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POSSIBLE WAYS TO CREATE 3D ARTHROPOD MODELS FOR BIOLOGY EDUCATION

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Thanks to developing technological tools, we can incorporate photogrammetry methods into the teaching process. Models have been used in education for a long time and have always facilitated writing. Our aim is to present the possibilities to develop 3D models, specifically defined as arthropod models, and of course to include them in the teaching process. Mobile phones, cameras and other technical devices have reached a level of technology where the photographs they help us to take are of sufficient quality to create 3D textured models. It can make the classroom more interesting even for students with possible phobias, as it is possible to study the species without the physical presence of a living animal, which often involves the destruction of the specimen, and without seasonal restrictions. Furthermore, 3D models can have the great advantage that only a single individual is needed to create a model, so that the number of individuals is not reduced, which is a welcome feature for a rare species, as a single individual can be used to create a 3D model that is easily accessible to all and can faithfully represent the characteristics of the species.

Keywords: education, 3Dmodels, photogrammetry

Introduction

According to the literature, a model is an idealised picture of a larger or smaller part of reality, but a law or a concept can also be a model. However, models are most effectively used to describe, analyse and explain how a system works. Modelling therefore facilitates understanding (comprehension of the system) (Kirkby 1987; Makádi et al. 2013).

Modelling and the use of models is a common form of communication, because if you ask for directions on the street, the -director will gesticulate and use his hands to point you in the right direction. The same phenomenon can be observed in the playground, when young children play a game of make-believe in the sandpit using branches and various „tools". In this way, they are doing nothing more than imitating and modelling a phenomenon that they have seen so many times before (Gilbert - Ireton 2003; Geda, 2011).

The models show a detail of reality. A model can be qualitative, which helps learners to understand structures and shapes, or quantitative, which helps them to understand functions and relationships. However, a model can have both quantitative and qualitative aspects (Gilbert - Ireton 2003; Nagy et al., 2020).

According to Huszti and Revákné (2012), the types of models are:

1. Structural models. Enlarged or reduced copies of the structure of a natural object or phenomenon. They reflect reality in form and content, but differ in size from the macroscopic or microscopic scale of the original structure. Examples: flower model, relief model, human torso, etc.
2. Functional models. Models for understanding the interrelationships of natural phenomena and processes. Their structure is often fundamentally different from the original structure, showing only the elements of the structure that are essential for its functioning. Examples: a Donders model to illustrate the process of inhalation and exhalation, a model of a volcano made of sponge, glass jars of different shapes and sizes to illustrate the laws of transport, etc.
3. Symbolic models. Using words and symbols to represent real objects and their relationships. Examples: system diagrams, flow charts, blueprints, concept maps, etc. 4. Models for quantitative values and evaluation and for describing relationships. Examples: formulae, equations, graphs.
5. Computer models. Models that illustrate a structure, process or relationship in electronic form, based on existing data. They are usually constructed on a mathematical basis and can be used to show simultaneously the relationships between structure and function. They can be used to illustrate the structure of matter, processes at the molecular level, as well as abstract natural phenomena, possibly on a gigantic scale (Huszti & Revákné, 2012).

The didactic function of modelling can play a dual role, depending on the purpose of the application. At a given stage of the lesson, it can be used as a method of illustration to visualise and understand a phenomenon or process. When presenting scientific phenomena, we must always strive to present reality. If this is not possible, we can use other means or methods to illustrate the phenomenon, such as modelling. We must distinguish between the tool as model and the method as modelling. A model is only a tool in the process of learning to understand using a system of symbols (model) (Huang et al. 2019; Maneenova & Chadimová, 2015).

Almost a century ago, John Dewey said that the most effective education is experiential, because learning is through personal experience and action. The nearly a century of educational research that followed proved Dewey right and that active learning and experiential learning are highly effective. Some disciplines have always been capable of experiential learning. Disciplines such as environmental sciences, electrical engineering and other inherently practical disciplines are well suited to this type of teaching and learning. Other disciplines are more difficult to engage in experiential education. In some, hands-on experience is challenging (e.g. medicine), in others, subjects can only be accessed through mediators and models (e.g. molecular biology, theoretical physics). A key feature of 3D technology is that it enables experiential teaching and learning in many disciplines where this would otherwise be challenging or impossible. 3D technology can make the invisible visible, the inaccessible accessible. Perhaps the most straightforward use of 3D technology is to recreate objects and spaces that exist in the real world, but in a virtual environment (Field 2015; Dewey 2011).

Science education has long taught students about the natural world through textbooks, lectures and laboratory experiments. But with the advent of 3D modelling technology, educators can bring science alive for their students with a new, innovative tool. 3D modeling in science education allows students to interact with scientific concepts in a more engaging and immersive way, which helps them better understand complex concepts and theories (Alhonkoski et al., 2021).

Objective

The aim of the work is to present the possibilities, tools and methods to create real 3D models for teaching biology.

Tools and methods

A total of 394 photographs were taken around the selected hornet (*Vespa crabro*) at various altitudes. The photographs were taken with a Canon EOS 5D camera with the following parameters: full frame (35mm), CMOS, 13 MPx, JPEG/RAW, 4368 x 2912 pixels. In addition, a Canon EF 16-35mm f/2.8L II USM lens and 21MM and 13MM intermediate ring macro adapters were used.

Figure 1: Photography tools (photo: D. Dancsa)

To take the photos, the model was placed on a turntable Figure 2, so that we could easily take the right number and quality of photos from all sides by rotating the turntable. The camera was fixed while the photographs were taken. Markers of different colours and heights were placed around the central axis to help the software interpret the movements of the specimen as it was rotated.

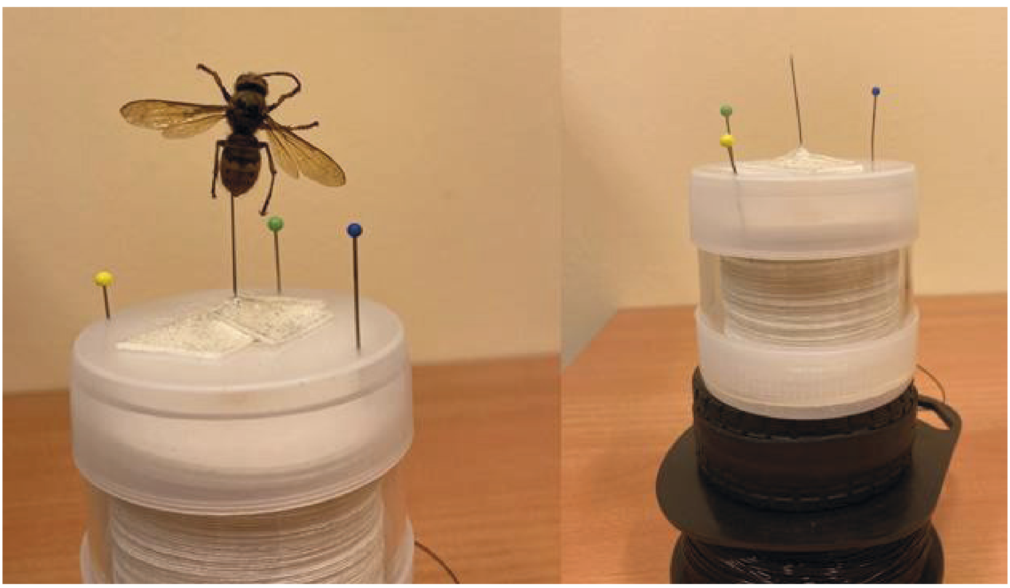

Figure 2: Turntable (photo: D. Dancsa)

Pix4D software was used to create the 3D model. It is a professional photogrammetric software that has already given us positive results. The photos were processed at the Intelligent Robotics Centre of Selye János University with the following hardware parameters:-CPU: Intel(R) Xeon(R) CPU E5-1650 v3 @ 3.50GHz-RAM: 32GB-GPU: 32GB: NVIDIA Quadro K4200 (driver: 9.18.13.4121).

Before we start taking photographs, we must first choose the object we want to model. In our case, it is a hornet (*Vespa crabro*) that we have previously collected, prepared and fixed. We then plan how to photograph it, because generally speaking, you can get better results if you spend a little time planning.

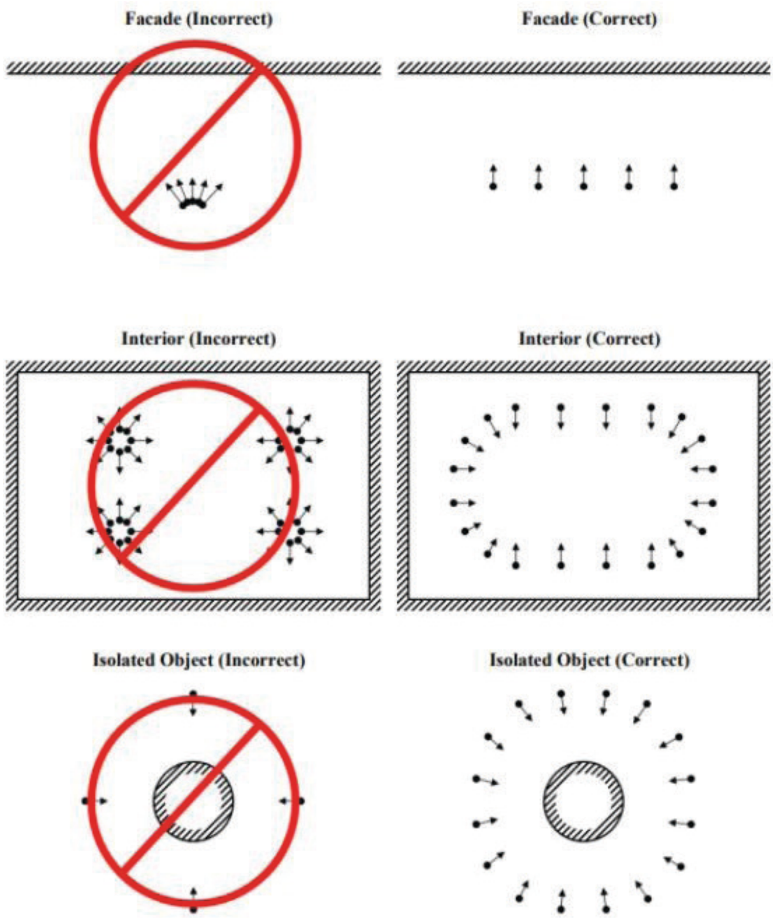

Figure 3: The right way to take a photo (Agisoft, 2019)

Take pictures of the selected object in several planes, preferably 360 degrees. When taking photos, make sure to repeat the shooting in multiple elevation planes to take as many photos as possible for better results.

Results

It is not possible to specify the exact number of photos, but it can be said that better results are obtained if more photos are used, but experience has shown that more than 250 photos can also reduce the quality of the model, as the number of photos increases in proportion

to the number of errors. In addition to the right amount of images, the positioning of the object is also important. The aim should be to ensure that the subject of interest, in this case the hornet, is dominant in the photographs, i.e. that it occupies as much space as possible in the image. However, if parts of the object are missing in some of the pictures or are sticking out of the picture, this is not a problem and does not affect the quality of the model.

In order to get a model of the right quality, you also need to ensure that the images you take overlap properly. Also during our experiments, we found that overlaps between 50% and 70% of the images resulted in good quality images.

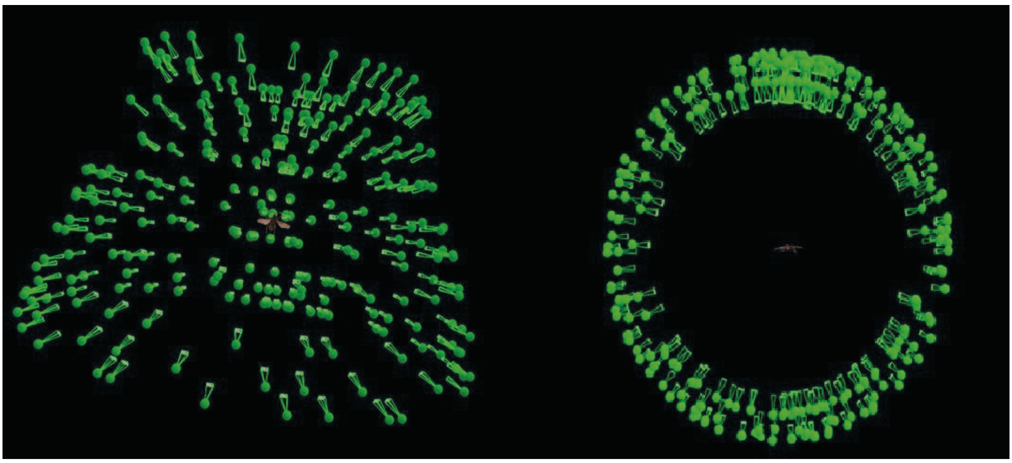

Figure 4: Camera position around the selected object (Source: Own edit)

Once the photos have been taken, the images are imported into a computer, and then we can use software to create a 3D copy of the selected object. We did this using a software called Pix4D. By starting a new project, we can start creating the model by selecting all the photos we have taken and using them to start creating the 3D model.

The position of the cameras is shown in Figure 4, where the points in front of the cameras represent the so-called vertices. These are points that have been identified in several images - for example, the tip of the tentacle. Figure 5 shows the number of automatic tie points. The number of automatic tie points (ATPs) per pixel averaged over all images of the camera model is shown in black and white colour-coded. The white colour indicates that on average more than 16 ATP points were obtained at that pixel location. Black indicates that an average of 0 ATPs were extracted at that pixel location. Figure 3 Number of automatic binding points. Therefore, it is important that the white area covers the area of interest, which is satisfied in this case. The ideal case (but not always) is when the entire square area is white. The worst case, however, is when the square area is completely black.

Figure 5: automatic tie points (source: own editing)

In Figure 6, the point cloud of the hornet and its immediate surroundings. It is clear that the binding points and the point clouds are not the same. While binding points do not carry any information about the position of a point in the coordinate system, point clouds do.

As it is an ametric system, length, area or volume measurements can be taken at these points if necessary (Takáč et al., 2023). We are already researching how to achieve these measurements as accurately as possible.

Figure 6: Tie points (Source: own ed)

The resulting models are far from perfect and can be used immediately. Rework is necessary in almost all cases. However, the software provides the tools to improve the model. One of the most important steps is the manual assignment of tie points. This step is used when the quantity of images produced is insufficient, or not all sides of the model have been imaged, or the quality of the images produced is not good enough so that manual assignment of tie points may be necessary. In our case, 14 such manually assigned tie poins were required to produce a model of the hippo.

Figure 7: Tie point repatriation (source: own edit)

The final 3D model is shown in Figure 8. In the final 3D model, we can observe that the surface is not perfectly smooth, but contains noise, especially at the edges, which is a typical defect in 3D modeling. The next step is to remove the cloud that is disturbing the interpretation of our model. This function is provided by the software and can be used when we need to cut off the cloudy excess from the model or when we want to remove unnecessary backgrounds and environments. The mechanism of occurrence of these errors depends on many factors and will occur in all cases. It is a painstaking and slow job to remove this distracting excess, which can take long hours as we want to preserve the detail of the model. In several cases, as can be seen in Figure 6, the completed model can become almost submerged in the surrounding noise cloud, making it a challenge to remove. However, with care and precision, the end result is a movable 3D model, Figure 8, which can be used in biology lessons, avoiding the destruction of additional animals.

Figure 8: The finished model before and after post-painting (source: Own editing)

Of course, photogrammetry is not only used in the biological field, it can also play a major role in the conservation of cultural heritage (Takáč et al., 2023), as it can be used to model large-scale structures, even those under protection, which can be preserved for future generations or as a starting point for possible reconstruction. At the same time, the Pix4D photogrammetric software we use can also be used to model surface mines and other large- scale spaces.

Science is seen as an isolated subject. But this is not the case. Promoting science subjects and making them attractive to pupils can have a positive impact. Several experiences in Hungary and abroad show that the discovery method of teaching has proven to be very useful (Nagy, 2007). (Nagy et al., 2021), and the use of models can make education more experiential and focus on issues of motivation and creativity (Puskás, 2017, 2019).

The staff of the Department of Informatics at the Faculty of Economics and Informatics of Selye János University also work on modelling. This work mainly visualises the exterior and interior architecture of buildings in 3D (Czakóová – Takáč, 2020; Fröhlich et al.; 2016, Gubo et al.; 2020, Takáč 2017, 2020; Takáč – Végh 2021a, 2021b).

These models can be used even in biology, but even more valuable are the experiences that can be used to improve the modeling of biological objects (Takáč – Végh, 2021a, 2021b, 2021c; Takáč et al., 2023).

Our planned further research is likely to have a novel impact, as 3D models have so far been used very little in education. The models we produce could bring students closer to a world and its structure that we don't see every day. And if education is repeatedly confined to online settings, they can be virtually the only means for teachers to replace common field or laboratory demonstrations. Our expected results would probably be welcomed not only by education, as it is also much easier to store a 3D model, so that it can be used in classrooms and possibly museums. Of course, it is their incorporation into education that could be of greatest importance.

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