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Research Idea

Bio-photogrammetry: digitally archiving coloured 3D morphology data of creatures and associated challenges

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Abstract

Morphological data of life forms are fundamental for documenting and understanding biodiversity. I developed a photogrammetry technique for reconstructing the outer coloured morphology of various creatures and published more than 1000 models online (https://sketchfab.com/ffishAsia-and-floraZia). By suspending it with nylon fishing line(s), taking digital photos from multiple angles and analysing the photos with photogrammetry software, we can obtain a fine 3-dimensional (3D) model of a creature. I believe the challenge could contribute to various fields, such as taxonomy, museology, morphology, anatomy, ecology, education, artificial intelligence, virtual reality, metaverse and, eventually, open/citizen science. Herein, I report the idea and achievement, which I have termed “bio-photogrammetry.”

Keywords

3D model, biological specimen, metaverse, museology, photogrammetry, Sketchfab, virtual reality

Overview and background

The morphological data of creatures are fundamental for documenting and understanding biodiversity. As digital technology develops, digital libraries and archives of biological morphology data/databases have become more important and active (Schambach et al. 2010, Berquist et al. 2012). This approach is usually conducted by computed tomography (CT) and magnetic resonance imaging (MRI) scanning (Schambach et al. 2010, Berquist et al. 2012, Kano et al. 2018, Kano et al. 2019). CT and MRI scanning are powerful methods for determining the internal structure of objects, such as the bones and internal organs of creatures. However, we cannot use them to obtain colour information of the object's surface. Furthermore, as the capital and running costs of using this equipment are extremely high, it is nearly impossible to conduct the scans at the individual level.

Photogrammetry is the technology of obtaining information about physical objects by analysing photographic images, radiant imagery and other measuring equipment. In various fields of science, photogrammetry has become popular, especially in the remote sensing and architectonics fields; the 3-dimensional (3D) physical structure of geography, landscape and architecture can be digitally reconstructed through photogrammetry technology (e.g. Honkavaara et al. 2009, Colomina and Molina 2014, Nieminski and Graham 2017, Carnevali et al. 2018). If photogrammetry is conducted using photographic images, we can obtain the surface colour data of objects, as well as the outer physical structure. In addition, compared to CT/MRI, we can conduct photogrammetry at a reasonable cost without expensive equipment.

Recently I developed a photogrammetry technique for reconstructing various creatures' outer morphology with colour and published more than 1000 models online at Sketchfab https://sketchfab.com/ffishAsia-and-floraZia (e.g. Figs 1, 2, 3), which are associated with multimedia biodiversity databases (https://ffish.asia and https://floraZia.com).

At the moment, I am mainly focusing on aquatic animals, such as fishes (e.g. Fig. 1, *Zacco platypus*, *Mustelus manazo*), including several type specimens (e.g. *Gasterosteus nipponicus*, *Rhinogobius biwaensis*), reptiles (e.g. *Mauremys reevesii*, *Pelodiscus sinensis*), amphibians (e.g. *Bufo japonicus japonicus*, *Cynops ensicauda popei*), molluscs (e.g. Fig. 2, *Mimachlamys nobilis*), crustaceans (e.g. *Cambaroides japonicus*, *Panulirus japonicus*) and water bugs (e.g. *Kirkaldyia deyrolli*, *Cybister chinensis*). However, models of terrestrial animals (e.g. hornet – *Vespa analis*, snake – *Elaphe quadrivirgata* and mantis – *Hierodula patellifera*), plants (e.g. Fig. 3, *Wisteria floribunda*) and Fungi (e.g. *Morchella esculenta*) are also available and I expect to increasingly produce more such models in the future.

I believe the trial could contribute to various fields, such as taxonomy, museology, morphology, anatomy, ecology, education, artificial intelligence (AI), virtual reality, metaverse and, eventually, open science. Thus, I herein report my photogrammetry challenge and results, obtained by "bio-photogrammetry."

Figure 1. doi

Movie of the 3D model of the sailfin poacher, *Podothecus sachi*. Original data: https://skfb.ly/otRSM or https://ffish.asia/f/84092. The embedded cube with a color chart indicates 10 mm and is scaled according to the real object. The object colour is not standardised (the colour chart is just a rough indication).

Methods

The object is suspended by a nylon fishing line(s) and slowly spun and photos are taken from multiple angles (Fig. 4). There are several technical points to remember when taking photos. First, the aperture value should be at a minimum setting, such as f/30–f/40 (depending on the lens), in order to focus on various parts of the object. A strong photoflash is required for taking appropriate photos with such a small aperture value. Second, a plain background (Fig. 4) is better which can be obtained by working in a large laboratory or using a black anti-reflective plate as the background may be an alternative. Third, as many photos as possible should be taken. As the photogrammetry software I use (as explained below) allows a maximum of 500 photos for 3D model reconstruction, I take more than 500 photos and select the best 500 for inputting into the software. When choosing the best 500 photos, the file size is one of the measures; relatively low file size photos (i.e. low information and less contribution to 3D reconstruction) can be eliminated. I also reject blurred, out-of-focus and duplicated photos.

There are many photogrammetry software packages available. I use 3DF Zephyr Lite (3Dflow s.r.l., Verona, Italy), but I believe other photogrammetry software would be also suitable for the above protocol provided they accept a high number of photos (at least a few hundred photo images are required to produce an excellent model).

Figure 2. doi

Movie of the 3D model of the long arm octopus, *Octopus minor*. Original data: https://skfb.ly/os7OA or https://ffish.asia/f/83541.

Objectives, significance and application

“Bio-photogrammetry” is especially useful in museology and taxonomy, as the outer morphology of biological specimens can be semi-permanently conserved as digital files. In particular, it is worthwhile 3D modelling valuable or type specimens (e.g. https://skfb.ly/ou8xy). Museums can also contribute to open science by publishing 3D models of their collections (e.g. https://skfb.ly/osGFZ, https://sketchfab.com/search?q=museum&type=users). For taxonomists, the outer coloured 3D model can be published in a paper describing a new species, as well as internal CT/MRI scan data and the DNA sequence.

The models can be also applied to artificial intelligence (AI) that identifies species from a photo image through deep learning (e.g. Siddiqui et al. 2017, Norouzzadeh et al. 2018). We can obtain almost unlimited snapshot images of a 3D model at various angles; the accuracy of AI’s species identification increases by learning the augmented snapshots from a 3D model in addition to general 2-dimensional (2D) photo images (Kano et al., in preparation).

Figure 3. doi

Movie of the 3D model of the hirsute raspberry, *Rubus hirsutus*. Original data: https://skfb.ly/o9tQ9 or https://floraZia.com/f/2353.

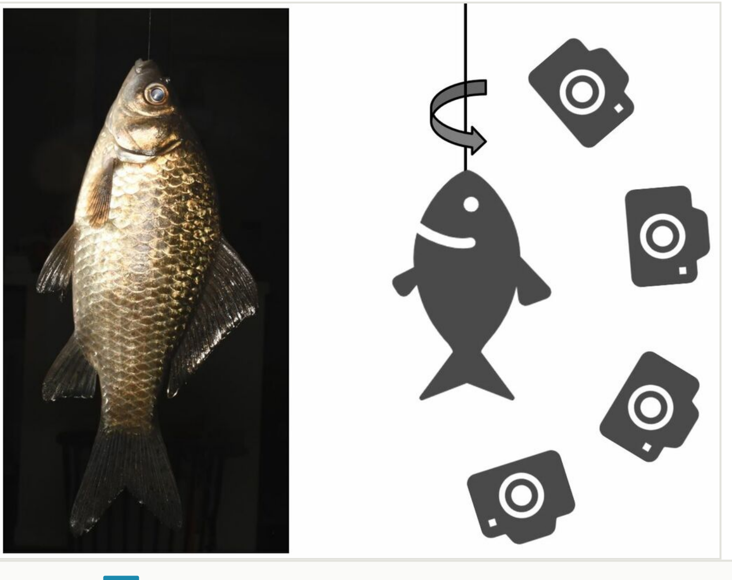

Figure 4. doi

A simplified diagram of the photogrammetry method. The slowly spinning object (*Carassius auratus langsdorfii*), suspended by a nylon fishing line, is photographed from multiple angles. The resulting 3D model is shown at https://skfb.ly/6ZRDz or https://ffish.asia/f/80064.

3D models are also useful in education (Aristov et al. 2021, Aristov et al. 2022, Chenoweth et al. 2022). Students/mentees can understand objects viscerally; the coloured 3D models may give them a much higher interest and affinity in biodiversity than 2D photo images/ sketches. I expect that they are also available in the fields of the metaverse and virtual reality associated with environmental education.

Issues

The bio-photogrammetry technique has several limitations. For example, transparent creatures, such as some shrimps, cannot be reconstructed. Additionally, reconstruction of eyes, which physiologically absorb light, sometimes fails (e.g. *Xylocopa appendiculata circumvolans*, *Sebastiscus marmoratus*). Furthermore, it is almost impossible to make small (< 5 mm) or large (> 1 m) models of objects using this technique (but see Chenoweth et al. 2022) and smooth surfaces (such as the inside of mollusc shells) are usually expressed in a disorderly manner (e.g. *Hemifusus tuba*, *Turbo sazae*).

Complex and/or delicate objects are very difficult to reconstruct: thus far, I have failed to produce models of most middle-large sized (< 30–50 cm) herbs with large leaves (but see *Arisaema serratum*), Comatulida (feather stars) and nudibranchs. However, I believe with further development of software and protocols, these issues will be resolved.

As for CT and/or MRI, "morphosource.org" would be an academically standard repository. However, as far as I know, there is no equivalent repository that archives biological 3D photogrammetry data (while morphosource.org can archive photogrammetry data, the number is still few and they are mostly bones/skulls). Numerous data of biological 3D photogrammetry might exist separately in the respective department or personal websites. As bio-photogrammetry becomes more popular, I expect the emergence of a new online academic repository for the data or the development of the existing platforms (e.g. morphosource.org and Sketchfab), by which the bio-photogrammetry data are made globally standardised, integrated and major.

Impact

In the long history of biology, describing the physical morphology of creatures has advanced gradually from handwritten sketches to digital photo images. Unfortunately, these 2D representations are insufficient for a complete understanding of object morphology. I expect, as a next step, that 3D models produced by “bio-photogrammetry” will enable exciting innovations in various fields.

Data resource

Movies of coloured 3D models of wild creatures made by photogrammetry (Figs 1, 2, 3) (Kano 2022a): https://doi.org/10.5281/zenodo.6581034

Examples of coloured 3D models of wild organisms made by photogrammetry including the original data of Figs 1, 2, 3, 4 (Kano 2022b): https://doi.org/10.5281/zenodo.6577143

The author's account of a global platform of the 3D model sharing (Sketchfab 2022): https://sketchfab.com/ffishAsia-and-floraZia

All the data of the author's 3D model of animals (ffish.asia 2022): https://ffish.asia/?page=file&q=.gltf

All the data of the author's 3D model of plants and fungi (floraZia.com 2022): https://floraZia.com/?page=file&q=.gltf

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Ethics and security

This research was conducted ethically under the associated laws. The copyright of all data in this study belongs to the author.

Conflicts of interest

The author declares no conflicts of interest associated with this manuscript.

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