

Supplementary material for paper: 3D reconstruction of insects: an improved multifocus stacking and an evaluation of learning-based MVS approaches

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1. Introduction

This document contains some additional material and results for our submission.

2. Multifocus multiview stereo reconstruction

For conventional multifocus image capture, the camera and lens move together away from or towards the object. This changes the centre of the pinhole camera model, leading to changes in perspective image formation and introducing artefacts to the resulting focus stacked image. To avoid this problem, a fixed-lens camera setup is used. Fig. 1 illustrates the overview of multiview-multifocus stereo reconstruction using fixed lens: an insect (left) is mounted on a pan-tilt stage and a camera sensor on multifocus rail capturing the insect images (right) through a fixed lens. For each combination of pan and tilt angles, a set of multifocus images are captured with difference positions of the image sensor such that the resulting stacked image is free of out-of-focus effect. Note that f is lens focal length while d_2 is camera focal length.

3. Calibration target for homography estimation

To estimate the homography transformation between images for focus stacking, images of a 3D calibration target is used and validated. This target consists of two circular dots targets forming an angle of 90° as shown in Fig. 2. During image rendering, the camera faces towards the corner. In the

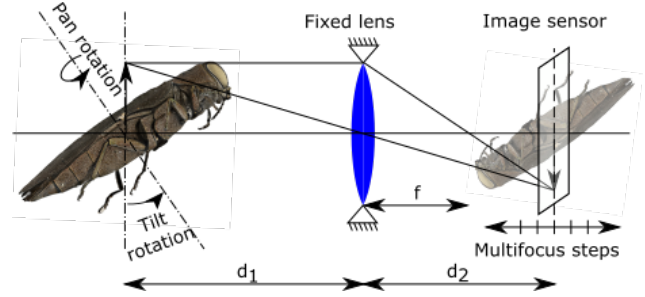


Figure 1: Illustration of a fixed-lens multifocus multiview image capture setup for an insect specimen.

main paper, the scale and shift components of the homography estimation using calibration target images is shown to be reliable within the depth of the target and match well with the theoretical values.

4. Transparent structure and reflective surface

For more validation, we also include the NeRF and NSVF reconstructed results from synthetic images of a spaceship 3D model with transparent cockpit dome and reflective metal surface. A set of 200 images of 800×800 pixels were rendered at random poses around the 3D spaceship model. Meshroom was unable to reconstruct the 3D model of the spaceship, even with ground truth poses. NeRF and NSVF successfully generate meshes very close to the ground truth as shown in Fig. 3. Impressively, both the glass dome and the visible cockpit inside are also reconstructed as shown in Fig. 4.

NSVF has in general a smaller reconstruction error than

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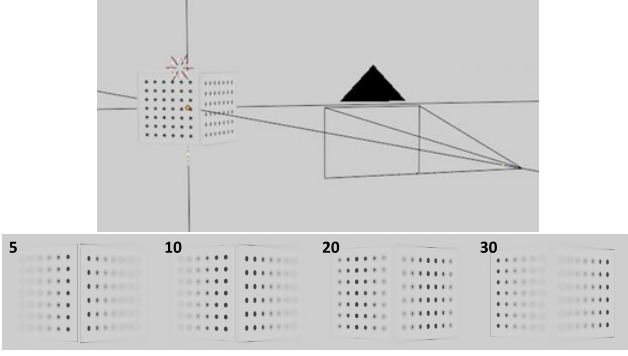


Figure 2: Top: A 90° dual calibration target viewed in Blender. Bottom: examples of multi-focus images of calibration target in a 61-image stack.

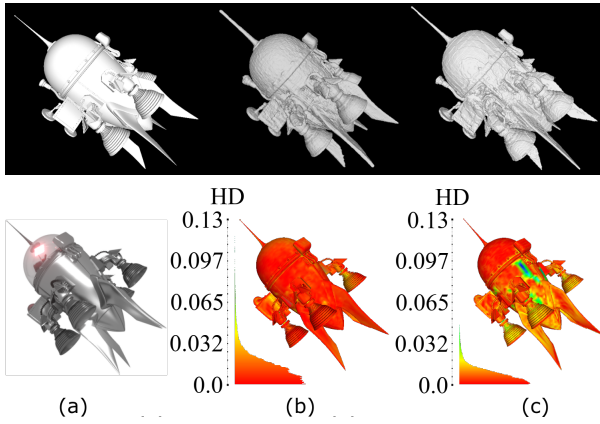


Figure 3: The spaceship reconstructed results: (a) Ground truth (b) NeRF (c) NSVF. Bottom-left inset shows an input image of the spaceship with transparent glass dome and strong reflections. Normalised Hausdorff distance is 0.00360 for NeRF and 0.00198 for NSVF.

NeRF as shown in Fig. 3. Every small and complex structure in the spaceship has been reconstructed successfully. The transparent cockpit glass is also reconstructed successfully. The section view in Fig. 4 shows that all reconstructed structures inside the cockpit, including the pilot seat, the monitor, and control panel.

More importantly, the section view shows that the cockpit glass has two layers. It is a very inconspicuous feature, but NeRF and NSVF could resolve it nicely.

5. Insect species used for 3D reconstruction validations

We use a number of specimens of different shapes and material from [3, 1] including:

- *Agrilus Anxius* (AA) is a wood-boring beetle with elongated body shape (Figure 5a).



Figure 4: Section view of the spaceship reconstructed by NeRF and NSVF.

- *Anoplophora Chinensis* (AC) is a longhorn beetle with very long and thin horns (Figure 5b).
- *Fagus Sylvatica* (FS) is a common beech nut, holo inside and with lots of spikes. This is not an insect but with interesting shape (Figure 5c).
- *Melitaea Britomartis* (MB) is a butterfly with large, symmetric and thin wings (Figure 5d).
- *Cicindela Campestris* is a green tiger beetle (Figure 5e).

The dragonfly (Figure 5f) is a handmade 3D model from [2] and does not have species name specified.

References

- [1] disc3D. Digital archive of natural history (DiNArDa). <https://sketchfab.com/disc3d>, 2021. 2, 3
- [2] mrjeong. Bend swap — dragonfly. <https://blendswap.com/blend/14777>, 2021. 2, 3
- [3] Bernhard Ströbel, Sebastian Schmelzle, Nico Blüthgen, and Michael Heethoff. An automated device for the digitization and 3D modelling of insects, combining extended-depth-of-field and all-side multi-view imaging. *ZooKeys*, 759(759):1, 2018. 2



(a) *Agrilus Anxius*



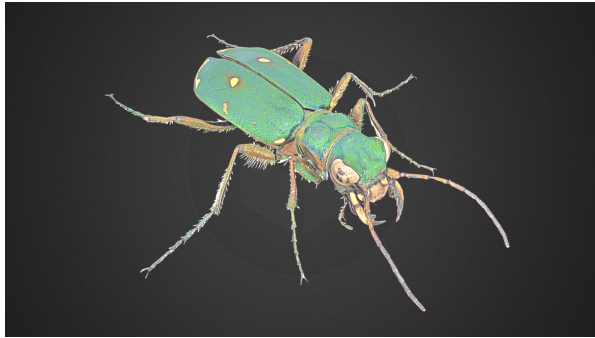
(b) *Anoplophora Chinensis*



(c) *Fagus Sylvatica*



(d) *Melitaea Britomartis*



(e) *Cicindela Campestris*



(f) Dragonfly

Figure 5: Insect models downloaded from [1, 2] and used in this paper.