Visible Ape Project -disseminating great apes anatomy using 3D models and scientific illustrations

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Abstract

With the rise of technology, scientific illustration, a language mechanism used to communicate science, seeks new methods of creation using digital techniques as documental and didactic resources — including 3D illustration — which may help to perception and knowledge about nature surrounding humans. In this work, schematic and objective 3D models of the common chimpanzee muscular system were made and presented, created using Zbrush sculpting application. These models will serve as the construct-basis for modelling muscular systems of other great apes. Both, 3D models and scientific illustration will be used in "Visible Ape Project" platform. This project was created to exclusively disseminate massive information about anatomy and morphology of the main primates, through scientifically correct and aesthetic appealing models, in order to cross borders beyond academic community and reach non-specialized public.

Keywords
Visible Ape Project, Anatomy, Morphology, Muscular System, 3D Models, Scientific Illustration.

Introduction

Representing a particular aspect of any living organism by an image is a effective way to communicate scientific aspects e complex concepts. Scientific illustration is usual resource used in science communication, whether is strategically directed for an audience of specialists or for a more undifferentiated audience of non-specialists. For this purpose, this kind of images usually encode and convey a scientific message in a perceptible and objective graphic process [1] [11].

Scientific illustration usually use drawing to represents an organism or species in bidimensional model, where volume is virtual (optical illusion that deceive perception). Real volume is achieved if a third dimension is added (3D) and the visualization mode evolves to modelling. Virtual models in 3D are an upgrade in the information encoded in itself as what is shown is not only a static view, but all the potential views kept in a shape of an entity (a mineral, an organism, etc.). It has a huge potential as didactic resource — if included in dynamic interactive applications and/or digital platforms — and may be use to disseminate complex scientific knowledge [12].

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Currently there is any plataform using 3D anatomy reconstructions of apes, ease to access and that allows a wider audience to interact and acquire knowledge, specially of a field that is little known worldwide and that is usually confined to a scientific and research audiences. This justifies the need to create mechanisms of scientific communication from innovative dissemination scientific projects such as the Visible Ape Project (VAP).

In VAP it's intended to create 3D models of all great apes: Bonono (*Pan paniscus*), Chimpanzee (*Pan troglodytes*), Gorilla (Gorilla gorilla), Orangutan (Pongo sp.) and Gibbon (Hylobates sp.), which will be taxonomic archetypes. Which model will developed from several characteristic phenotypes of the species. It fit the purpose of focusing relevant aspects that provide the viewer a clear and objective interpretation of the reality regarding the muscular composition of the species under study.

The use of 3D reconstructions as means of visual scientific communication not only allows the observer of the information, to synthesize a series of technical and complex elements that are common in the field to be treated, in this case the apes anatomy, but also subtracts possible elements that can generate emotions (that distort and hinder an adequate interpretation of reality, for example, the fact to observe dissections with blood and deformed structures little perceptible) [13].

One of the most relevant advantages of 3D representation on 2D is that it shows a manipulability that has direct interaction with the observer, which will acquire a wider spectrum of information, while 2D shows a series of successive views in the same way (initially chosen by others than viewer, as scientific supervisor, or the illustrator). Although useful it requires that the observer create and mentally reconstruct the volumetric (3D) model, an exercise that is limited to a specific audience that usually works with this specific issues [12] [13]).

VAP website and app may be regarded as transformative tools, because they will be the first resources to provide a comprehensive, easy to use compilation of detailed visual information about general anatomy of neonates, juveniles and adults of each major ape group. It will be an easy to use and permanent resource about ape anatomy that will be freely available to the diverse research communities of biologists and anthropologists, as well as to the medical, veterinarian and broader scientific communities. Also it will open abundant avenues for further biological anthropology research and technological development, which will in turn stimulate interaction between the anthropology and biology communities, innovative networking and collaborative strategies, and new research directions.

VAP will also be of interest to the media and broader public. Moreover, by showing how similar humans and apes are "on the inside," this will draw attention to just how close our relationship is to these extraordinary apes whose continued existence in the wild is threatened. In particular, VAP will be based on, and will comparable to, the extremely successful Visible Human Project, another outreach program that has been exceptionally useful, to the scientific community, and became extremely popular and well accepted within the general public.

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Methodology and Methods

Methodology used in this word was divide in 2 different phases: first to collect and process anatomical data in order to be ready to be use for generate 3D models.

The anatomical data used to generate the 3D muscle reconstructions are based on dissections of 35 ape specimens comprising four genera that are described in full in a series of anatomical atlases produced by the Diogo and his collaborators [2], [3] [4], [5], [6], [7], [8], [9]. Both males and females, as well as ontogenetic stages ranging from fetus through adult are represented throughout the sample. Many specimens were fresh (often subsequently frozen) and studied as soon as possible after death, but some specimens were formalin embalmed. Please see Table 1 for specific details on specimen provenance, sex, ontogenetic stage, and preservation. A professional camera was used to take photographs of the musculoskeletal system of each specimen, and the photographs were scrutinized and subsequently labeled. For each muscle, it was recorded presence or absence, described the origin and insertion points, and listed any observed variation in its attachments among the individuals of the same species. The weight of the muscles in grams, as well as muscle nerve supply, were also recorded when specimen conditions allowed.

To complement the information gleaned from the dissections, comparisons were made to information from ape dissections completed by other researchers following a comprehensive literature review [2], [5]. This allowed researchers team to approximate what is the most typical phenotypic configuration of the musculature for each species and represent this "normal" presentation in the 3D reconstructions.

Table 1. Information on specimens used to generate 3D anatomical models.

Species	Specimen	Source Institution	Sex	Ontogenetic Stage	Preservation
Hylobates lar	HU HL1[a]	HU	M	Adu	Fo
	GWU HL1	GWU	F	Juv	Fo
Hylobates muelleri	DU HM1[b]	DU	M	Adu	Fo
Hylobates syndactylus	DU HS1[b]	DU	M	Adu	Fo
Hylobates gabriellae	VU HG1[c]	VU	M	Inf	Fr
	VU HG2[c]	VU	M	Adu	Fr
Hylobates klossii	VU HK1[c]	VU	M	Adu	Fr
Pongo pygmaeus	HU PP1	HU	M	Neo	Fo
	GWU PP1	GWU	M	Adu	Fo
	VU PP1	VU	F	Adu	Fr
	VU PP2	VU	F	Adu	Fr
Gorilla gorilla	CMS GG1	CMS	M	Adu	Fr
	VU GG1	VU	F	Adu	Fr
	VU GG2	VU	F	Adu	Fr
	VU GG3	VU	M	Adu	Fr
	Uncat[d]	BV	M	Neo	Fr
Pan troglodytes	HU PT1	HU	M	Inf	Fo
	GWUANT PT1	GWU	F	Adu	Fo
	GWUANT PT2	GWU	F	Adu	Fo

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	Uncat[a,d]	DU	M	Adu	Fo
	VU PT1[e]	VU	M	Adu	Fr
	VU PT2[f]	VU	M	Adu	Fr
	VU PT3[c]	VU	F	Adu	Fr
	PFA 1009	PFA	F	Adu	Fr
	PFA 1016	PFA	F	Adu	Fr
	PFA 1051	PFA	F	Inf	Fr
	PFA 1077	PFA	F	Inf	Fr
	PFA UNC[d]	PFA	M	Inf	Fr
Pan paniscus	ZIMS 164031	AZ	M	Adu	Fr
	ZIMS 164046	AZ	F	Adu	Fo
	ZIMS 164047	AZ	F	Ado	Fr
	ZIMS 164040	AZ	M	Inf	Fr
	ZIMS 164041	AZ	M	Inf	Fr
	ZIMS 164042	AZ	F	Inf	Fr
	ZIMS 164052	AZ	F	Fet	Fr

Source Instituion: HU = Howard University, GWU = George Washington University, DU = Duquesne University, VU = Valladolid University, CMS = Canadian Museum of Nature, BV = Bioparc Valencia, PFA = Primate Foundation of Arizona, AZ = Antwerp Zoo // Sex: F = female, M = male // Ontogenetic Stage: Fet = fetus, Neo = neonate, Inf = infant, Juv = Juvenile, Ado = Adolescent; Adu = Adult // Preservation: Fr = fresh (frozen), Fo = Formalin embalmed // Notes: a) Originated from the Yerkes Regional Primate Center where it had the number YN87-134; b) Originated from the Cleveland MetroParks Zoo; c) Originated from the Bioparc Fuengirola; d) Uncatalogued specimen; e) Originated from the Fundación Mona; f) Originated from the Zoo-Aquarium of Madrid

Fig. 1. Initial modeling step of a common chimpanzee head done in Zbrush 3D editor

To develop each 3D model, it was used a 3D editor application (Zbrush) which allows sculpting and manipulating the digital entity shaped in all directions. Each 3D object is composed of an interactive and dynamic mesh subdivided into polygons that could be edited and shaped producing organized and uniform structures in 3D. Various sculpting tools (brushes) were used to build and transform all surface elements of muscular and skeleton systems: muscles and bones, linked by tendons.

After having an initial not detailed base, the mesh was updated to recalculate the polygons that were initially deformed (Fig.1). In result is was a achieve a compact base that allow continuity and details improvement until correctly represent the diagnostic character worked in that particular specie (Fig. 2). Then a standard color was added and the 3D model was ready for rendering, after configuring elements such as light, shadow, material, position, etc. Each render act as a “photograph” of the scientific reliable model and therefore may be consider as an accurate scientific illustrations as it was “drawn” in 3D. From one single 3D model it is possible to do as may different scientific illustrations as are needed, viewed from any spatial perspective. This method will be successively used to achieve a realistic appearance 3D models of heads and upper/lower limbs of each of others 4 apes species.

Results

Below are present the results obtained from the rendering of 3D models and muscular system reconstructions of the head, neck and upper/lower limbs of a common chimpanzee, all of them done using sculpting and coloring tools of Zbrush 3D editor (Fig. 2-4)

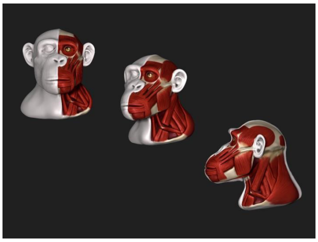

Fig. 2. Musculature reconstruction of the head and neck

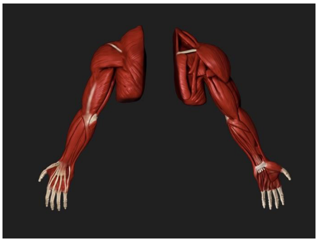

Fig. 3. Upper limb (left: rear view; right: front view)

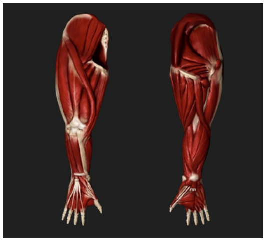

Fig. 4. Lower limb (left: front view; right: rear view)

Discussion

Within the 3D representation processes that anatomists have used, as well as people who acquire disciplinary training in these fields, platforms have been designed that allow interaction with 3D scans and the creation of render depending on the structure to be analyzed, citing the study carried out by Taerum et al 2005 [14] with software that allows doctors to obtain a volumetric image of various structures, which can be manipulated from different planes. Initially this was an innovative tool since it allows having a broader spectrum than what is intended to be investigated [2] [13]. It is a very useful tool for people who have an initial or deeper scientific knowledge of the discipline.

Although there are such innovative tools that have facilitated the study of anatomical structures, this is not entirely perfect, since the effective interpretation of each 3D scan depends directly on the prior knowledge that the observer has, which limits the access to said information to a specific audience and said 3D scans made from the used specimens, largely lack visual aesthetics and some structures are deformed, which implies that the receiver must create an interpretation process using scientific knowledge [2].

Nowadays, with the technological advances, the aim is to approach a broader public that understands the complexity of anatomical structures and biological processes in a more simplified way [12], which is why software for making digital sculpture such as 3D MAX, blender, Zbrush, has been implemented. etc, which have generally been used in the entertainment industry, but which the scientific illustrator uses as a resource and thus reconstructs biological structures in three dimensions from basic forms, taking into account the rigor of scientific information and subtracting elements that distort a correct interpretation.

There are alternative projects regarding the production of anatomical models of primates, in this case by the Jun's anatomy project, an artist from the United States, where he has done 3D scale models of the great apes and other animals have been made, which have have been rendered and offered for sale to the public. Unlike visible Ape Project, these models are not mounted on an application or platform for direct interaction with the observer and despite having scientific rigor and correct proportion, the position of the limbs would not be adequate in terms of anatomical disclosure to understand The entire structure, in this case muscular, this can hinder the perception of morphological elements that can be diagnostic depending on the species. Another relevant aspect to note is that they are unicolor models, preventing differentiation of elements such as muscles, tendons and bones.

In terms of human anatomy, recently there are projects that involve 3D models in applications and didactic platforms with easy access, such as Essential anatomy, Visible human project or Visible body, which allow the observer to interact and learn through models that are aesthetically presented and with scientific rigor.

In Visible Ape Project there are currently few didactic models that reliably present the morphology of this group under study. Therefore, a need rises to create visual representations scientifically corrected that may efficiently communicate, in a simplified and objective way, the complexity of a field as wide and complex as anatomy is.

An objective representation of each species with its muscular composition is constructed and validated by previous dissection studies and documented scientific descriptions, as well analysis and observation done by illustrator himself using atlases, scientific articles, documentaries and even images of the specimen in life. This representation constitutes a visual taxonomic model, idealized by the exercise of intellectual nature (observation, interpretation, reflection), outsourced by 3D modeling as a process, and which is designated as 3D archetype [1].

The results show another way to communicate science through the use of 3D models that functionally illustrate, according to previous studies and results, the overall anatomy of the muscular system (AMS) of 5 species of apes. Head and neck, as well upper and lower limbs of common chimpanzee will be the clone-based model that will be applied to reconstruct AMS of the other major primates: Bonono, Gorilla, Orangutan and Gibbon.

This works aims not only to build a model where realistic anatomical elements are used, but also to produce procedures to be be followed when presenting an anatomical figure in scientific publications. For example, the posture in which the upper or lower limb should be illustrated, if is necessary to visualize it in an extended position and providing a ventral and dorsal views. This method is based on a principle that schematic and, at the same time, scientific rigorous models may be comprehensively read at different levels and provide the viewer with a broader and understandable conception of anatomy, fighting the perception that this kind of communicational products are limited to a specialized audience. In the chimpanzee models herewith in presented, each characteristic morphological aspect of the muscular system is enlighten in detail. Is favorable to comparison procedures and promotes the understanding that apes muscular system is very similar to what may be seen in human being.

Intuitively, the user may conclude by himself the evolutionary and anthropological correlations and interpretations that corroborate phylogenetic relationship between humans and primates. This point of view indicates that scientific illustration/3D scientific models not only fits primary goals (communicating characteristic anatomical aspects of a particular species), but also provides visual data that may connect and enrich knowledge about other related disciplines.

Conclusion

Most researchers are trained to conduct science, not to draw it, nowadays scientific communication needs to be written and rigorous, as well as its illustrations. Over time, various softwares have been developed that have facilitated the representation of processes. complex biological, or as is the case study, anatomical structures.

Initially, there were 2D representation mechanisms, where programs such as illustrator, Photoshop or even Power Point, among others, were mainly used to create close-up compositions of biological processes or structures depending on the characteristics and needs of the publication. Later, programs were developed that provided a 3D plane, in which the scientist could interact directly with the object of study, in this case from scans of the structures, thus transforming his cognitive capacity and perceptions of reality by manipulating an object where They incorporate volumetric elements in different perspectives affected by external variables such as light, shadow, texture, etc.

Later, programs were designed to make digital sculpture, which serve as a scientific illustrator as a resource to reconstruct models with scientific rigor without depending on a 3D scan (which is currently still necessary as objects of study). This generated a great impact and approval in the scientific community in terms of divulgation, because are presented aesthetic and scientifically correct models. As in the traditional illustration, the illustrator can manipulate factors such as texture, light and shadow, which gives a final value to the illustration.

Using 3D reconstructions in benefit of scientific communication will bring several advantages in a future nearby, as it expand perception of scientific knowledge and make it clearer allowing to access interesting and useful information usually restricted to academic and research communities. Also it will allow illustrators to use other image creation procedures and resources, making use and integrating technological advances to better feed the constant need to generate new dissemination mechanisms that improve communicating processes of biological (medical, paleontological, others) complex concepts. 3D model provides wide visual resources that may fulfill two functions, always depending on the intended use: direct interaction with the viewer through a digital platform to improve perception of anatomy, or allow a 2D presentation where realistic illustrations are presented showing different or unusual perspectives.

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References

1. Correia, F.: Vamos desenhar...assimetrias numa lesma. Parques e vida salvagem. Pag 71, Aveiro, (2019).
2. Costa, M, Sousa. Ebert Don Stredney, Nikolai A. Illustrative Visualization for Medical Training Computational Aesthetics in Graphics, Visualization and Imaging, Department of Computer Science, School of Electrical and Computer Engineering, Biomedical Applications Research Group University of Calgary, Canada Purdue University, USA Ohio Supercomputer Center, USA, (2005)
3. Diogo, R., Wood, B.A.: Soft-tissue anatomy of the primates: phylogenetic analyses based on the muscles of the head, neck, pectoral region and upper limb, with notes on the evolution of these muscles. J. Anat. 219: 273–359. (2011).
4. Diogo, R., Wood B.A.: Comparative anatomy and phylogeny of primate muscles and human evolution. Taylor & Francis, Oxford (2012).
5. Diogo, R., Potau, J. M., Pastor, J. F., de Paz, F., Barbosa, M. M., Ferrero, E. M., Bello, G., Wood, B. A.; Photographic and descriptive atlas of Gorilla – with notes on the attachments, variations, innervation, synonymy and weight of the muscles. Taylor & Francis, Oxford (2010)
6. Diogo, R., Potau, J. M., Pastor, J. F., de Paz, F., Barbosa, M. M., Ferrero, E. M., Bello, G., Aziz, M. A., Burrows, A., Wood, B. A.: Photographic and descriptive atlas of gibbons and siamangs (*Hylobates*) – with notes on the attachments, variations, innervation, synonymy and weight of the muscles. Taylor & Francis, Oxford (2012).
7. Diogo, R., Potau, J. M., Pastor, J. F., de Paz, F., Barbosa, M. M., Ferrero, E. M., Bello, G., Aziz, M. A., Burrows, A., Wood, B. A.: Photographic and descriptive atlas of chimpanzees (*Pan*) – with notes on the attachments, variations, innervation, synonymy and weight of the muscles. Taylor & Francis, Oxford (2013a).
8. Diogo, R., Potau, J. M., Pastor, J. F., de Paz, F., Barbosa, M. M., Ferrero, E. M., Bello, G., Aziz, M. A., Burrows, A., Wood, B.A.: Photographic and descriptive atlas of orangutans (*Pongo*) – with notes on the attachments, variations, innervation, synonymy and weight of the muscles. Taylor & Francis, Oxford (2013b).
9. Diogo, R., Pastor, J. F., Hartstone-Rose, A., Muchlinski, M. N.: Baby gorilla: Photographic and descriptive atlas of the skeleton, muscles and internal organs – including CT scans and comparisons to other gorillas and primates. Taylor & Francis, Oxford (2014).
10. Diogo, R., Shearer, B., Potau, J. M., Pastor, J. F., de Paz, F. J., Arias–Martorell, J., Turcotte, C., Hammond, A., Vereecke, E., Vanhoof, M., Nauwelaerts, S., Wood, B. A.: Photographic and descriptive musculoskeletal atlas of bonobos – with notes on the weight, attachments, variations, and innervation of the muscles and comparisons with common chimpanzees and humans. Springer, New York (2017).
11. Madhusoodanan, J. Science illustration: Picture perfect. Enlisting the help of an illustrator can add impact to research papers and outreach projects. Nature (2016)
12. Perkel, J. The software that powers scientific illustration The web-based tool BioRender has become a staple of biomedical research drawings, Nature (2020)
13. Preim, Bernhard & Meuschke, Monique. Medical Animations: A Survey and a Research Agenda. (2019).
14. Taerum, T. & Costa Sousa, Mario & Samavati, Faramarz & Chan, S. & Mitchell, Joseph. Real-Time Super Resolution Contextual Close-up of Clinical Volumetric Data.. Proc. Eighth Eurographics/IEEE VGTC Symp. Visualization (EuroVis '06). 347-354. 10.2312/VisSym/EuroVis06/347-354 (2006).