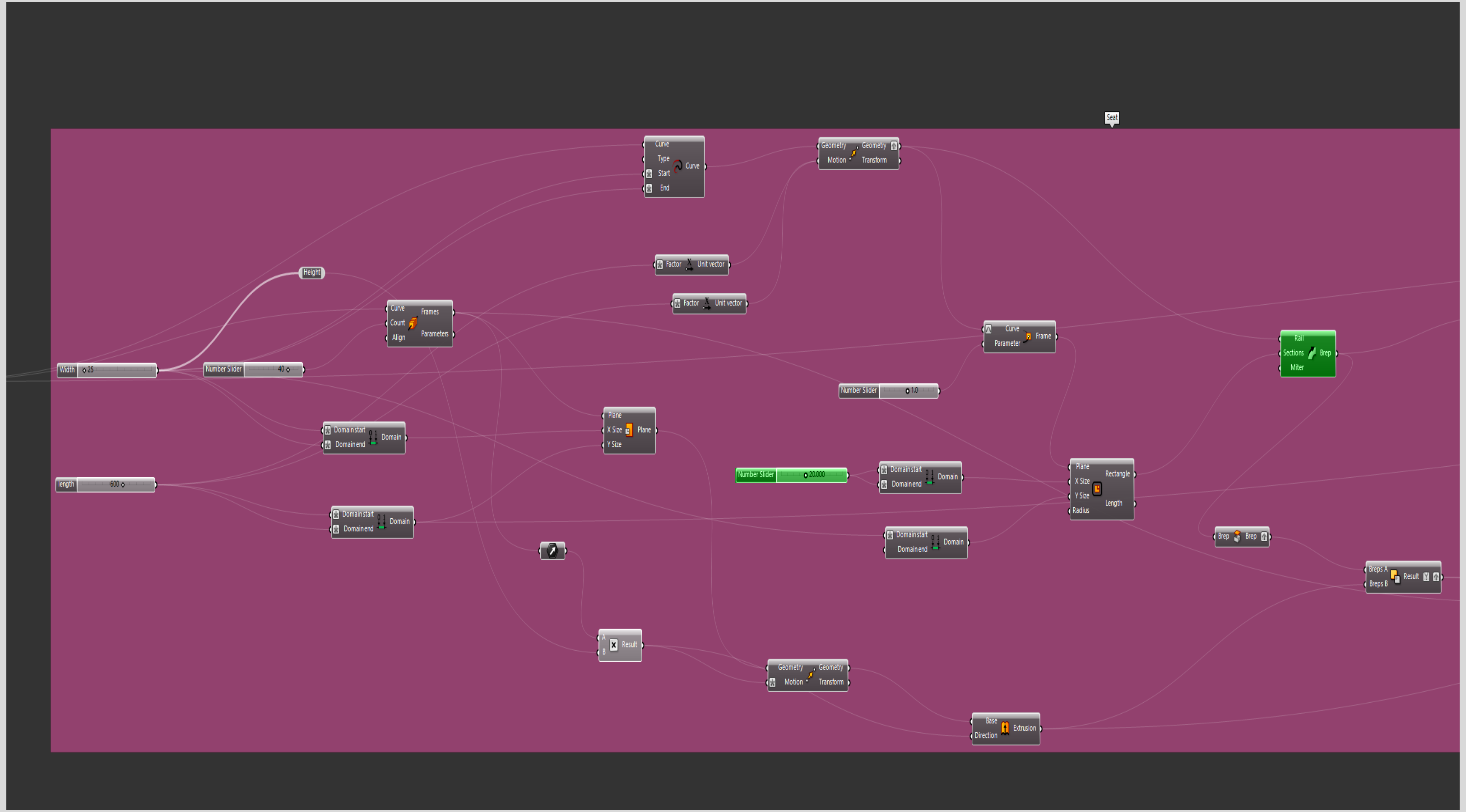




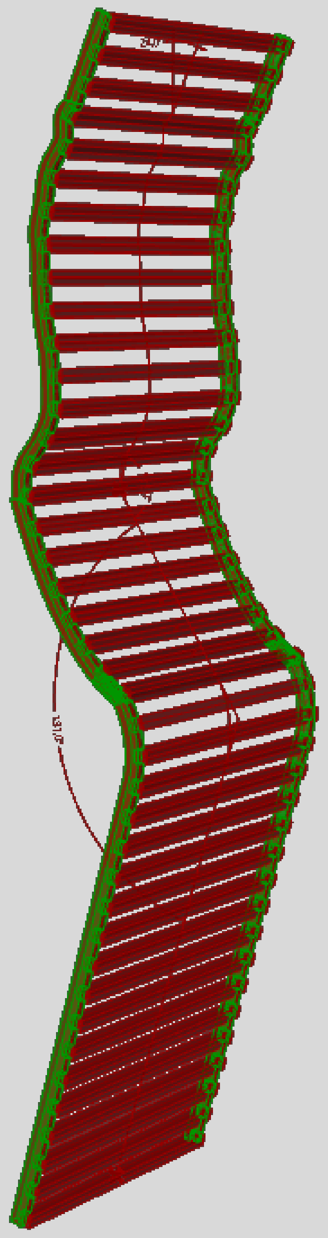
Extruded geometry of seating.

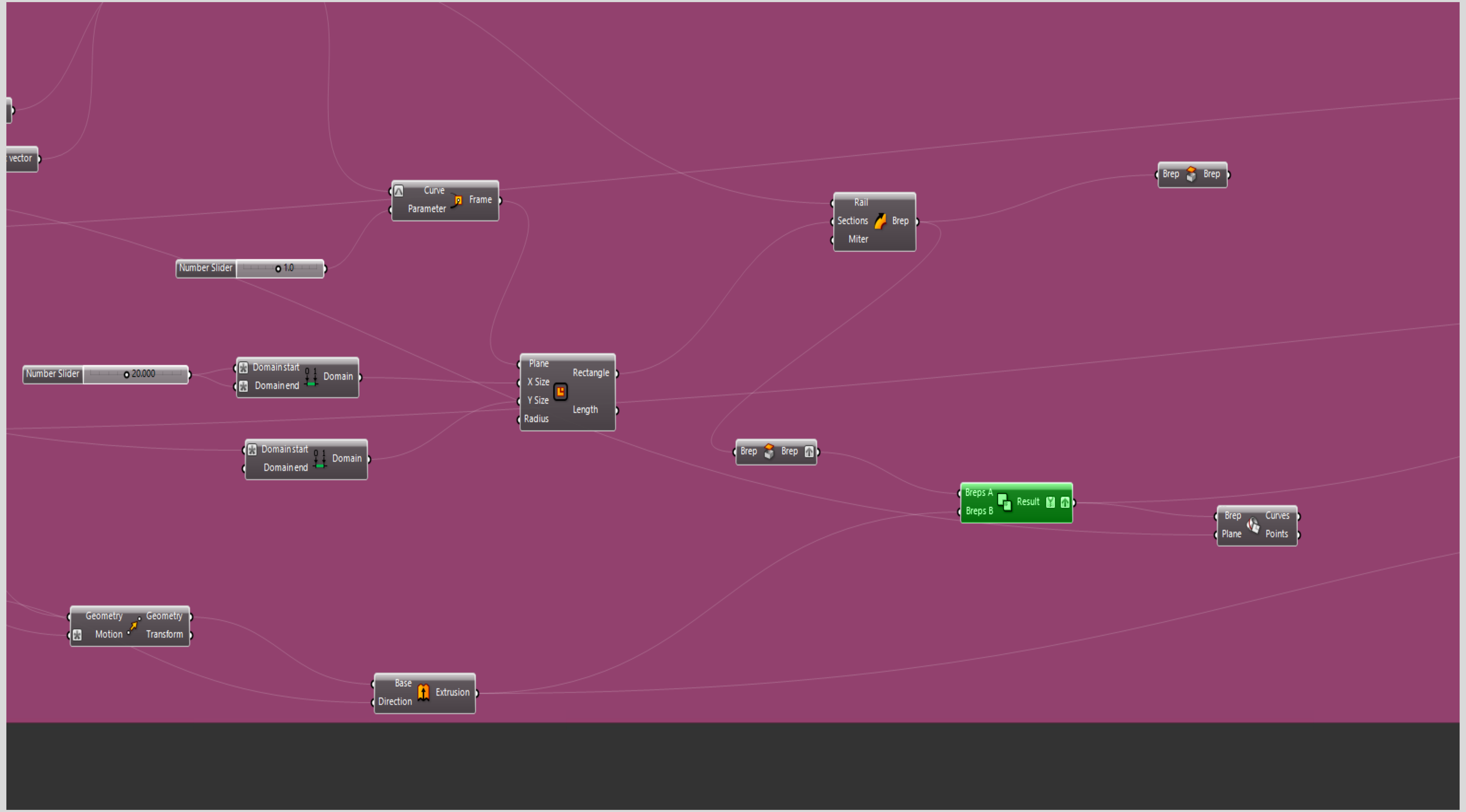




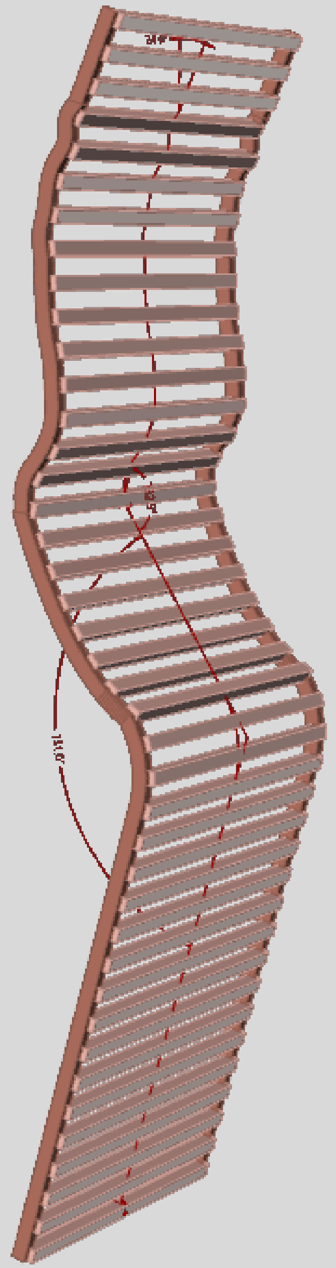


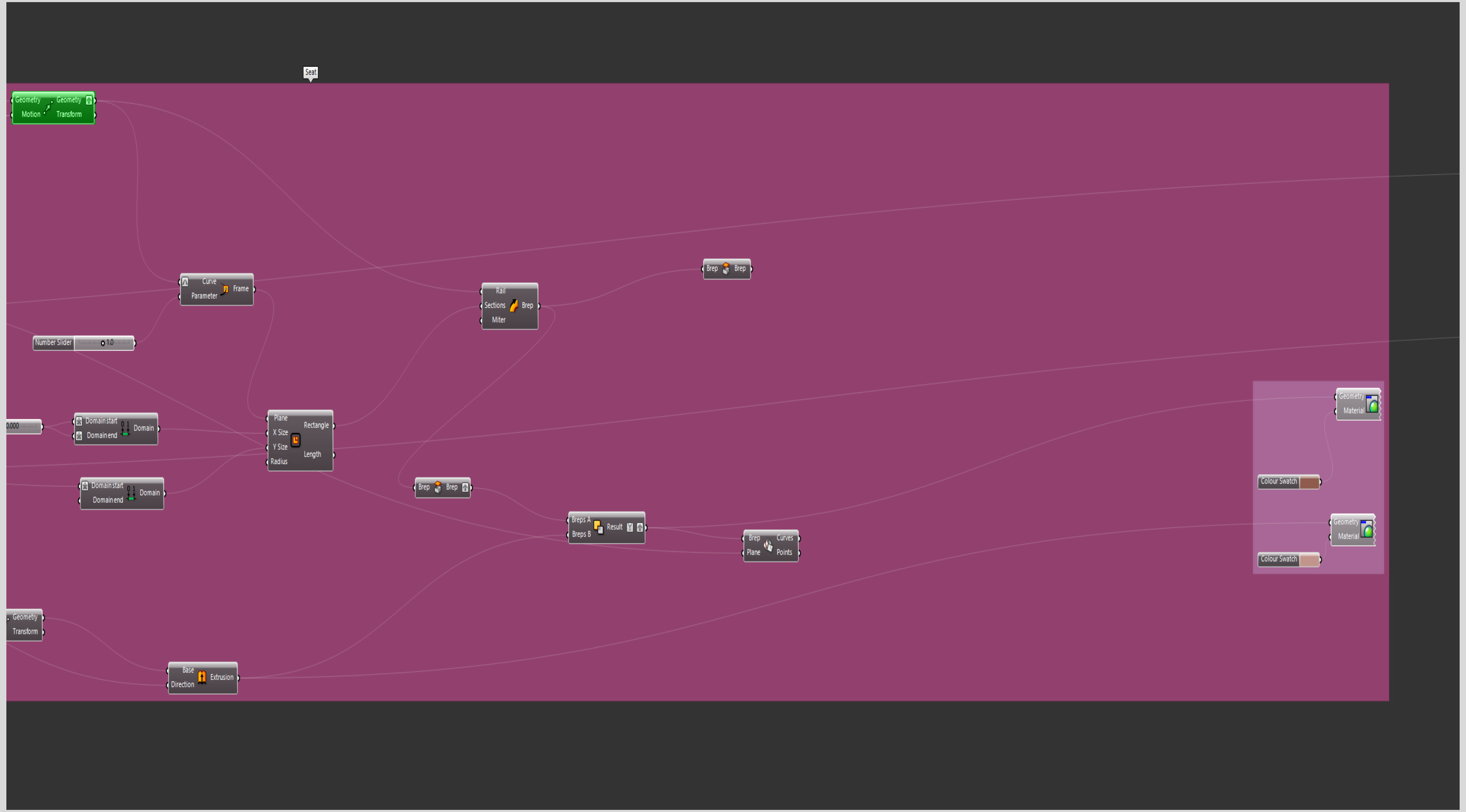
Length of arms is set to 2cm.



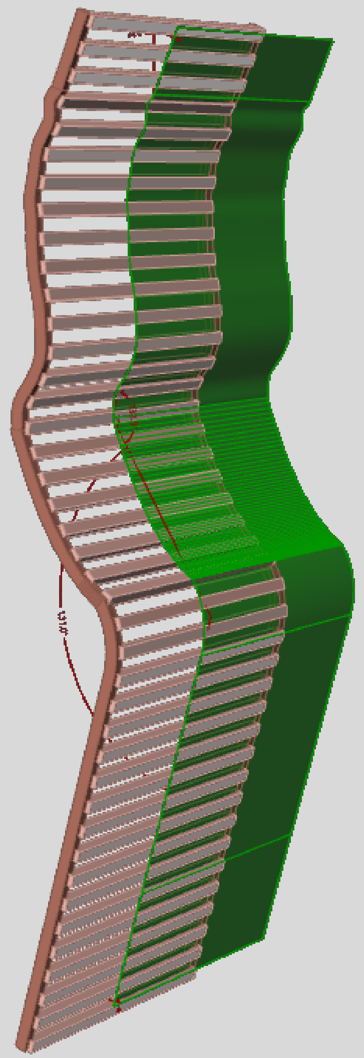


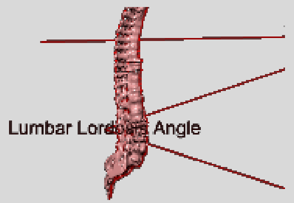
Difference between arms and sitting pieces is calculated.

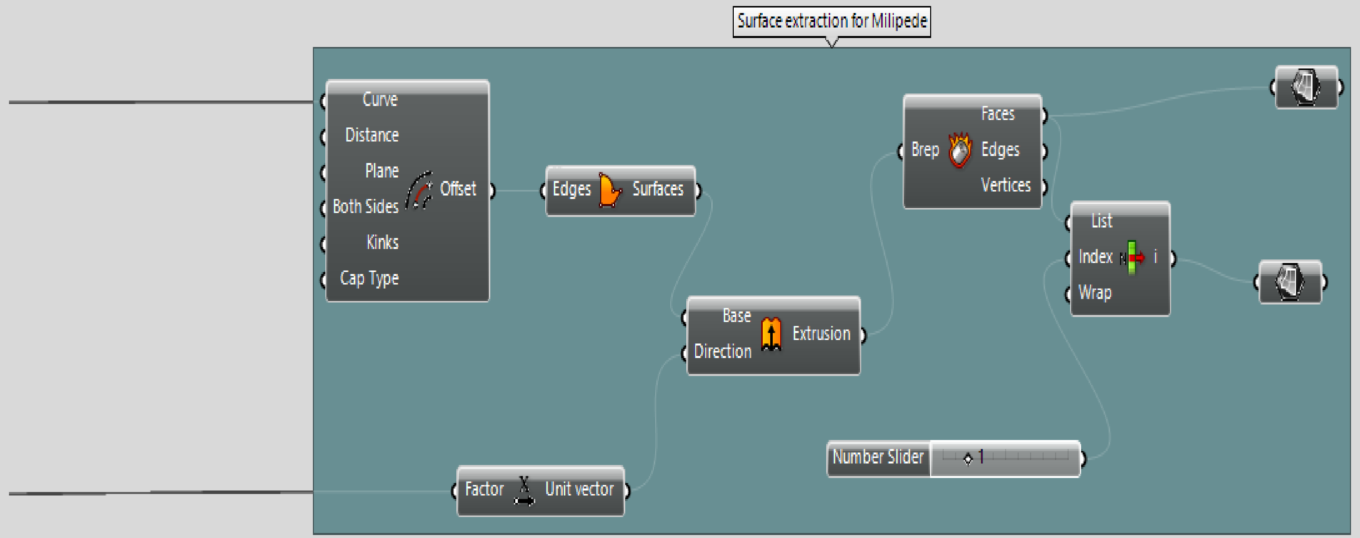




Final seating geometry is displayed.

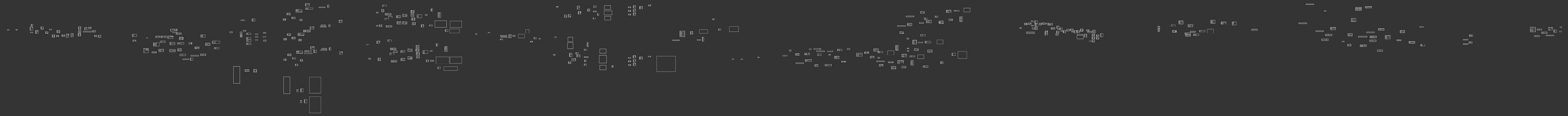






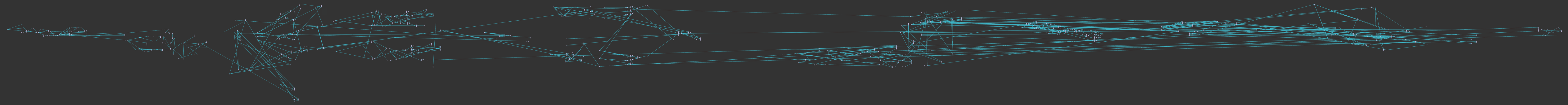
Surface calculation for milipede fem analysis.


Side View Analysis
Spine Outline Calculation
Curves
Curvical Curves
Thoracic Curves
Lumbar Curves
Vertabrae % of Spine
Thoracic Kyphosis Angle Calculation
Lumbar Lordosis Angle Calculation
Rebuild of Curve
Machine Learning
Data to Test
Training Data
Neural Network
Angles
Filter
Curves of Seating
Seating
Surface extraction for Milipede



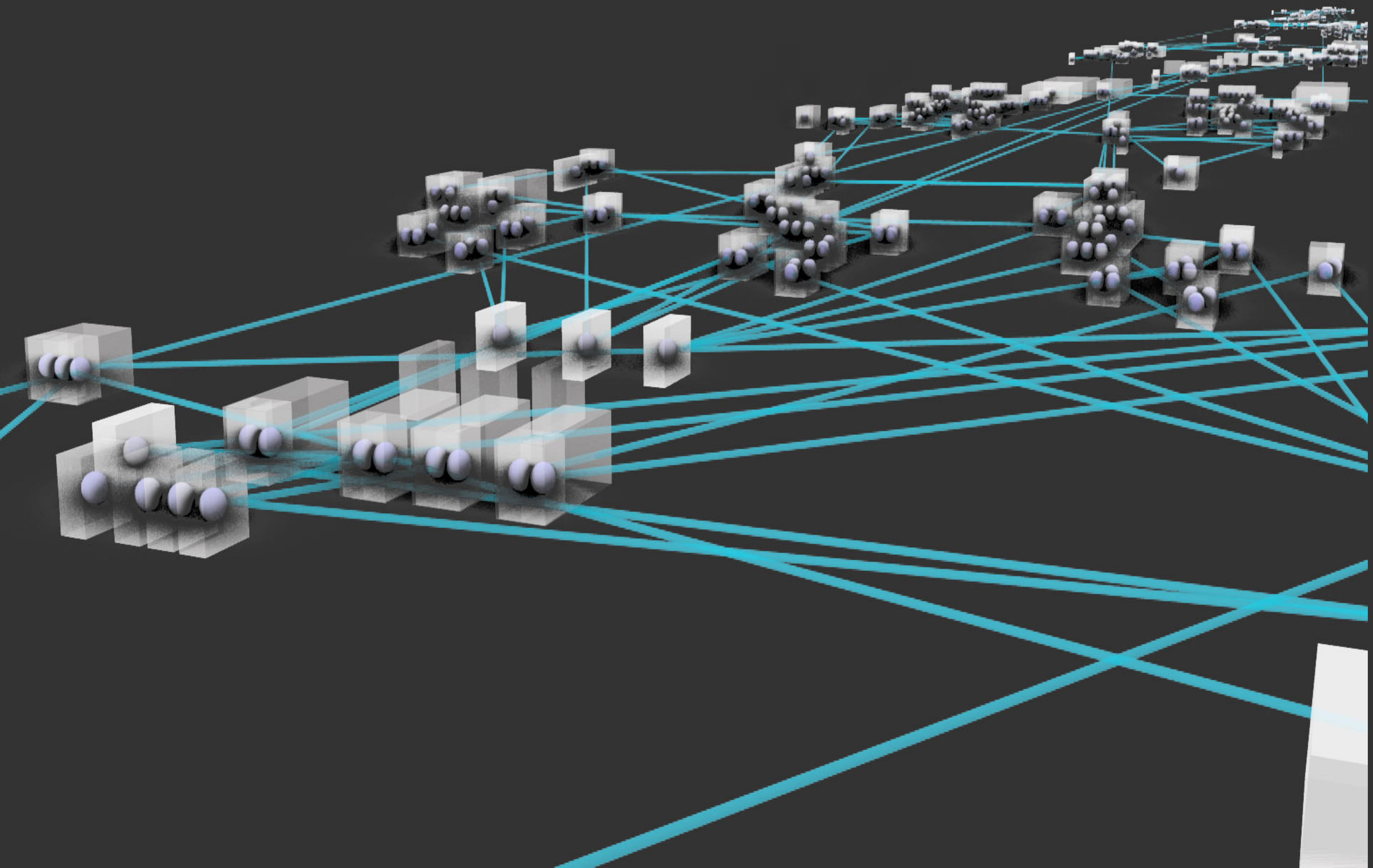
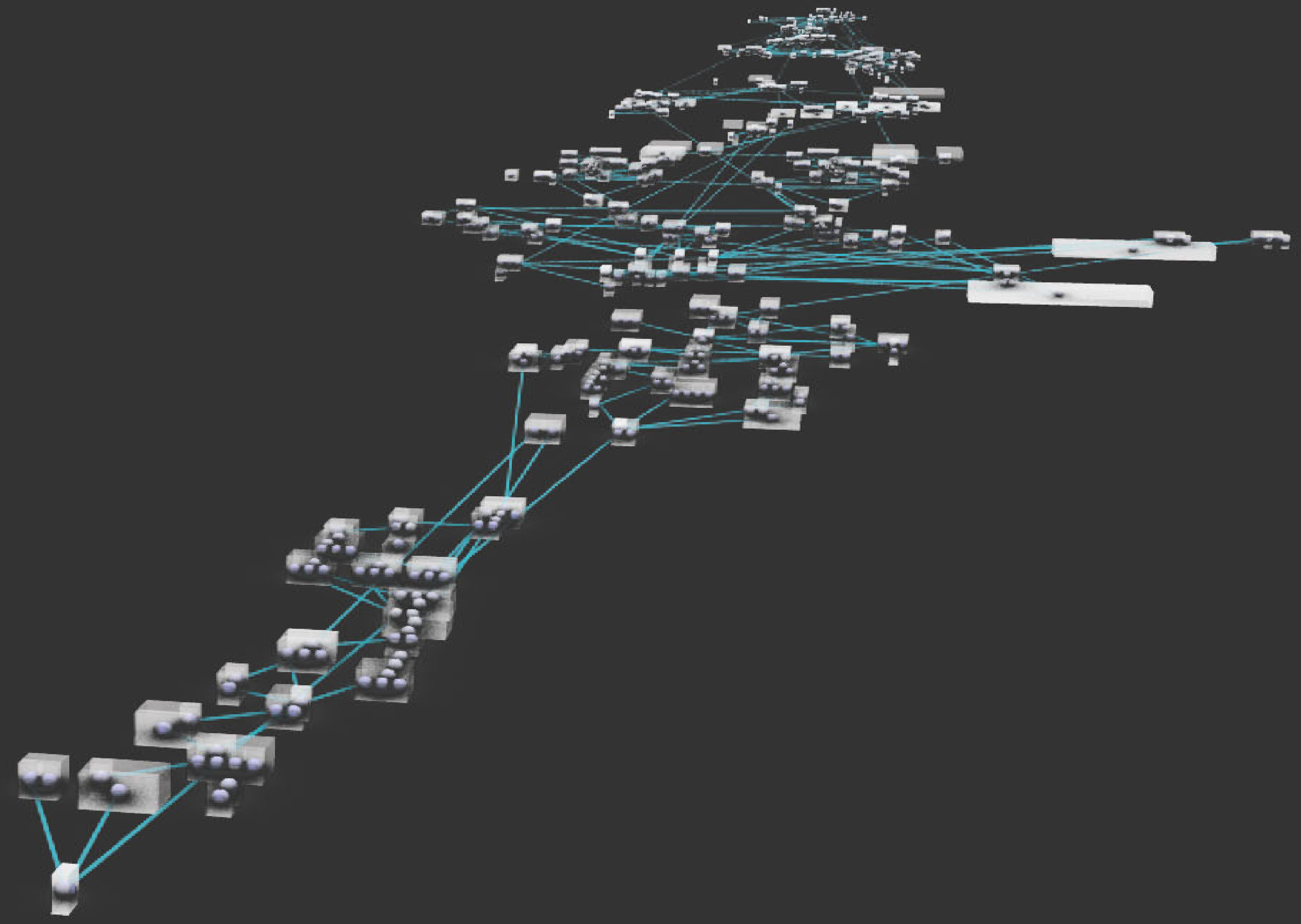
318 COMPONENTS

140 PARAMS



540 WIRES

703 INPUTS

Circular Economy

Circular economy with ecological footprint could be achieved with the use of recycled plastic to print a social sitting system for professional use or an individual for residential use.

This research focuses in three basic stances as it is mentioned at the beginning (supine position, semi Fowler's position and perching position). However a frontend environment (Image 50) where the user has the freedom to create his own geometry based on adjustable parameters can be quite practical. Parameters like width & length of material, variation of angles which refer to neck, trunk-thigh, knee and finally the height of the user for the right proportions of the outcome.

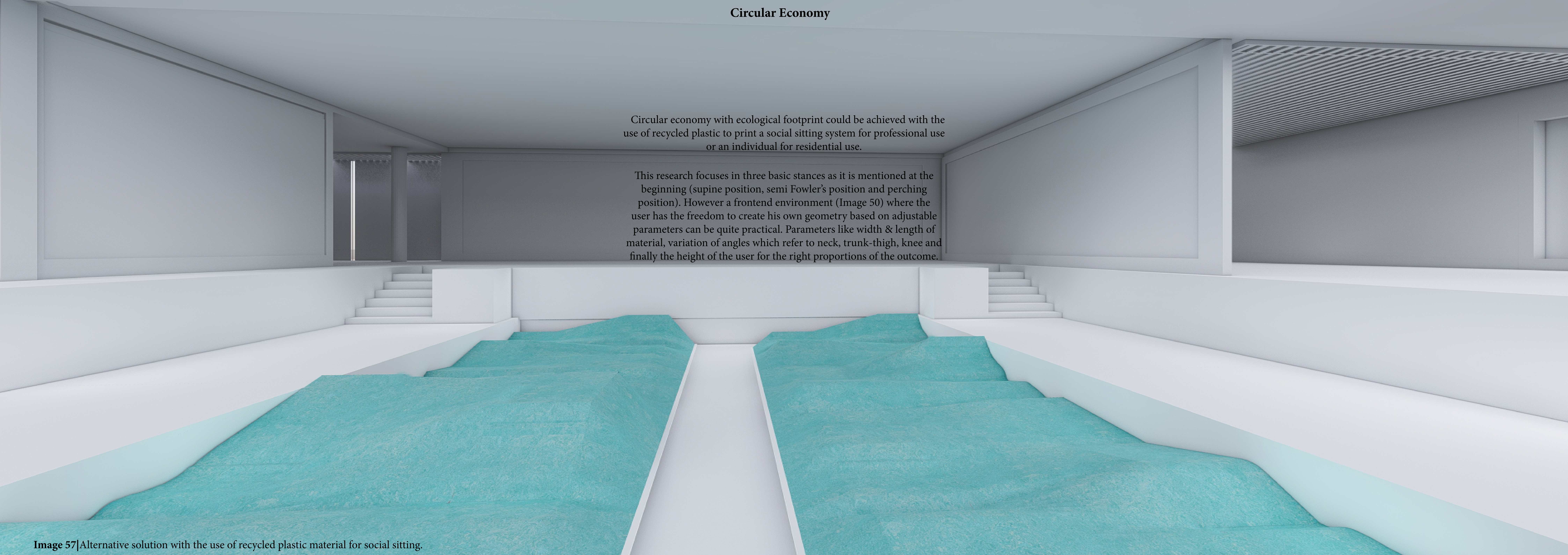


Image 57|Alternative solution with the use of recycled plastic material for social sitting.

Frontend

Image 58|GUI where the user sets his own parameters for seating design.

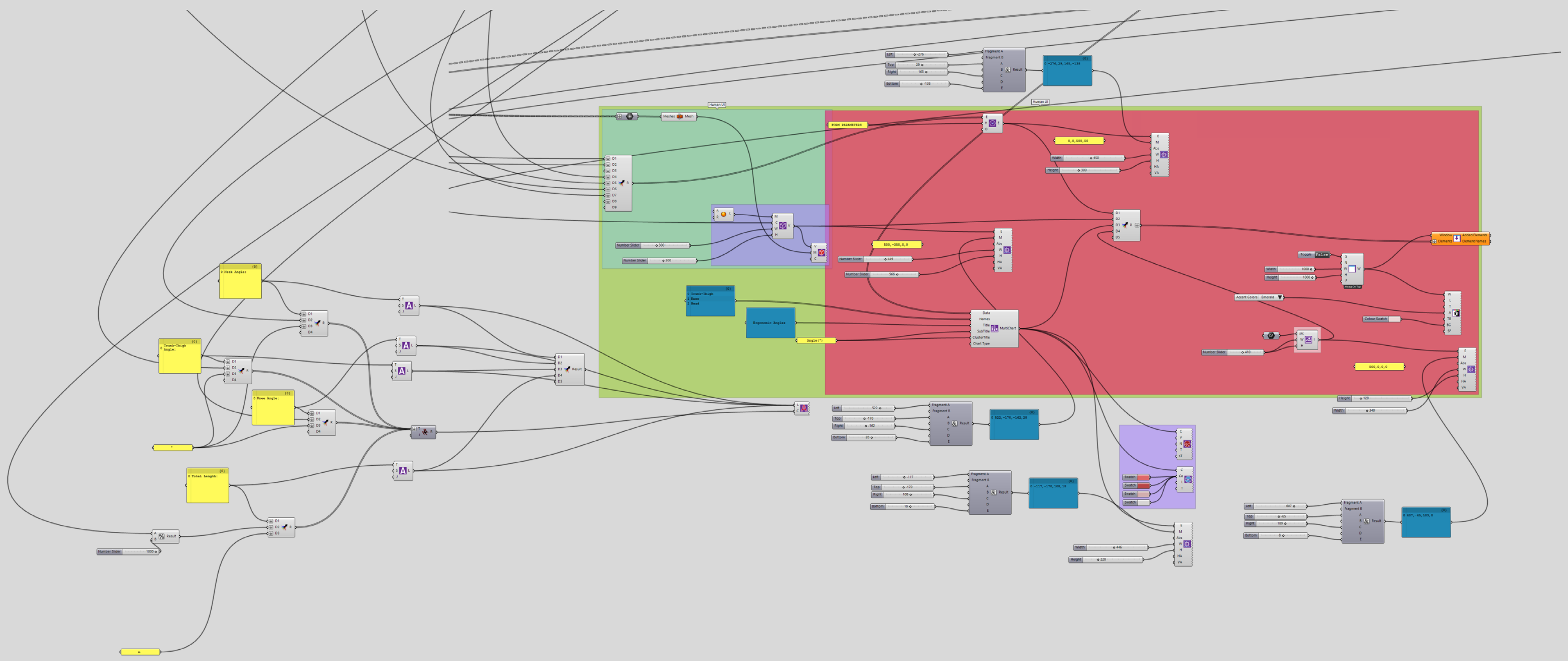
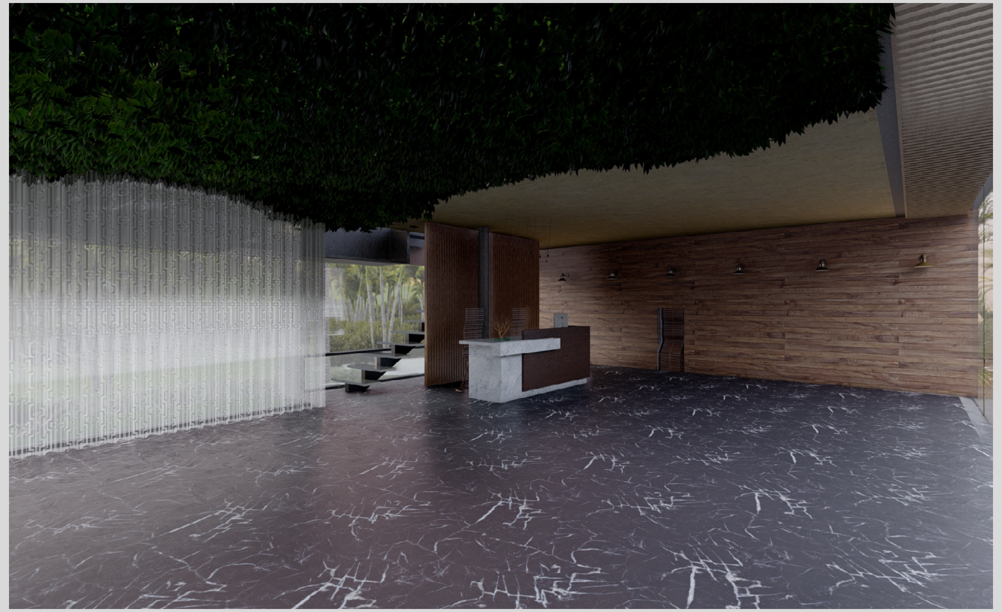
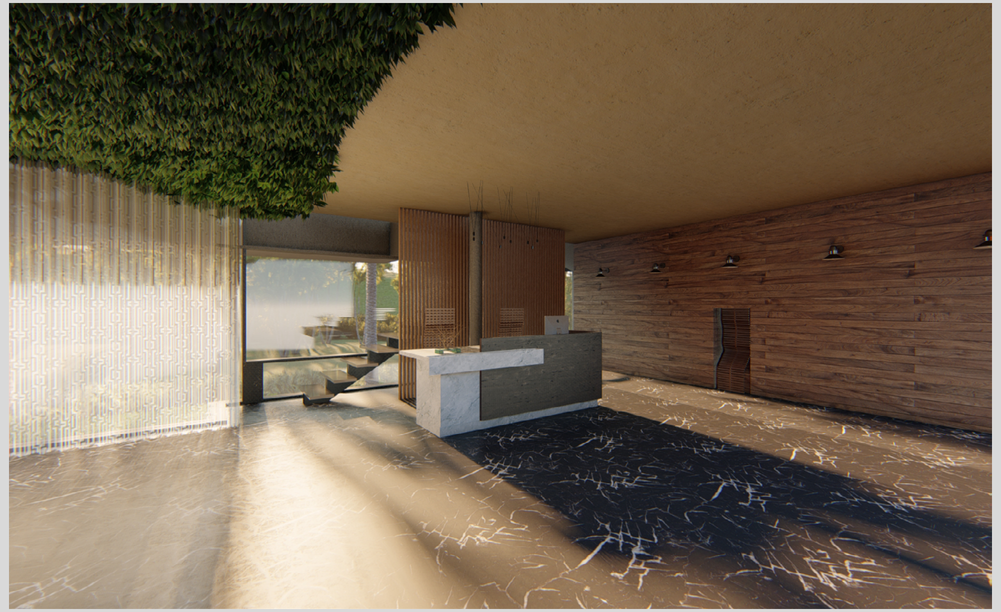
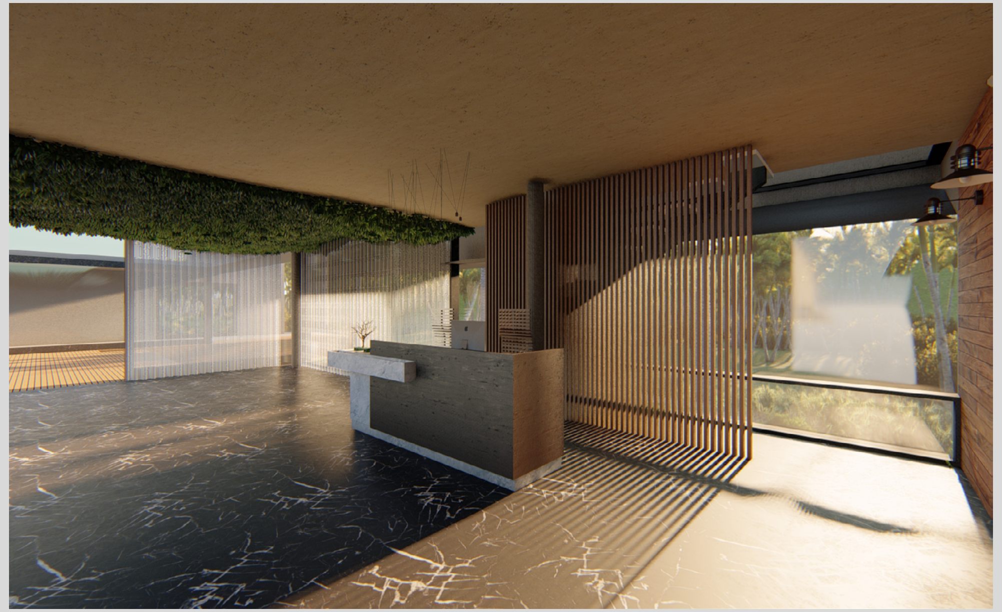
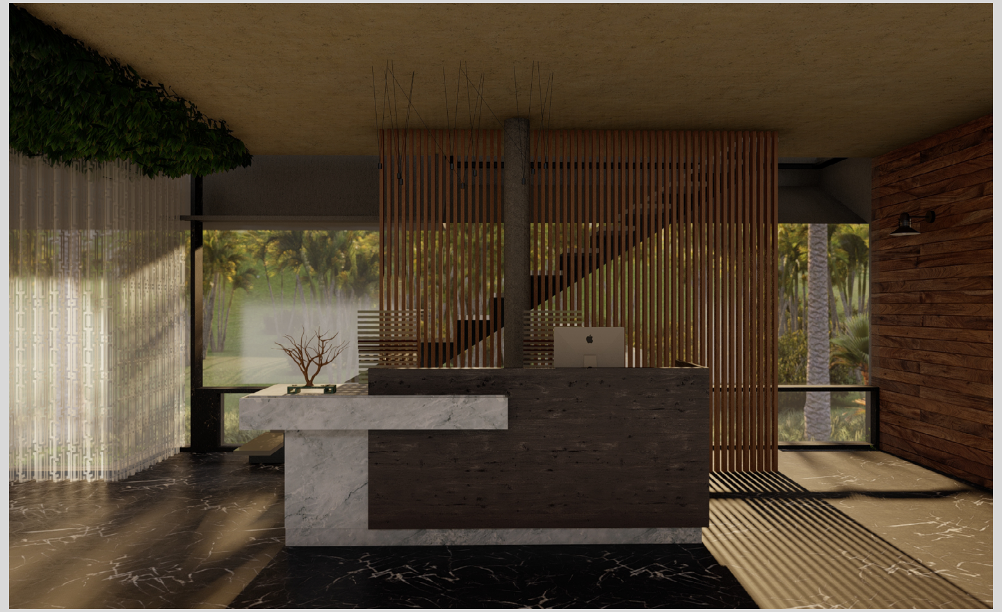
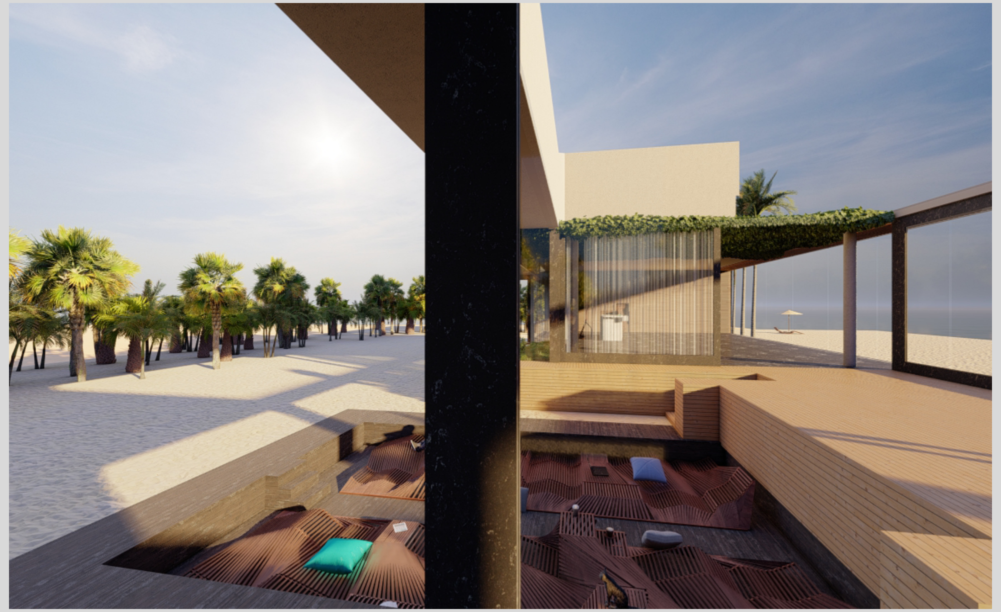


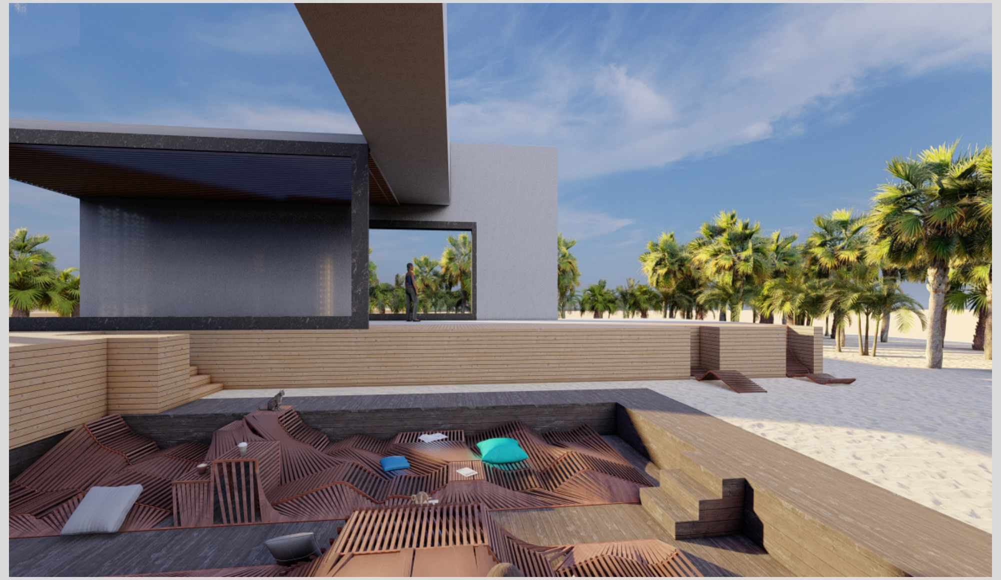
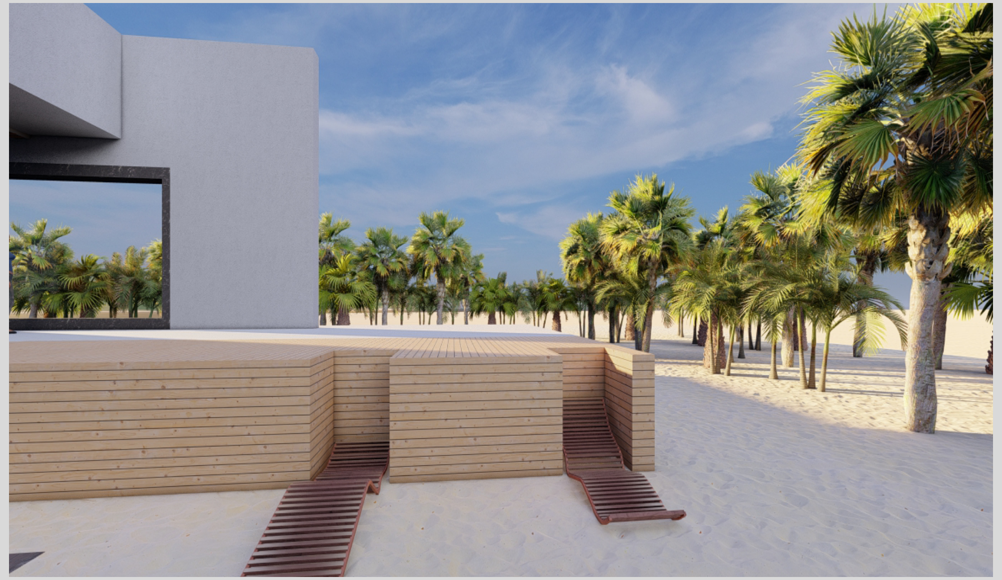
Image 59|Code created with Human UI plug in for the GUI of seating by the user.

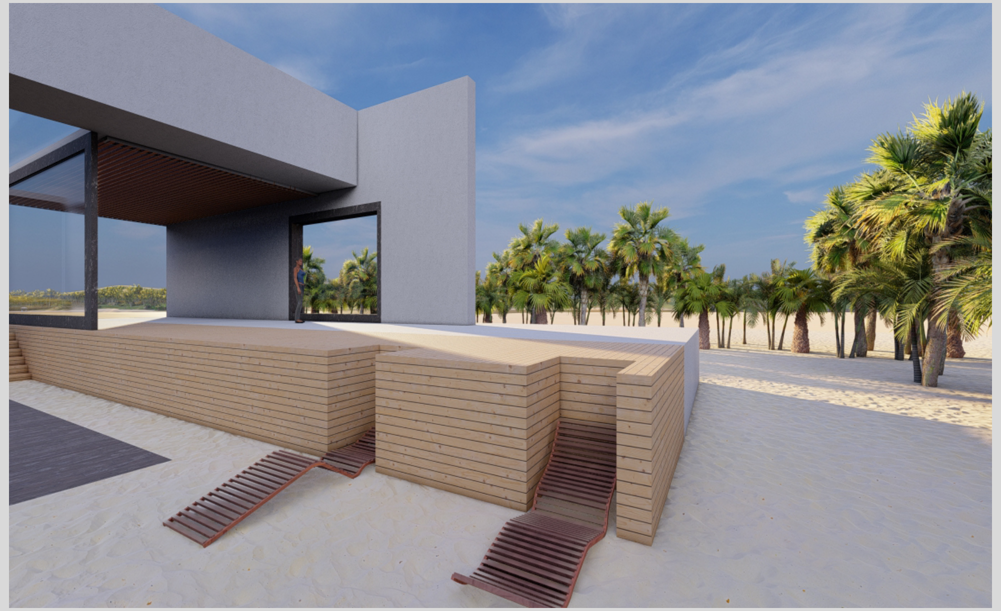
Results of the Analysis











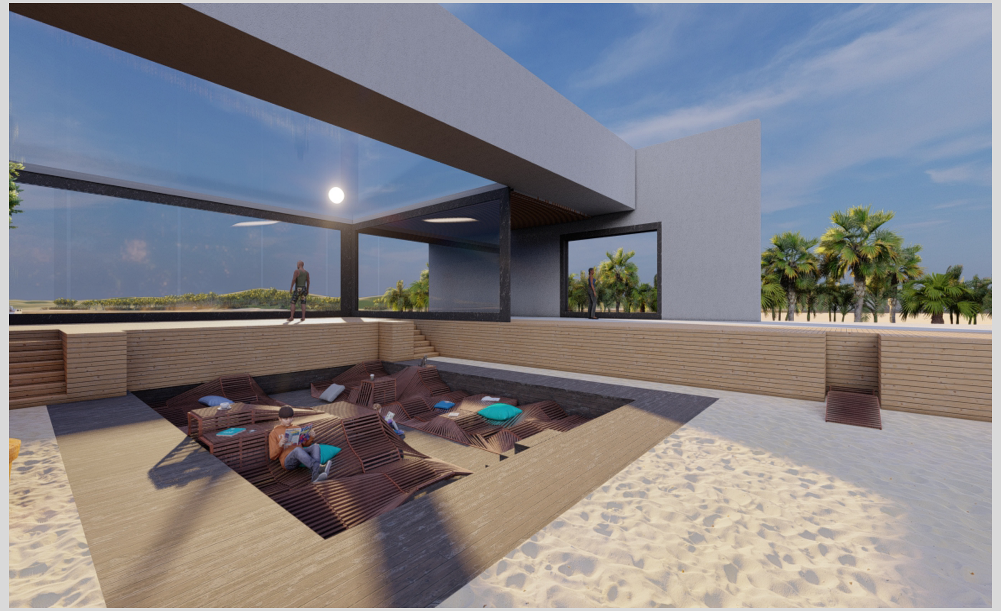




Image 60|Outcome of perching position.

Image 61|Outcomes of supine position & semi-Fowler's position.

Image 62|The combination of supine position furniture & semi-Fowler's potition furniture creates a social-urban seating with multiple uses.

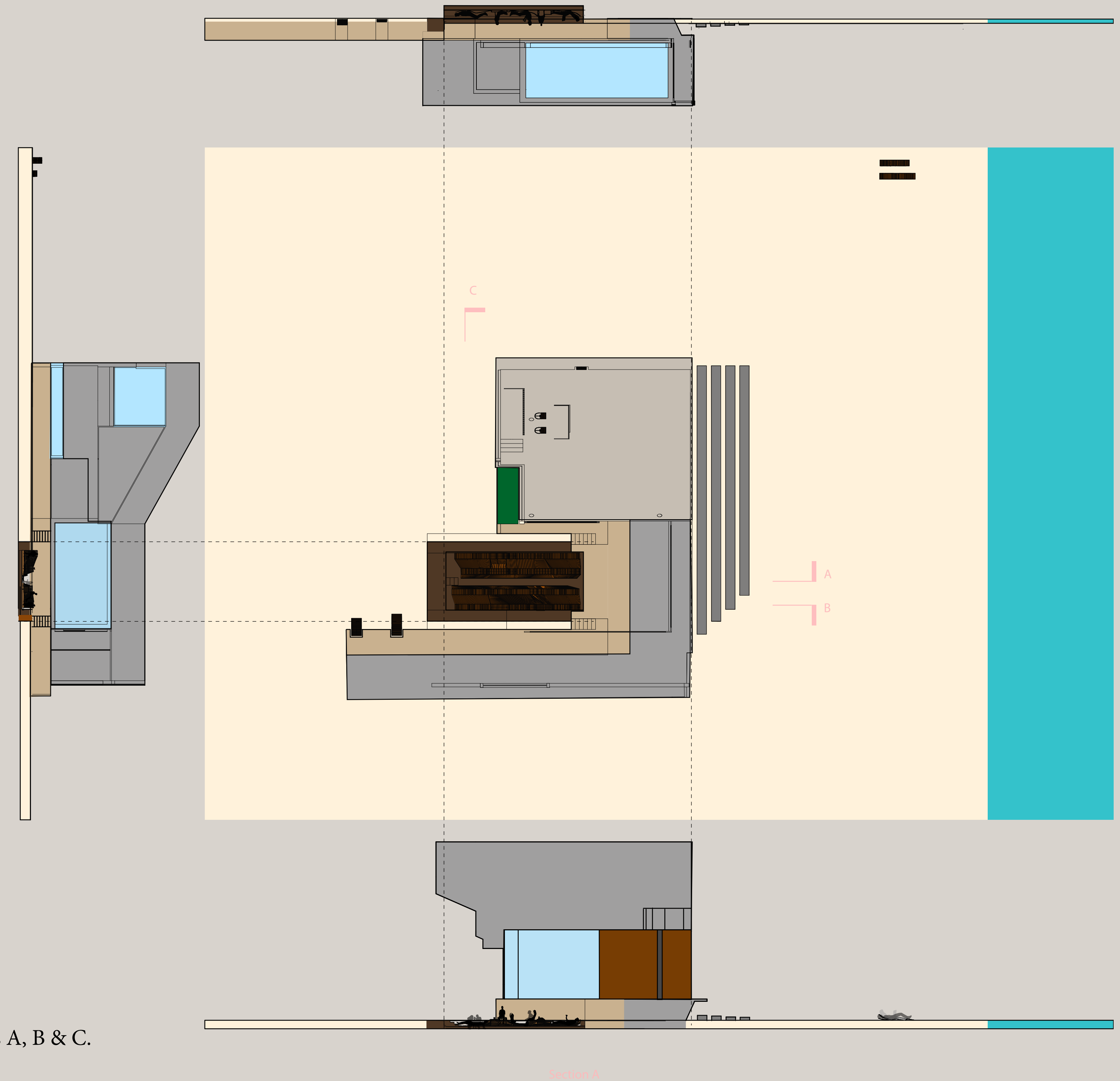


Image 63|Top view & Sections A, B & C.

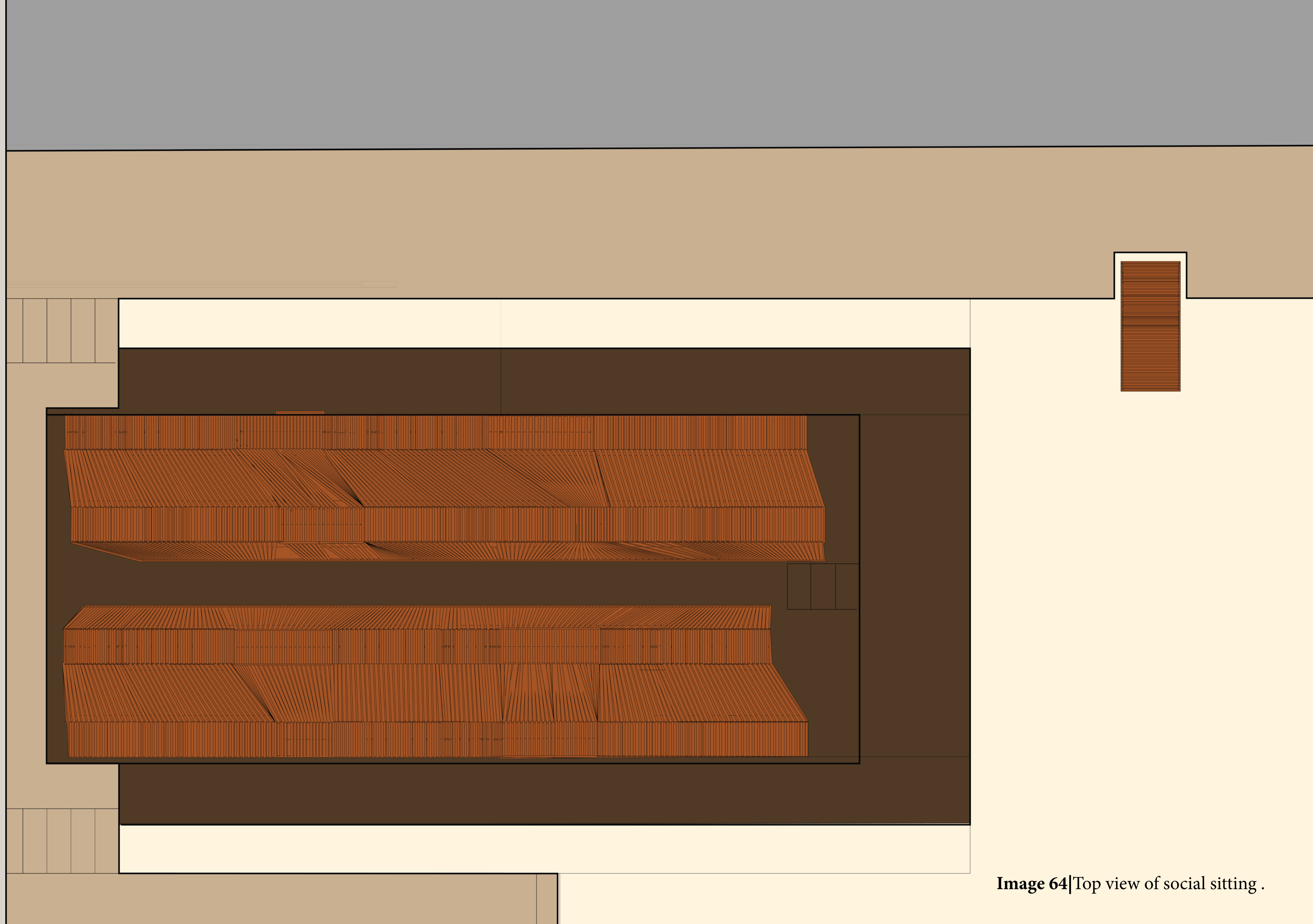


Image 64|Top view of social sitting .

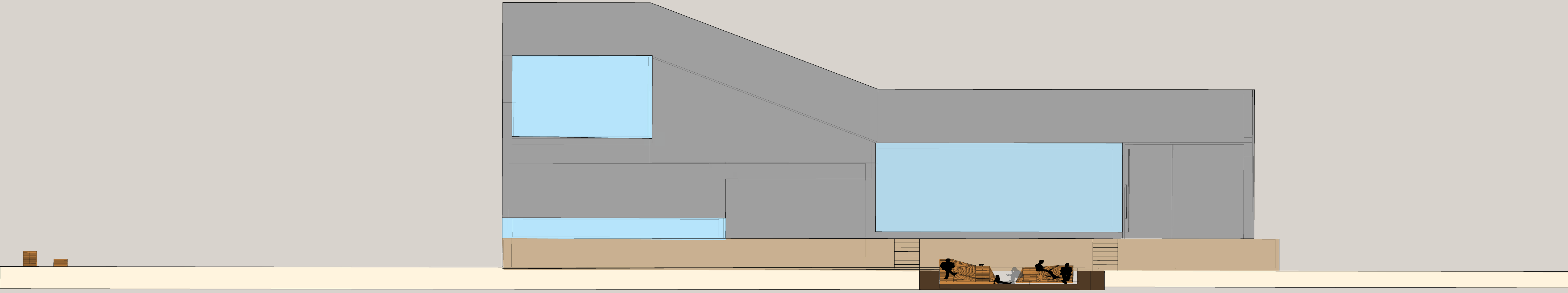
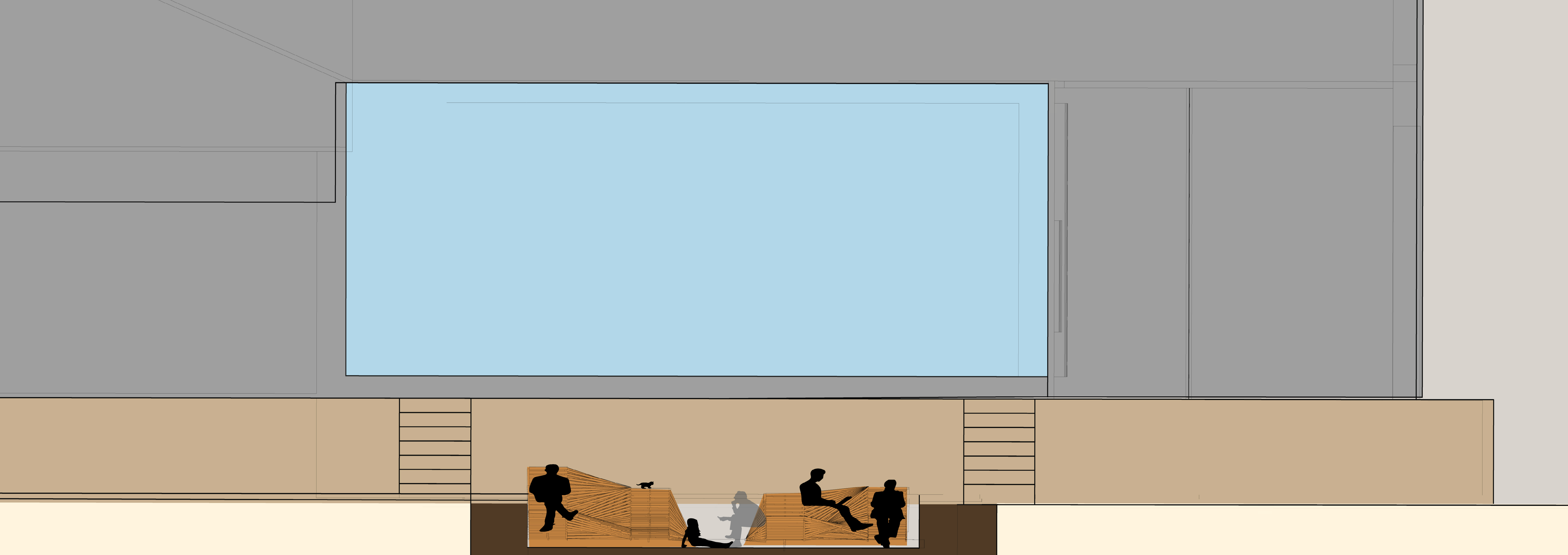


Image 65|Section C.



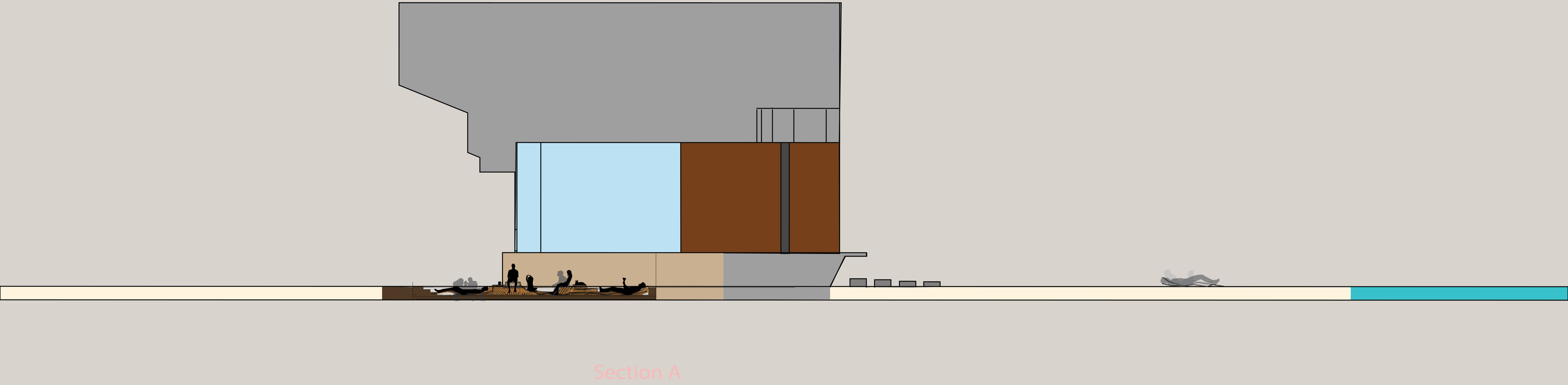
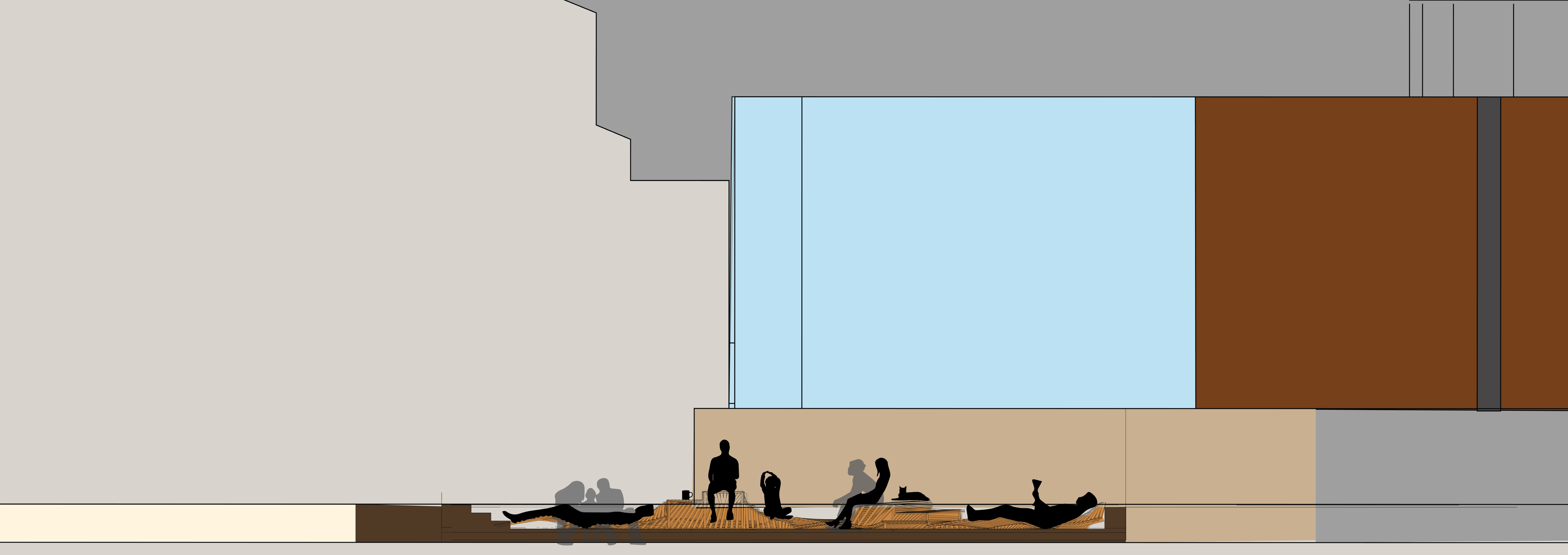


Image 66|Section A.



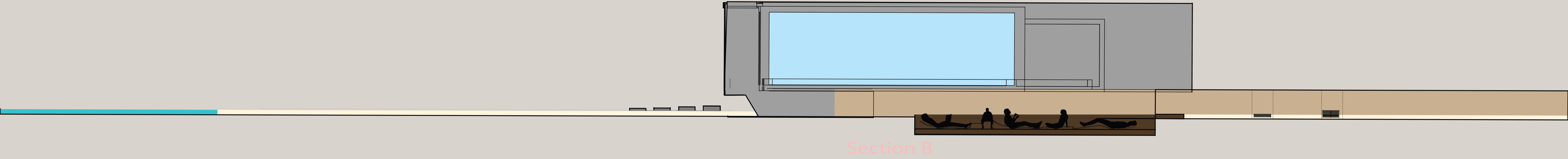
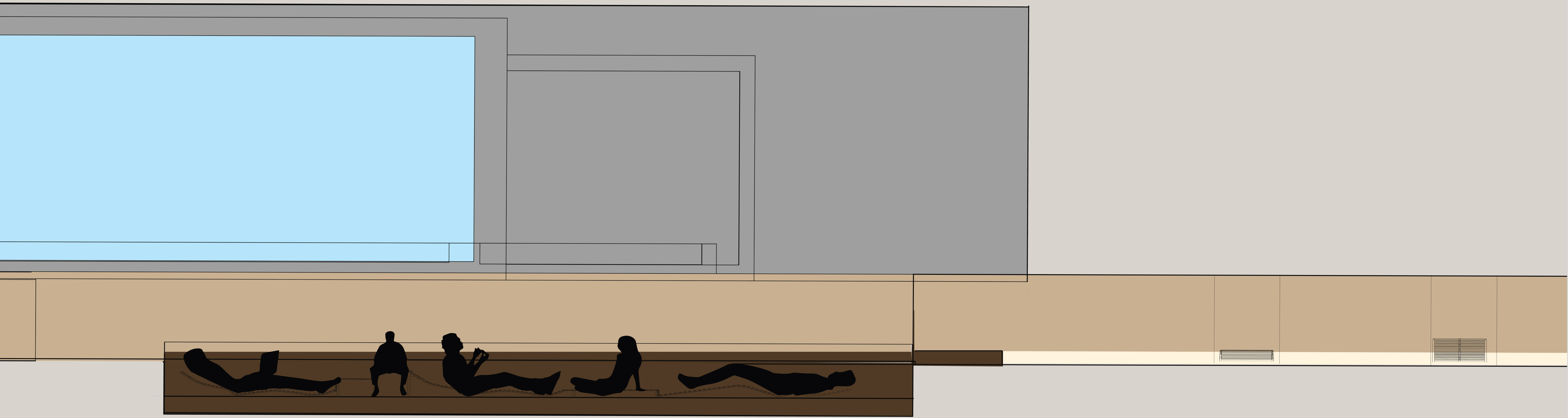


Image 65|Section B.



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PARAMETRIC DESIGN APPROACH AND OPTIMIZATION OF ERGONOMICS FOR RESIDENTIAL-PROFESSIONAL EQUIPMENT

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