Reality Computing: An end-to-end process for Herpetological Heritage

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Abstract. Documentation of institutional biological collections are essential for scientific studies and conservation of the biodiversity of a region. In particular, preserved specimens require the development of a short- and long-term plan to prevent damage.
In this context, the 3D digitisation of this type of documentation provides innovative mechanisms to safeguard the valuable information provided by the collections and at the same time prevent any possible loss of information. At the moment, the potential of laser scanning in model reconstruction is well-known, but developed works using this method for 3D construction reveal a lack of reliable, precise and flexible solutions. Furthermore, visualisation of results is often very useless and does not go beyond web-based applications.
This work presents an analysis of 3D modelling using two digitisation techniques: laser scanning and photogrammetry; combined with real time VR and AR visualizations and 3D printing.

Keywords: Reality Computing, Digital Photogrammetry, 3D Scanning, Virtual Reality (VR), Augmented Reality(AR), 3D Printing.

1 Introduction

Generally, digitisation has been identified as one of the major trends changing society and business in the near and long term future, breaking down industry barriers and creating opportunities for new applications [1, 2].

Particularly, three-dimensional digital models have become relevant in many applications such as inspection, navigation, object identification, visualisation and animation [3–5]. It can be said that the most important use it has been given in the last years is cultural heritage digital archiving thorough different motivations: documentation in case of loss or damage, virtual tourism and museum, educational resources, interaction without risk of damage, and so forth [6].

In this context, nowadays there are institutional biological collections which are specialised repositories of strong scientific matrix, being essential for scientific studies on the biodiversity of the region and its conservation [7, 8]. These collections are very useful for students, professors, researchers and other professionals, turning them into centres of scientific and social studies. Consequently, these collections are usually digitised. Nevertheless, similarity among digital collections with real collections will depend essentially on the used technique [9, 10].

At present, in computer graphics, capturing geometric models is a result of the use of *laser triangulation* and/or *image processing*[11, 12]. Particularly, 3D reconstruction from images has undergone a revolution in the last few years [13, 14, 12]. Computer vision techniques use photographs from data set collection to rapidly build detailed 3D models. The results are promising because the obtained models are beginning to challenge the precision of laser-based reconstructions [15].

Furthermore, the fast popularisation of sophisticated human-computer interaction devices has brought unrivalled convenience and entertainment experience in human life [16]. Thanks to technologies such as *Virtual Reality* (VR) and *Augmented Reality* (AR), the user has the ability to manipulate the perception to such an extent that can enter to another type of reality [17]. VR allows the creation of interaction's environments that facilitate new contexts of exchange and communication of information. Currently, VR applications consist in user immersion into a computer-generated environment, resulting in a natural idea to improve the impression of living in a simulated reality. On the other hand, an AR system can overlay computer-generated contents on views of the physical scene, augmenting a users perception and cognition of the world. Development of AR technology with precise information augmentation in real-time is a foreseeable reality that can be used in almost any domain. Over the past decade, AR has undergone a transition from desktop to mobile computing [18].

3D digitisation have promoted not only the mentioned technologies but also 3D printing technology. 3D printing technology was a change in the industrial/manufacturing field and in the way of human life. Basically, the printing process is defined as the process of joining materials to make objects from 3D model data. In recent times, many educational research have begun to use this technology like a learning tool [19].

This work explains the set of processes developed for the preservation and use of a representative set of type herpetological specimens through digital techniques. The specimens were processed into a three-dimensional textured model that can be used in VR and AR environments and 3D printing, allowing for multiple educational and research purposes.

2 Context

This effort aims to preserve and enrich the collections of the *Unidad de Herpetología* at the *Universidad Nacional de San Luis*, due to the fact that it is a space that concentrates specimens of the type series and typical sites, bibliographic material of difficult achievement, as well as a vast photographic record, which represents and protects a large part of the herpetological heritage of the Argentinian Central and Patagonian Regions.

It is common for samples of preserved specimens to suffer deterioration that can sometimes affect their functionality, the most common wear and tear is due to the passage of time and the handling of users.

With the aim of protecting and conserving the heritage of the *Unidad de Herpetología*, this work consisted of generating digital replicas of a representative set of type specimens, thus achieving the corresponding 3D models of the real samples. These 3D models are intended to be used for the creation of a structured and organised digital collection of the preserved specimens, developed according to a predefined conceptual scheme, in order to expand the didactic-scientific potential of these resources. In addition, digitisation will improve the professional and educational transfer capacity of the *Unidad de Herpetología*, given the valuable and specific educational contribution that the collections can offer [20].

The virtual interaction with the documented specimens on the computer (e.g. deliberate cross sections; changing perspectives) allows for a more detailed understanding from it. These computer-based 3D representations of reality also offer various possibilities for reproducing models for publication and presentation purposes. A comprehensive 3D process chain can also result in animations, games and elaborate computer applications [21, 22].

3 Digitising

Today a large number of remote sensing sensors and data are available for mapping purposes and digital recording of visual Cultural Heritage. Generally optical recording sensors are divided in passive and active systems. Passive sensors deliver image data which are then processed with some mathematical formulations to infer 3D information from the 2D image measurements. On the other hand, active sensors can provide data directly from 3D information or ranges [23].

This work was developed by researchers from the *Laboratorio de Computación Gráfica* at the *Universidad de San Luis*, which has the necessary equipment to work with both sensor systems.

At first, to obtain the digital models corresponding to the herpetological specimens, the process chain was started using optical recording sensors based on active systems because this method was recommended for beginners in digitisation.

3.1 Active sensors systems: Laser scanning

These systems use laser scanning technology that analyses and captures the geometry and colors of physical objects to transform them into digital 3D models [24]. In this instance, the *NextEngine* 3D laser scanner was used and the following steps were established:

1. **Object positioning:** In this case, *ScanStudio*, the *NextEngine* scanner software, was employed. The scanner has a rotating platform dedicated to holding the objects to be scanned. Different orientations of the specimens were analyzed, obtaining the best result by vertically aligning the spine.
2. **Object and Turntable Setup:** Before starting the scanning process, the area to be scanned is selected to limit the amount of foreign information registered by the scanner. Then, it is rotated 360 degrees to the object, stopping momentarily to analyze the surface of the object using triangulation techniques by infrared light. As a result of this process, the quality of a model is directly related to the amount of analysis (stops; 32 in this case) carried on the object.
3. **Model and Texture Scanning:** Each surface analysis is accompanied by an object's snapshot, which is associated with the digitized model. Different resolutions were considered and the highest resolution of those offered by the tool was selected (2.048×1.536 pixels).
4. **Model Verification and Correction:** Once the digitized model was obtained, it is necessary to check it. Digitisation failure are displayed by incomplete or incorrect parts, and manual corrections had to be made. For this issue, the *Blender 3D* modelling tool was used. In reptile specimens the areas most prone to problems are claws and tail.

The 3D models resulting from this digitisation methodology were analysed by the *Unidad de Herpetología* people without obtaining their approval. The reason was the poor detail obtained from both the 3D model and the texture, specifically, the appreciation of each specimen scale at the lumbar and ventral area, the reproductive region and the head area. Therefore, a more professional method of obtaining realistic digital models was needed.

3.2 Passive sensors systems: Photogrammetry

There is a technique based on passive sensor systems known as *Digital Photogrammetry*. It is based on image data processing and can deliver accurate, metric and detailed 3D information at any scale of application with estimates of accuracy and reliability of unknown parameters from a set of images [25].

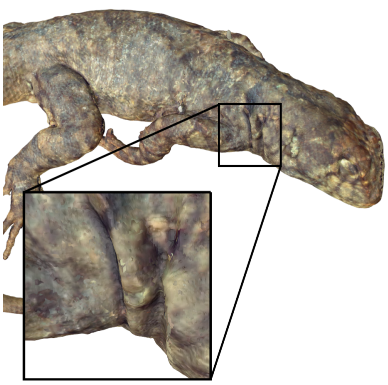
Objects well suited for this technique should have amorphous geometries, structured surfaces, many edges, many corresponding image points and an inhomogeneous colouring, characteristics of typical objects in herpetology and preservation of specimens.

Currently, there are tools dedicated to digital photogrammetry such as *ReCap*, *Agisoft* and *Regard 3D*, which require high performance computers for the large amount of calculations that this methodology requires. According with these tools, the following stages of the digitization process can be set:

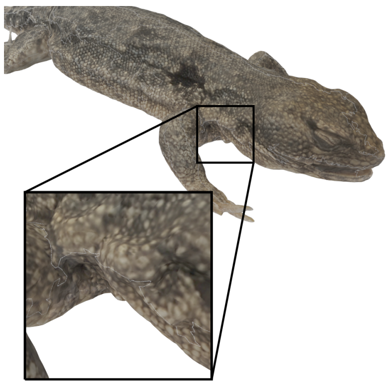
1. **Data acquisition:** Ideally, images of the specimen should cover each region in order to achieve a complete 3D reconstruction. In this work, a *Nikon D3400* camera with a resolution of 3.872×2.592 pixels was used to capture

specimen images (over 100 captures per specimen). Climate is a key factor, because it directly influences the light received by the objects and the texture of the digitised model. Therefore, a cloudy weather is recommended where light rays are distributed evenly. For this reason, the main setting on the camera is light sensitivity (ISO).

2. **Data processing:** The processing of image data consist of image matching algorithms which identify homologous points between images by correlating grey level variations and contrast within a template window. This step achieves the alignment of the photos and the generation of a cloud of dense points representing the outer skin of the object. In this stage it must be adjusted, among other variables, the number of points that will be searched in other captures (set 60.000 points) and the number of points of links between different captures (set 4.000 points).
3. **3D model generation:** This stage reconstructs a 3D polygonal mesh representing the object surface based on the dense or sparse point cloud. Generally there are two algorithmic methods available that can be applied to 3D mesh generation: for planar type surfaces or for any kind of object. Due to the specimens are complex objects and it is desired to obtain high quality meshes, it was specified that the final models are conformed by at least 50.000 polygons.
4. **Texturing:** After geometry is reconstructed, it can be textured. Different texturing modes determines how the object texture will be packed in the texture atlas. Because it is important to record small details, such as specimen scales, it was necessary to obtain high resolution texture images (4.096×4.096 pixels).
5. **Model Verification and Correction:** In this case, it was necessary to reconstruct some small parts of the specimens (claws) using *Blender 3D*.



(a) Laser scanning



(b) Digital Photogrammetry

Fig. 1: Texture detail.

Figure 1 shows the texture returned by the digitization methodologies tested. Once again, the new resulting 3D models were analysed by the herpetology unit people and in this time, with a positive feedback. The main reason for the improvement of the 3D models is the possibility of selecting certain areas of the specimens to maximize the detail of the resulting model.

On the other way, the *Unidad de Herpetología* people expressed the need to show each 3D specimen model to users for analysis and study.

4 3D models implementations approaches

Once an object has been digitised, in this case a specimen, the computer uses are almost endless. It can be displayed as a two-dimensional image through a process called *3D rendering* or used in a computer simulation. Accordingly, display methods are classified into those that perform real-time processing and those that do not.

Consequently, since the 3D modelling process was performed from real objects which is usually called *Reality Capture*, this work use this in combination with 3D printing to create an end-to-end process known as *Reality Computing*. In this process the virtual model allows the physical recreation of the real object using 3D printing devices [26].

In accordance with the above, the following subsections describe the developments in both visualisation and 3D printing in which the 3D models obtained were included.

4.1 Visualization

The *Laboratorio de Computación Gráfica* works with different real-time visualization paradigms such as virtual reality and augmented reality, among others. These paradigms were proposed as a solution for the appreciation of digitized specimens to users.

Immersive Virtual Reality: It is known Virtual-reality-enhanced interactive learning environments are increasingly common. VR brings together a mixture of virtual and real-life scenarios for a wide range of potential possibilities in teaching and learning. Particularly, the *Laboratorio de Computación Gráfica* of *Universidad Nacional de San Luis* owns a Cave-like multi-VRmedia System which comprises the hardware and software necessary to gather the information obtained during the interaction between the user and the system: via a motion sensing device, sound system, microphone, screen/projection surfaces and projectors, among others.

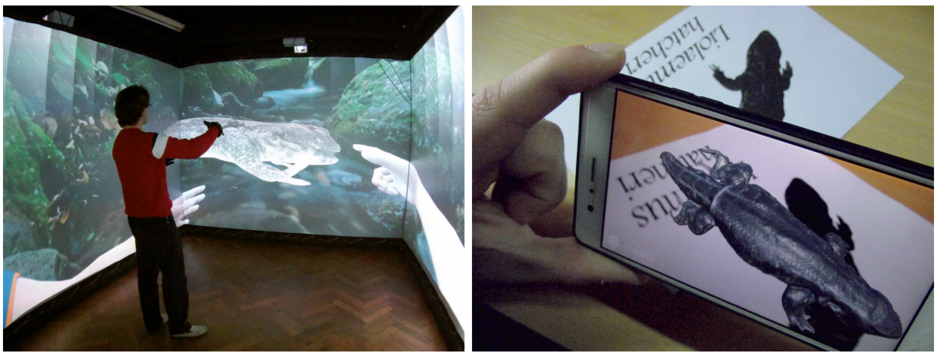
This system provides the necessary structure for attributes definition, rendering and collaborative multi-visualizations, as well as the needed interactive resources. Therefore, as an innovative and interesting way where users can interact and observe the different digitised specimens, a scenario, set up with ambient sound, inanimated objects (trees, plants, ground) and animated objects (specimens) was modelled and rendered. The specimens on stage are dynamic objects which are controlled by an avatar (representing the user). The user can control (e.g. rotate) the virtual replica of the specimen by using a keyboard, mouse and motion detection devices. In this way, the user will be able to observe it in more detail and from various angles (See Fig. 2a).

Augmented Reality: Many students and general audience of San Luis province don't know about biodiversity of the region and its conservation. Thus, a interesting way of diffusion of specimens' biodiversity located in San Luis is trough mobile applications, which are highly popularised.

As was mentioned, an AR system allows overlay computer-generated contents on views of the physical scene. In this case, an AR mobile application was implemented where image-based tracking uses 2D targets denominated *markers*. The goal is to stimulate learning interests in a less complex way when compared to other traditional teaching methods (books, web sites, among others).

The application consisted of 3D visualisation of native reptiles and amphibians so that people can understand and observe the skin texture, the traits and the structure. The user must use the camera of mobile device to identify visual specific markers (one marker per specimen), to showcase an overlay only when a marker is sensed by the device (See Fig. 2b).

Once the marker is recognised, a 3D virtual version of the corresponding specimen is displayed on the screen. In such a way, the user will observe it in more detail and from various angles and by rotating the marker would rotate the virtual replication as well.



(a) Immersive Virtual Reality System (b) Augmented Reality System

Fig. 2: Visualization Systems

4.2 3D printing

The end-to-end process from *Reality Computing* ends with 3D printing. Once a suitable 3D model is created, it can quickly be produced by a 3D print.

3D printing is a form of additive manufacturing technology where a three dimensional object is created by laying down or build from successive layers of material. 3D printing is a great way to create objects because you can create objects that you couldn't make otherwise without having complex expensive molds created or by having the objects made with multiple parts.

A 3D printed herpetological specimen can be edited by simply editing the 3D model; in such manner, for example, it is possible to scale a reptile or modify its original pose.

A type of filament called Acrylonitrile Butadiene Styrene (ABS), was used for printing reptile models. According to the characteristics of each model, printing tests and modifications were made to the models in order to achieve prints without the need to use supports on the parts. It is because the supports must be cut increasing the chances of damaging the printed specimen.

Figure 3 shows a real specimen and its printing.

(a) Real Specimen (b) Printed Specimen

Fig. 3: Reality Computing

5 Conclusions and Future Works

This paper describes an approach to digitising herpetological specimens. The digitising process allows to built a 3D model from a real object. Because different ways lead to a 3D model for the development of this work, more than one technique was tested.

At the beginning, this work consisted in the survey of a representative set of type specimens, which were digitised through the *Laser Scanning Method* in order to achieve a three-dimensional textured model of each one. According with the *Unidad de Herpetología* feedback these models and theirs characteristics were not suited to the needs, interests and preferences, herpetologically speaking. Then, the *Photogrammetry Method* was carried out which allowed obtaining models with a higher resolution; which in turn were considered as more accurate replicas and according to the needs of the *Unidad de Herpetología*.

In order to the digitised models to be visualised, two applications were developed: an *Augmented Reality* application that allows the visualisation of the specimens in an attractive way and from any mobile device; and an *Immersive Virtual Reality* application that achieves a more personalised and detailed use of the digitised samples. In addition, the *3D prints* allowed to obtain tangible replicas of the herpetological specimens in which it is possible to appreciate the non-textured characteristics of a specimen.

Given the interdisciplinarity of the work carried out, the technologies used for its implementation and the unique characteristics of the collections, the process generated is, in itself, unique and innovative, and its result is a trigger for a wide range of scientific and educational activities. The obtained 3D photorealistic models offer new possibilities for the daily practice of herpetology, protection and conservation of specimens. As well as being objective 3D documentations, they achieve a reliable conservation of the herpetological heritage.

Future works will include: reproduce the process with all the specimens of the *Unidad de Herpetología*; build a 3D digital library of the *Unidad de Herpetología*, which can be accessed online; incorporate animations to give more realism to the models; automate the process related to the capture of photographic samples, with the necessary equipment, as a rotating base, light-box photo studio, among others.

References

1. Christophe Degryse. Digitalisation of the economy and its impact on labour markets. Working Paper 2016.02, European Trade Union Institute, Brussels, 2016.
2. Harry Bouwman, Mark de Reuver, and Shahrokh Nikou. The impact of Digitalization on Business Models: How IT Artefacts, Social Media, and Big Data Force Firms to Innovate Their Business Model. Technical report, 2017.
3. Nady Hoyek, Christian Collet, Franck Di Rienzo, Mickael De Almeida, and Aymeric Guillot. Effectiveness of three-dimensional digital animation in teaching human anatomy in an authentic classroom context. 7, 11 2014.
4. Hammad H. Malik, Alastair R.J. Darwood, Shalin Shaunak, Priyantha Kulatilake, Abdulrahman A. El-Hilly, Omar Mulki, and Aroon Baskaradas. Three-dimensional printing in surgery: a review of current surgical applications. *Journal of Surgical Research*, 199(2):512 – 522, 2015.
5. P. Santos, M. Ritz, C. Fuhrmann, and D. Fellner. 3d mass digitization: a milestone for archeological documentation. *Virtual Archaeology Review*, 8(16):1–11, 2017.
6. Nicola Lercari, Jurgen Shulze, Willeke Wendrich, Benjamin Porter, Margie Burton, and Thomas E. Levy. 3-D Digital Preservation of At-Risk Global Cultural Heritage. In C. Catalano and L. De Luca, editors, *Eurographics Workshop on Graphics and Cultural Heritage*. The Eurographics Association, 2016.

7. Claude Lavoie. Biological collections in an ever changing world: Herbaria as tools for biogeographical and environmental studies. *Perspectives in Plant Ecology, Evolution and Systematics*, 15(1):68 – 76, 2013.
8. D. Bakk and R. Urban. Scientific and social value of biological collections. pages 6–9, 08 2014.
9. Reed S. Beaman and Nico Cellinese. Mass digitization of scientific collections: New opportunities to transform the use of biological specimens and underwrite biodiversity science. *Biological Reviews*, 209:717, 2012.
10. S. Keaveney, C. Keogh, L. Gutierrez-Heredia, and E. G. Reynaud. Applications for advanced 3d imaging, modelling, and printing techniques for the biological sciences. In *2016 22nd International Conference on Virtual System Multimedia (VSMM)*, pages 1–8, Oct 2016.
11. Francesco Nex and Fabio Remondino. Uav for 3d mapping applications: A review. 6, 03 2014.
12. Wassim Moussa. Integration of digital photogrammetry and terrestrial laser scanning for cultural heritage data recording, 01 2014.
13. Mesapam Shashi and Kamal Jain. Use of photogrammetry in 3d modeling and visualization of buildings. 2, 01 2007.
14. Mozhdeh Shahbazi, Gunho Sohn, Jrme Thau, and Patrick Menard. Development and evaluation of a uav-photogrammetry system for precise 3d environmental modeling. 15:27493–27524, 10 2015.
15. Alfonso Ippolito and Michela Cigola. *Handbook of Research on Emerging Technologies for Digital Preservation and Information Modeling.* 01 2017.
16. D. Vajak and . Livada. Combining photogrammetry, 3d modeling and real time information gathering for highly immersive vr experience. In *2017 Zooming Innovation in Consumer Electronics International Conference (ZINC)*, pages 82–85, May 2017.
17. S. Aukstakalnis. *Practical Augmented Reality: A Guide to the Technologies, Applications, and Human Factors for AR and VR.* Usability Series. Addison-Wesley, 2016.
18. Peng Chen, Xiaolin Liu, Wei Cheng, and Ronghuai Huang. A review of using augmented reality in education from 2011 to 2016, 09 2017.
19. Simon Ford and Tim Minshall. 3d printing in teaching and education: A review of where and how it is used, 10 2017.
20. B. Espeche, Y. Alvarado, G. Rodríguez, N. Jofré, M. Jofré, and R. Guerrero. Repositorio virtual de ejemplares - Unidad de Herpetología - UNSL, Argentina. In *XVIII Congreso Argentino de Herpetología*, 2017.
21. Naci Yastikli. Documentation of cultural heritage using digital photogrammetry and laser scanning. *Journal of Cultural Heritage*, 8(4):423 – 427, 2007.
22. Jocelyn Behm, Brenna R. Waite, S. Tonia Hsieh, and Matthew R. Helmus. Benefits and limitations of three-dimensional printing technology for ecological research. *bioRxiv*, 2018.
23. Giovanna Sansoni, Marco Trebeschi, and Franco Docchio. State-of-the-art and applications of 3d imaging sensors in industry, cultural heritage, medicine, and criminal investigation. *Sensors*, 9(1):568–601, 2009.
24. Susan C Kuzminsky and Megan S Gardiner. Three-dimensional laser scanning: potential uses for museum conservation and scientific research. *Journal of Archaeological Science*, 39(8):2744–2751, 2012.
25. Toni F Schenk. *Fotogrametría digital.* Number Sirsi) i9788426713315. 2002.
26. R. Deutsch. *Convergence: The Redesign of Design.* AD Smart. Wiley, 2017.