【Grant-in-Aid for Scientific Research (S)】

# Photogrammetry through co-design of data-driven 3D estimation and imaging systems



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## Purpose and Background of the Research

### ●Outline of the Research

When we "see" an object in the real world, what our eyes actually perceive is the light projected toward our eyes from the object. This light is produced by a portion of the light emitted from a light source, such as the sun, reflecting off of the object's surface, transmitted through the object, or emitted by the object itself. Therefore, if a real-world object's three-dimensional shape, surface reflectance, and color can be digitized correctly, a digital copy can be created that has the same appearance as the actual object under any light source. Furthermore, the created digital copies can be placed in a virtual space for virtual reality and video production applications. In addition, by digitizing cultural assets, it can benefit academic research, digital heritage preservation, and dissemination/education activities.

In recent years, the need for 3D digitization of real-world objects using cameras has increased more than ever toward the realization of the digital twin. Until now, the main focus of camera-based 3D digitization (photogrammetry) technology has been the acquisition of coarse shapes (macro-shapes). On the other hand, a faithful digital copy requires the acquisition of more detailed "meso-shapes" (pixel-wise shape information) and "micro-shapes" (finer shape distribution representing the reflectance of the object) (Figure 1). However, acquiring such information currently requires large-scale, specialized equipment and remains a difficult problem for application to daily-use scenarios.

This study aims to establish a new photogrammetric technique that can easily acquire macro, meso, and micro shapes using a camera and light sources. To achieve this, we aim to create a data-driven 3D shape estimation technique that uses prior knowledge, and at the same time, simplify the imaging system (arrangement of camera and light source).

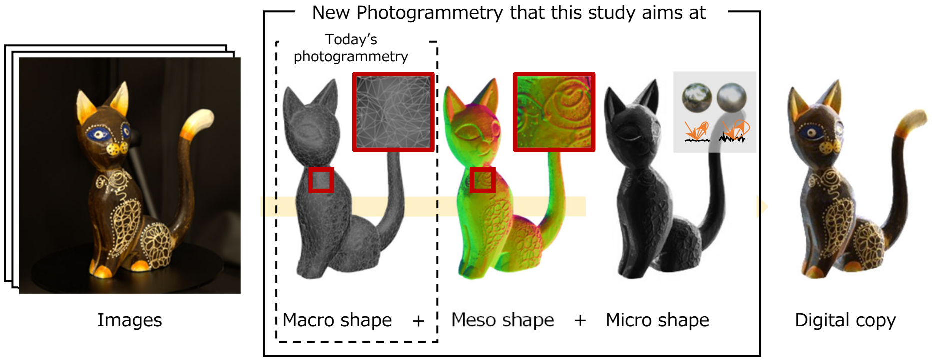


Figure 1. We aim to establish a new photogrammetry technique that allows acquisition of macro, meso, and micro shapes based on the joint design of data-driven 3D reconstruction and imaging setup.

### ●Data-driven 3D shape estimation

The principal investigator's research group has been working on data-driven 3D shape estimation using prior knowledge data. In this context, we have proposed a photometric stereo framework using deep learning (Figure 2) for the first time for estimating object surface normals from image sequences observed under different light sources. It has achieved meso-shape estimation for scenes with a wide variety of materials.

In this study, we will further deepen this effort and attempt the simultaneous acquisition of macro, meso, and micro shapes and the optimal design of the imaging system.

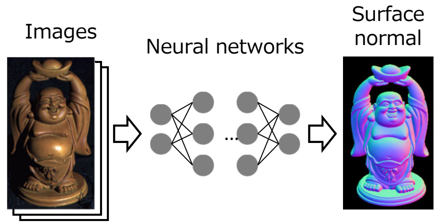


Figure 2. Illustration of "Deep Photometric Stereo"

## Expected Research Achievements

The key question of this research is the search for the minimum amount of information (observables) required for shape reconstruction at all levels of macro-, meso-, and micro-shapes in a setting where prior knowledge about real-world objects (such as prior knowledge about micro-shapes) is available. It leads to the co-design of data-driven photogrammetry and imaging systems. Real-world reflectance distributions (micro-shapes) and spatial distributions of normals (meso-shapes) are considered to distribute not randomly but as low-dimensional data with a certain structure. Making effective use of prior knowledge based on these data and exploring 3D shape estimation methods that work optimally in various environments is academically valuable and contributes to the simplification of imaging systems. By realizing easy-to-use photogrammetry based on prior knowledge data, we aim to democratize the creation of 3D digital content, which currently requires a large photography studio and specialized equipment so that anyone can easily create 3D digital content.

The 3D shape estimation algorithm and imaging system to be developed will be evaluated through 3D digitization of real-world objects. The data will be converted so that it can be rendered with standard 3D graphics pipelines and shared through common visualization tools (*e.g.*, Sketchfab) for public release. Furthermore, we plan to demonstrate the effectiveness of this research by digitizing cultural assets in collaboration with museums with which we have already established cooperative relationships (Figure 3).

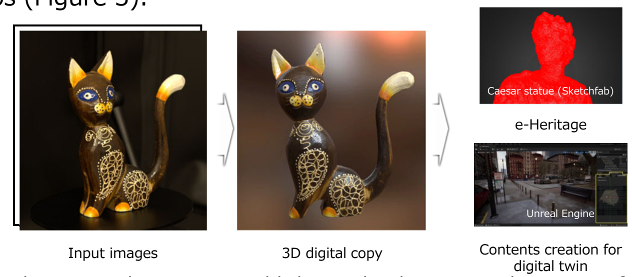


Figure 3. This research aims to establish a technology to easily create a faithful 3D digital copy from a sequence of photographs. The resulting 3D digital copies can be used for e-heritage and 3D digital content creation.

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| Homepage Address, etc. | Matsushita lab Home page: http://cvl.ist.osaka-u.ac.jp/en/ |