TOWARDS A CANON FOR DIGITAL HUMAN ANATOMY 3D MODELING

Hugo de Azevedo
Universidade Lusófona de Humanidades e Tecnologias
Lisbon Portugal
hugodeazevedo.phd@gmail.com

António B. Araújo
Universidade Aberta / CIAC-UAb
Lisbon Portugal
antonio.araujo@uab.pt

ABSTRACT

We argue that the notion of an anatomical canon is still useful in the current artistic environment and it must be updated to deal with new digital requirements and possibilities. We propose a canon with a view towards accurate digital human anatomy 3D modeling. These steps, which should require generation of the final output from the styled paper, are mentioned here in this paragraph. First, users have to run "Reference Numbering" from the "Reference Elements" menu; this is the first step to start the bibliography marking (it should be clicked while keeping the cursor at the beginning of the reference list). After the marking is complete, the reference element runs all the options under the "Cross Linking" menu.

CCS CONCEPTS

• Applied computing → Arts and humanities • Computing methodologies → Computer graphics

KEYWORDS

Anatomical canon, Human anatomy, Digital, 3D Model

1 INTRODUCTION

It is now as it ever was, that mastering the tools is only half the job of expertly sculpting the human figure. The other half, endless and laborious, is the acquisition of artistic skills within the study of human anatomy [5]. The latter challenge must be faced by the modern 3D sculptor with his digital tools as it was by the old masters of the renaissance with their chisels and scopes. Hence the digital tools, though arguably simpler to manipulate, still intimidate those who use them to model the base mesh or sculpt the detail of the digital human figure in three dimensions, if the anatomy itself is not on firm ground. One must have a compass to navigate this task. A classical tool for such a purpose is the anatomical canon. The canon is not, as a common misconception goes, just an arbitrary standard of anatomical beauty, but an anatomical mnemonic. It is a model of the body that above all must be simple enough to keep in the artist's mind, as a standard against which a real body may be triangulated and measured: upon seeing or conceiving a specific body the artist can ask: are the legs larger, are the shoulders wider than my reference canon? It is by comparison that one sees. Without a reference, all is confusion. So the canon — and in particular the digital canon — serves both as starting point, and as continuous support and guide during the process of sculpting; without such a guide, the potential inherent in the tools is nullified.

The canon is not unique. A ready-made canon is a simple and elegant tool that the artist — sculptor or draughtman — acquires at the start of his creative life, and then slowly changes to make his own, tweaking it to his preference for the rest of his life. What we propose here is one such canon, and in fact a first iteration of one, that is especially fitted to the needs of the digital sculptor.

The creation of a digital anatomical canon poses a particular challenge, for it must specify not only a geometry but also a topology: the geometric surface requires proportions both accurate and simple, so as to be easy to grasp in the mind; the topology — that is, the connectivity of the vertices and edges of the mesh that subdivides the figure — must be both simple and appropriate for a correct deformation in the animation process [10][15], that is, the digital canon must be inherently dynamic.

The modelling of realistic human anatomy in computer graphics has been an area of intense research since the early seventies. Simulating the behavior of the human body is extremely complex [13]. In the past few decades, artistic practice has converged on several techniques to model the human body in three dimensions, each one with its unique approach to the problem, and yet anatomic realism more often than not seems to remain an elusive goal. Despite this, there is a global consensus about modeling the human body, which can be summarized in two important key advices: good anatomical reference of the human body; skeleton model as a basis for muscle modeling [17]. The 3D model of the human skeleton is currently used in physical simulations of the anatomical structures of animated characters. This approach enables the deformation of a character's body in an anatomically and physically realistic way [9][4]. However, finding a suitable human skeleton model or modeling one with a correct anatomy and anthropometry is extremely difficult, and, in most cases, ends up becoming an inadequate basis because of its inaccuracies.

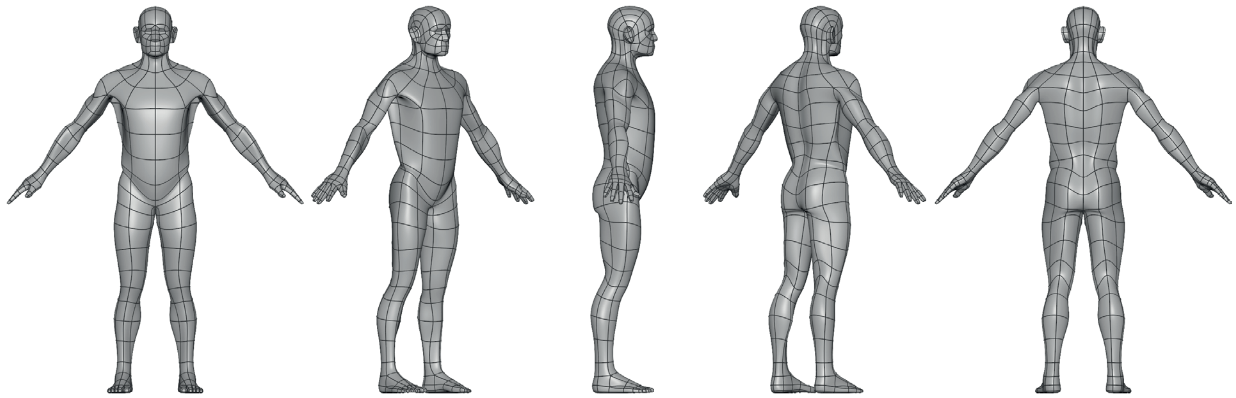

Figure 1: Anatomic low poly model.

Garvey [8] used a method to model the human body that started by creating several circles, positioned and scaled according to the anatomical reference projected in front and side views. At the end, these circles are used to create the surface of the model using NURBS. This method does not present an anatomic topology and it is very difficult to implement on human body areas, such as: head, shoulder, hand and foot. With the polygon subdivision technique, Ratner [12] creates the human model from a cube, by doing multiple geometry subdivisions and extrusions. This approach is complex because it requires numerous operations and uses several modeling tools. In addition, the topology has no anatomical precision, and the model is not suitable for digital sculpting because it does not avoid triangles and the mesh is not uniform. The method is also complex to implement by the artist because there is no easy way to memorize its construction sequence. Spencer [16] proposes a method to create a low poly base human model for digital sculpting. This method can be developed using 3D software, such as Maya, Blender, among others. It consists of blocking in the mesh by creating the basic forms and proportions of the human figure, however, the resulting geometry has no anatomical accuracy and the mesh's topology needs to be completely reconstructed within the digital sculpting process.

We propose a new canon that allows the construction of a low poly geometry human model. Our model's resolution increases in such areas where the human body's details are more relevant, (e. g., the face). The topology respects the main features of human anatomy and the traditional edge loops approach for animated geometry deformation (Figure 1).

2 PREMISES

Our proposal has three structural premises, considered fundamental for the artist who intends to model the human body using 3D software, with anatomical accuracy.

1. Low definition: According to Eaton [6] the basic geometry of a digital human model must be low definition while preserving the main features of human anatomy. A low poly base mesh allows you to change its shape by moving each single vertex at a time in a simple way. This provides an easy way to shape the critical landmarks and basic contours of the model's anatomy.
2. Anatomic topology: Base model topology must respect the human anatomy, however, it must be appropriate for the mesh deformation in animation. The model must be made with quad square polygons with uniform distribution, in order to achieve correct subdivision in the sculpting process [5]. Polygon edges serve as boundaries to define the muscles of the human digital model.
3. Anatomic precision: The previous two premises must provide solid structure to achieve anatomic precision. However, the human body cannot be understood only by the observation of its surface. It is necessary to understand the interior and its structural elements recorded in the mind [7]. The human anatomic study is an endless process necessary to achieve greater understanding about body mechanics and all its complexity.

3 REFERENCE

3.1 SCANNED HUMAN BODY

Our proposal was dominated, at its very beginning, by the need of a human body model as reference, in order to guarantee a real work basis and avoid possible divergences that may exist in models built merely on aesthetical considerations. Since our main goal is the adaptation of the anatomical canon to digital practice we decided to start from a well understood point, by adapting the classical canon: an adult male, with anthropometric proportions approximately equal to the eight head Greek canon; athletic body with relevant muscle mass; no significant body fat. In addition to the evident need for an appropriate human model for our study and proposal, the need of a skeleton suitable to this human model has also emerged. 3D scanning would be the obvious technology to capture our reference models. However, it became evident that it would be difficulty to find both a suitable and accessible human individual to perform photogrammetry on and also a complete skeleton with congruent features with the scanned human model, and our efforts would be better spent elsewhere. Instead, we decided to use one of the TEN24 [18] scanned models. The chosen model had high poly definition and it was part of a model pack with additional écorché and skeleton models fitted to the human scanned model.

3.2 OPTIMIZED MODEL

Based on the high-resolution écorché model, a new optimized 3D model was built with a correct topology suitable for human anatomy (Figure 2). This optimization was accompanied by a rigorous analysis of anatomical illustrations [3][14]. With the conclusion of the optimized model, we have created the digital skeleton using the TEN24 skeleton model as a reference for the joints position. This digital skeleton was made using the standard hierarchy adopted in the film and game industry for the characters creation.

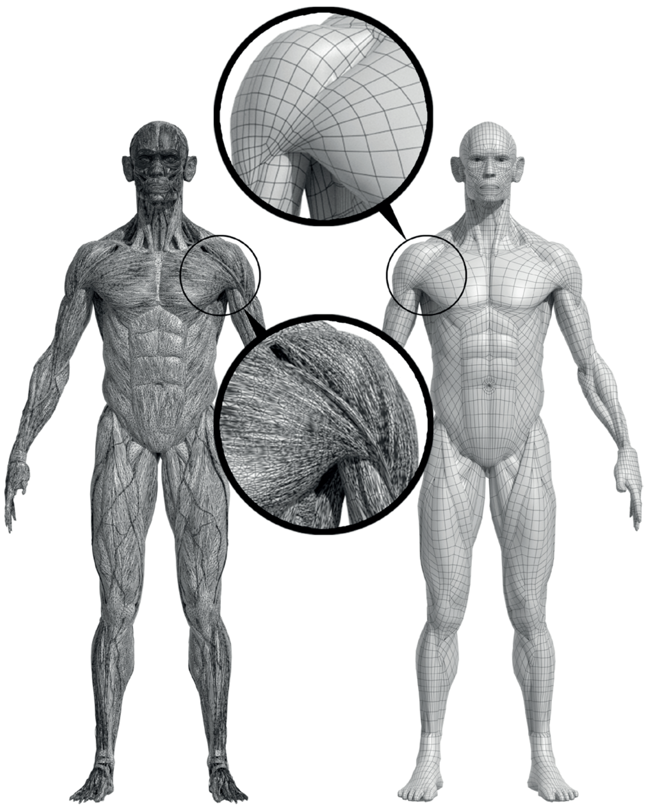

Figure 2: Original TEN24 [18] écorché model (left) and optimized model (right).

3.3 ANTHROPOMETRIC CORRECTION

After the digital skeleton creation along with the skinning process, we were able to move and rotate bones for the purpose of adapting our model to the chosen reference. As already mentioned, we used the eight head Greek canon for an adult individual. This canon was considered by Andrew Loomis [11] and Gottfried Bammes [1] as the one that presents the ideal human figure. More importantly, it is also the most used canon among artists. We performed the rigorous anthropometric correction of the optimized model using the measurements made by Bammes (Figure 3, «a»).

The joints were perfectly aligned with the references (anterior and lateral views), as well as the distance between the shoulder and hip joints, in relation to the Bammes model, maintaining the exact eight heads height (Figure 3, «b»). After this process, it was necessary to fix the mesh topology to avoid incorrect deformations caused by the bone displacement of the digital skeleton. The correction was performed using the scanned human model as reference.

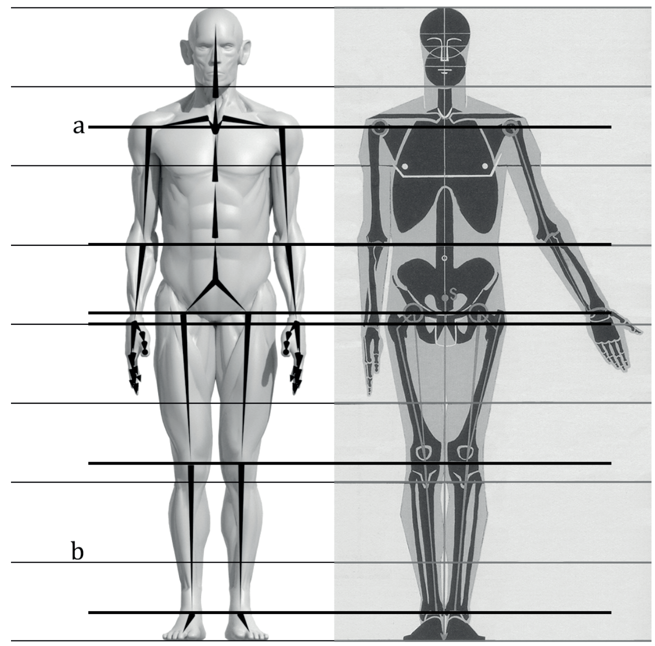

Figure 3: Optimized model with skeleton (left) aligned with reference from Bammes [1] (right).

3.4 ADOPTED POSE

Film and game industry usually adopt the «T» pose in character creation. In this pose, the arms are placed horizontally, which facilitates character modeling, skeleton creation and weights painting in the skinning process. The anatomical study tradition has a preference for the well-known «anatomical pose», chosen for the human osteological study, because the Radius and Ulna bones are parallel to each other and do not cross, thus facilitating the study of the anatomy of the forearm bones.

We considered inappropriate to use the «T» pose in our proposal because the Trapezius and Deltoid muscles are contracted. In addition, it seems more natural to portray the human figure with the arms close to the torso than with open arms — which is not the most common pose in our everyday life. The traditional «anatomical pose» was not used because, when the anterior hand face is oriented forward, the Radius bone is near to its maximum rotation, according to the KineMan [2] skeleton (Figure 4 - left).

Hence, we adopted a new pose with approximately 45 degrees arm rotation from the torso, and anterior hand face towards torso, similar to the scanned model. In this pose, the forearm is approximately half the amplitude of its rotation, and the 3D geometry of the forearm does not twist 160 degrees in just one direction, but 80 degrees for each direction. With this pose, the problematic deformation of the 3D model's forearm geometry is avoided, preventing anatomical inaccuracies. The only minor issue with this pose is related with diagonal arms position, which may be less convenient for the modeling process and skeleton creation, however, as mentioned above, this pose is near to human conventional posture and makes it easier to approach the anatomy of the forearm, arm and shoulder.

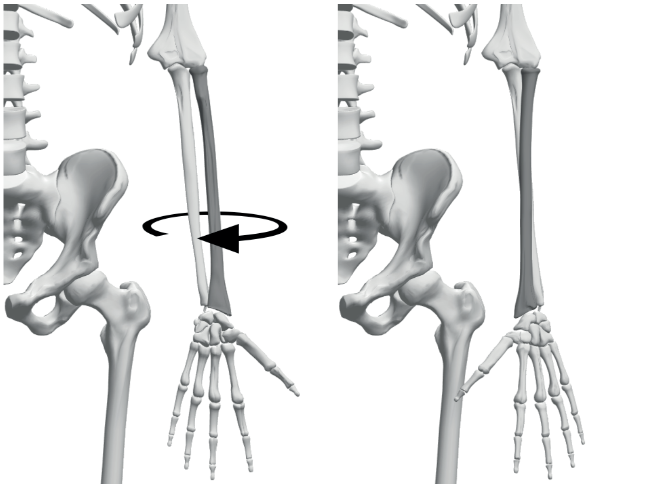

Figure 4: KineMan's [2] rotation range of the Radius bone. Left: Maximum rotation (5 degrees) «Anatomical Pose» Right: Minimum rotation (-155 degrees)

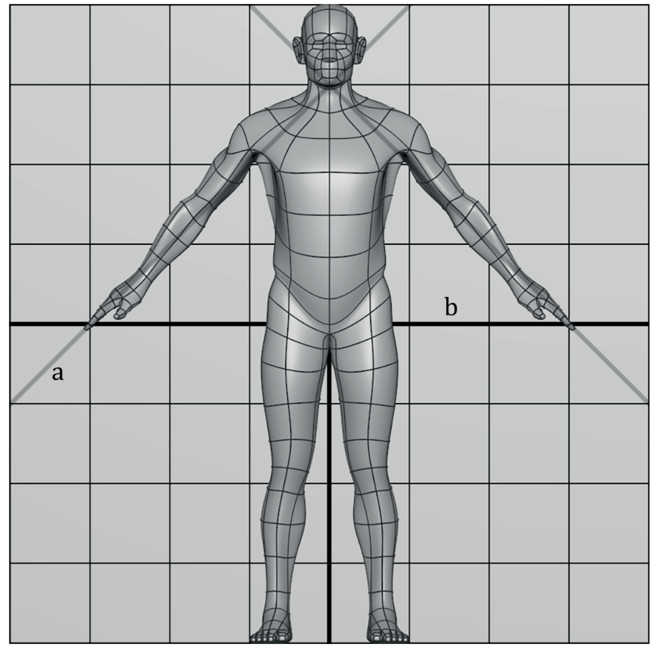

Figure 5: Anatomic low poly model (anterior view).

4 CANON

We present a three-dimensional low poly model constructed without detriment to the main anatomical features of the human body. The modeling process was developed with the smooth subdivision algorithm inherent to the main 3D software used in industry, such as: Maya, 3ds Max, Blender, among others. The model was built upon the new optimized écorché model and can be constructed with simple low poly 3D primitives, however, some changes were implemented in order to make it easier to portray the human figure in three dimensions, and prevent geometry issues (as stated above), but also, to create a good mnemonic for the artist. With the adopted arm rotation, they can be aligned with a 45 degree diagonal between the chin and the finger tips (Figure 5, «a»). This canon creates an easy mnemonic in which the model has eight heads height, six heads width, the trunk has approximately two heads width and the fingers are located with four heads height — half height of canon (Figure 5, «b»). It was decided not to bring the legs closer together, in order to make it easier to paint weights in the skinning process, and also, not to spread them further apart, to prevent changing the models height, hence, breaking the eight head base canon rule.

The upper and lower limbs have six faces for each ring. The symmetrical shape of the hexagon allows the intentional edge placement in the middle of the anterior and posterior leg face, intending to create a continuity line for the global model topology. The torso was made with ten polygons for each ring to connect with the upper and lower limbs and preserve the main anatomical features. All fingers have four polygons for each ring to ensure a correct connection with the hand and foot geometry. To respect the neck's anatomy, we decided to create its geometry with fourteen polygon rings. This will also provide a good connection with the head, shoulders and torso geometry. The head was made with more polygons, aiming to provide more detail and create the edge rings around ears, eyes and mouth. The final low poly model has 764 faces without smooth subdivision. With one level of smooth subdivision, the model presents 3020 faces. Our low poly model approach seems close to the minimum appropriate to achieve the main anatomical features in the digital human model. It is necessary to use smooth subdivision, yet, our main challenge was to develop a simple way to model the human body with the right proportions and anatomy. Our canon can also be adopted to create the human digital model using NURBS.

We present the description of the model in the anterior, lateral and posterior views. The edge location is quite deliberate, in order to ensure the preservation of the main anatomical features of the human body in such a low poly digital model.

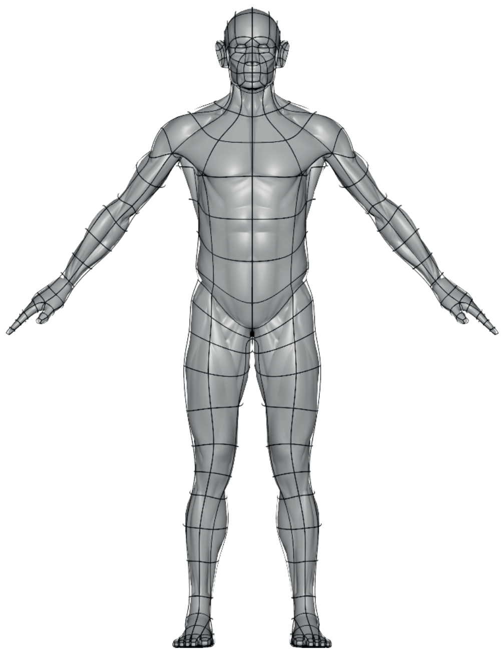

Figure 6: Anatomic low poly model overlay on reference anatomy model (anterior view).

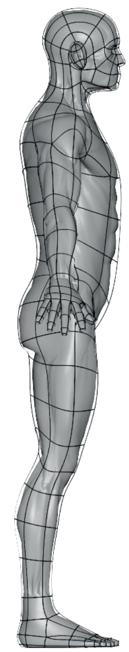

Figure 7: Anatomic low poly model overlay on reference anatomy model (lateral view).

Anterior View:

Head: the edge loops define the contours of the eyes, mouth, nose and ears, respecting facial muscle anatomy and providing an appropriate topology for the geometry deformation in animation.

Neck: the edges highlight the form of the Sternocleidomastoid and Trapezius muscles.

Back: only the Latissimus Dorsi muscle shape is visible.

Abdomen: it is noticeable the contour of the «V» shape with special emphasis on the External Oblique and Latissimus Dorsi muscles, marking the exact location of the umbilicus.

Shoulder: special attention is payed to the contours of Deltoid and Pectoralis Major muscles.

Arm: edges were placed over the Brachialis muscle, located between the Biceps Braquii and Triceps Brachii muscles. Another edge is located between the Biceps Braquii long and short head muscle.

Forearm: edges show the limit between the Brachioradialis and Flexor Carpi Radialis muscles.

Hand: edge loops were placed precisely over the finger joints and wrist.

Pelvis: the edges highlight the Gluteus Medius muscle, and the Crest of the Ilium.

Thigh: the concavity where the Great Trochanter is located; also, in the anterior face of the thigh, the edges cross the middle of the Rectus Femoris muscle, separating Vastus Lateralis and Vastus Medialis muscles, crossing the Patellar ligament.

Leg: the edges highlight the left head of Gastrocnemius muscle boundaries and the anterior crest of the Tibia bone.

Foot: the edges highlight the Medial and Lateral Malleolus, the toes and ankle joints.

Lateral View:

Head: edge loops define the contours of the ear and eyes.

Neck: the edges draw the shape of Sternocleidomastoid and Trapezius muscles.

Back: only part of the Latissimus Dorsi muscle shape is visible.

Abdomen: the separation between the External Oblique and the Rectus Abdominis muscles is noticeable.

Shoulder: the edges draw the shape of the Deltoid muscle.

Arm: edges are located over the Brachialis muscle.

Forearm: an edge line provides the Brachioradialis muscle volume.

Hand: the edge loops are placed over the finger and wrist joints.

Pelvis: an edge loop defines the contour of the Crest of the Ilium.

Thigh: an edge line is located between the Vastus Lateralis muscle and Biceps Femoris long head muscle, and the base line of the Gluteus Maximus muscle.

Leg: the limit between the Tibialis Anterior and Extensor Digitorum Communis muscles is highlighted.

Foot: the horizontal line defines the position of the Lateral Malleolus.

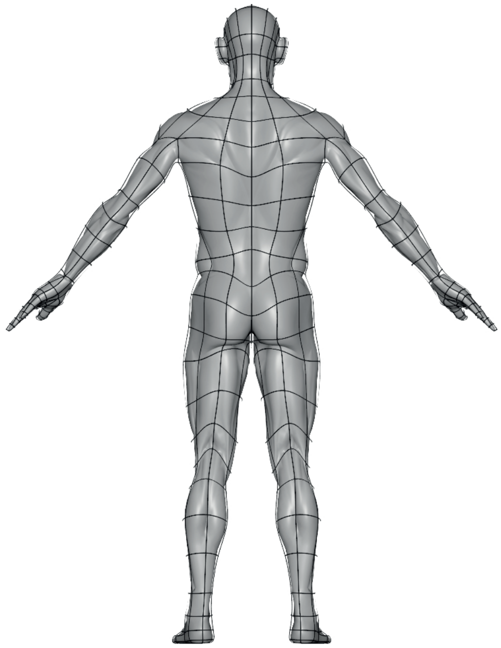

Figure 8: Anatomic low poly model overlay on reference anatomy model (posterior view).

Posterior View:

Head: the edges emphasize the shape of the Occipital bone and ears contours.

Neck: the line defines the Trapezius muscle volume.

Back: the Trapezius, Latissimus Dorsi, Infraspinatus and Teres Major muscles volume are highlighted. We did not outline the muscle shape, in an effort to maintain the model without triangles. However, some vertices are located with precision over the triangular shape of the Latissimus Dorsi and Trapezius muscles. To define the shape of these muscles it is only necessary to connect the vertices with diagonal edges.

Abdomen: only the External Oblique muscle and its edge border with the Latissimus Dorsi muscle is relevant.

Shoulder: the edges outline the shape of the Deltoid muscle.

Arm: is it possible to observe the line over the Long Head of the Triceps muscle.

Forearm: there is a precise line over the Olecranon and a line that divides the posterior face, from elbow to the hand.

Hand: edge loops are placed over the fingers and wrist joints. In the anterior surface of the hand, it is possible to observe the boundaries of the Flexor Pollicis and Abductor Pollicis muscles.

Pelvis: the shape of the Crest of the Ilium stands out. The edges also form the «V» shape between the two Gluteus Maximus muscles, formed by the Sacrum bone.

Thigh: and edge line defines the limit between the Vastus Lateralis and Biceps Femoris muscles.

Leg: the main highlight goes to the edge border between the Gastrocnemius left and right head muscle.

Foot: a horizontal line defines the location of the Lateral and Medial Malleolus and the ankle joint. A vertical line defines the Achilles tendon.

5 FUTURE WORK

Having started with a male figure, whose muscle proportions proved easier to model, we intend to move on to a female figure next. Concurrently, we hope to submit the current model to validation in a classroom context, in the teaching of 3D modelling of the human figure to beginning students.

ACKNOWLEDGMENTS

Author A. B. Araújo was funded by FCT national funds through project UIDB/Multi/04019/2020.

REFERENCES

[1] Gottfried Bammes. 2017. *The Complete Guide to Anatomy for Artists & Illustrators* (1st ed.). Search Press, Royal Tunbridge Wells.
[2] Andrew Barber. KineMan: Movable 3D Skeleton. Retrieved July 22, 2020 from https://www.kineman.com/
[3] Jean Baptiste Marc Bourgery and Nicolas Henri Jacob. 2008. *Atlas of Human Anatomy and Surgery*. Taschen.
[4] Simon Clutterbuck, James Jacobs, and Richard Dorling. Tissue | Weta Digital. Retrieved March 8, 2020 from https://www.wetafx.co.nz/research-and-tech/technology/tissue/
[5] Scott Eaton. 2006. 3D World. *Tutorials: Body Work*, 42–47.
[6] Scott Eaton. 2008. 3D World. *Tutorials: Body Electric*, 42–51.
[7] John Gage. 1980. *Goethe on Art*. Scolar Press. Retrieved from https://books.google.pt/books?id=zQMH2seIHtwC&pg=PA3&source=gbs_toc_r&cad=4#v=onepage&q=The human&f=false
[8] Gregory P Garvey. 2002. Workshop: Life drawing and 3D figure modeling with MAYA. In *ACM SIGGRAPH 2002 Conference Abstracts and Applications, SIGGRAPH 2002*, Association for Computing Machinery, Inc., 56. DOI:https://doi.org/10.1145/1242073.1242092
[9] James Jacobs, Jernej Barbic, Essex Edwards, Crawford Doran, and Andy van Straten. 2016. How to build a human: Practical physics-based character animation. In *Proceedings - DigiPro 2016: ACM SIGGRAPH Digital Production Symposium*, Association for Computing Machinery, Inc, 7–9. DOI:https://doi.org/10.1145/2947688.2947698
[10] Sung Hee Lee, Eftychios Sifakis, and Demetri Terzopoulos. 2009. Comprehensive biomechanical modeling and simulation of the upper body. *ACM Transactions on Graphics* 28, 4 (August 2009). DOI:https://doi.org/10.1145/1559755.1559756
[11] Andrew Loomis. 2011. *Figure Drawing for All It's Worth*. Titan Books.
[12] Peter Ratner. 2003. *3-D Human Modeling and Animation* (2nd ed.). John Wiley & Sons.
[13] Ferdi Scheepers, Richard E Parent, Wayne E Carlson, and Stephen F May. 1997. Anatomy-based modeling of the human musculature. In *Proceedings of the 24th Annual Conference on Computer Graphics and Interactive Techniques, SIGGRAPH 1997*, 163–172. DOI:https://doi.org/10.1145/258734.258827
[14] Fritz Schider. 1957. *An Atlas of Anatomy for Artists* (3rd ed.). Dover Publications, Inc.
[15] Hyewon Seo and Nadia Magnenat-Thalmann. 2003. An automatic modeling of human bodies from sizing parameters. In *Proceedings of the Symposium on Interactive 3D Graphics*, 19–26. DOI:https://doi.org/10.1145/641485.641487
[16] Scott Spencer. 2010. *ZBrush Digital Sculpting Human Anatomy* (1st ed.). Sybex, Indianapolis.
[17] 10 ways to improve your human anatomy modelling | Creative Bloq. Retrieved March 7, 2020 from https://www.creativebloq.com/advice/10-ways-to-improve-your-human-anatomy-modelling
[18] Ten24 – 3D scanning / Photogrammetry / Characters. Retrieved July 22, 2020 from https://ten24.info/