Digital archive, Virtual reality, Metaverse

Deep photometric stereo for high-fidelity 3D reconstruction

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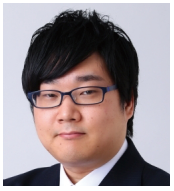


Abstract

3D reconstruction from images is one of the fundamental problems in computer vision. In particular, recovering a high-fidelity 3D shape is desired in various applications, such as a digital archive, virtual reality (VR), and robotics. We develop a high-fidelity 3D reconstruction method based on photometric stereo. Photometric stereo estimates a scene shape from multiple images captured by a fixed camera with varying lighting conditions. Since photometric stereo observes shading changes in a per-pixel manner, it is suitable for recovering per-pixel shape, resulting in high-resolution shape recovery.

Conventional photometric stereo requires knowledge about the material of a scene surface in advance to model reflectances on the surface. Since the reflectance model depends on the surface material, there has not been a unified method that can be applied to diverse materials in the real world. To deal with this problem, we introduce a deep learning-based approach, which learns the reflectance model from training data. As a result, it can handle diverse materials in the real world, which allows using photometric stereo in a wide range of practical applications.

Background & Results

Computer vision is a research field that aims to realize functions like human vision by computers. In particular, understanding 3D shape information from 2D images is one of the fundamental problems.

This work focuses on estimating a high-fidelity 3D shape by the photometric stereo. Photometric stereo estimates a scene shape from multiple images captured by a fixed camera with varying lighting conditions. Since the shading information can be obtained in a per-pixel manner, photometric stereo can recover high-resolution shape recovery.

Recovering a high-fidelity 3D shape is desired in various applications. For example, a digital archive is a project to digitally preserve the 3D shape and appearance of valuable assets, such as cultural heritage and arts.

Even though photometric stereo has the advantage of high-fidelity 3D shape reconstruction, it has not been widely used in practice. The primary reason is that conventional photometric stereo requires knowledge about the material of a scene surface in advance to model reflectances on the surface. Since the reflectance model depends on the surface material, there has not been a unified method that can be applied to diverse materials.

To deal with this problem, we introduce a deep learning-based approach, which we call a deep photometric stereo network. Instead of assuming a specific parametric model, our method learns the reflectances from data by using a deep neural network. As a result, it can handle diverse materials in the real world. Our proposed data-driven approach achieved state-of-the-art accuracy in a benchmark comparison and has become mainstream in recent photometric stereo studies.

Significance of the research and Future perspective

We have proposed a novel data-driven approach for photometric stereo, which is the first work in the world to introduce the use of a deep neural network in photometric stereo and achieve highly accurate estimation for scenes with diverse materials in the real world.

We are now interested in developing a more simplified capturing setup and more accurate estimation algorithm so that anyone can quickly obtain 3D data of an object in the real world.

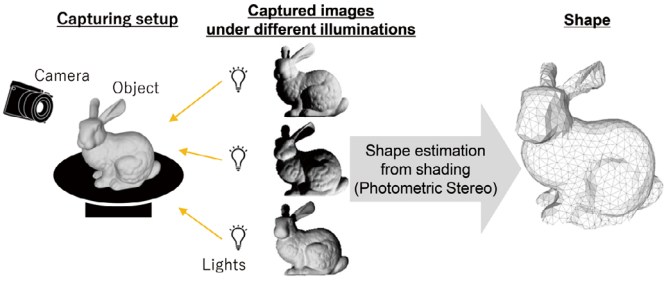

Fig1: Overview of photometric stereo

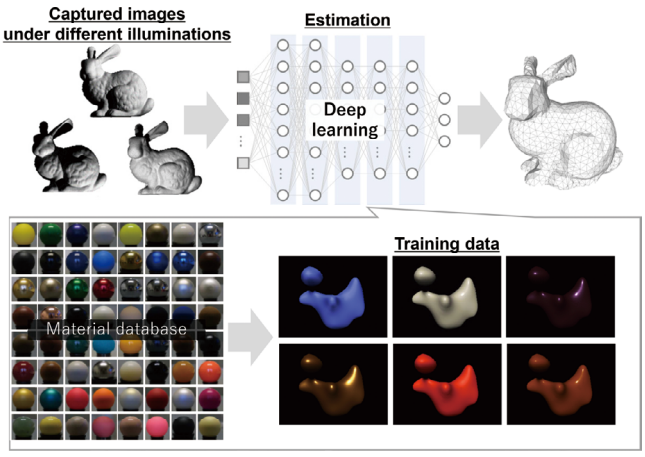

Fig2: Overview of the proposed deep photometric stereo

Patent	
Treatise	Santo, Hiroaki; Samejima, Masaki; Sugano, Yusuke et al. Deep Photometric Stereo Network, IEEE International Conference on Computer Vision Workshop, 2017, doi: 10.1109/ICCVW.2017.66 Santo, Hiroaki; Samejima, Masaki; Sugano, Yusuke et al. Deep Photometric Stereo Networks for Determining Surface Normal and Reflectances, IEEE Transactions on Pattern Analysis and Machine Intelligence (TPAMI), 2020, Vol. 44, No. 1, pp. 114-128, doi: 10.1109/TPAMI.2020.3005219 Santo, Hiroaki; Michael, Waechter; Matsushita, Yasuyuki. Deep near-light photometric stereo for spatially varying reflectances, European Conference on Computer Vision (ECCV), 2020, doi: 10.1007/978-3-030-58598-3_9 Minami, Kazuma; Santo, Hiroaki; Okura, Fumio et al. Symmetric-light Photometric Stereo, IEEE/CVF Winter Conference on Applications of Computer Vision (WACV), 2022, doi: 10.1109/WACV51458.2022.00039
URL	http://cvl.ist.osaka-u.ac.jp/en/ https://github.com/hiroaki-santo/deep-photometric-stereo-network https://github.com/hiroaki-santo/deep-near-light-photometric-stereo
Keyword	computer vision, physics-based vision, computational photography, 3D reconstruction, photometric stereo