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Progress in realising a fast information-enriched complex form measurement system

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Summary:

The measurement strategy of currently available non-contact optical measurement solutions is inefficient when it comes to measuring the complete form of complex objects with multiple self-occlusions, such as those produced by additive manufacturing (AM). A large number of incremental rotations and usually manual intervention are necessary to acquire a complete 3D measurement of such objects. Sensor fusion via on-board inertial sensors placed on a camera are used to accelerate both the self-calibration of a fringe projection system, and optimise the positioning of the cameras and projectors in the setup during the measurement to overcome self-occlusions. We demonstrate that the measurement of deep trenches and pillar-type self-occlusions is possible with a single camera and projector in a flexible information-enhanced system.

AM object self-occlusions

A single static camera and projector system has fundamental limitations in measuring objects with a large number of self-occlusions with high aspect ratios (Figure 1), such as those made possible via AM [1]. Solutions suggested for complete 3D object scanning of such objects, such as rotating the object on a turntable or adding multiple cameras and projectors, can partially solve some of these limitations. However, the nature of the solution has to be customised as they can only work optimally if the system is recalibrated according to the object measured. Optimising the setup for each object measured is cumbersome and time consuming. In this work, we aim to achieve continuous calibration of the setup in situ via use of sensors and a priori knowledge.

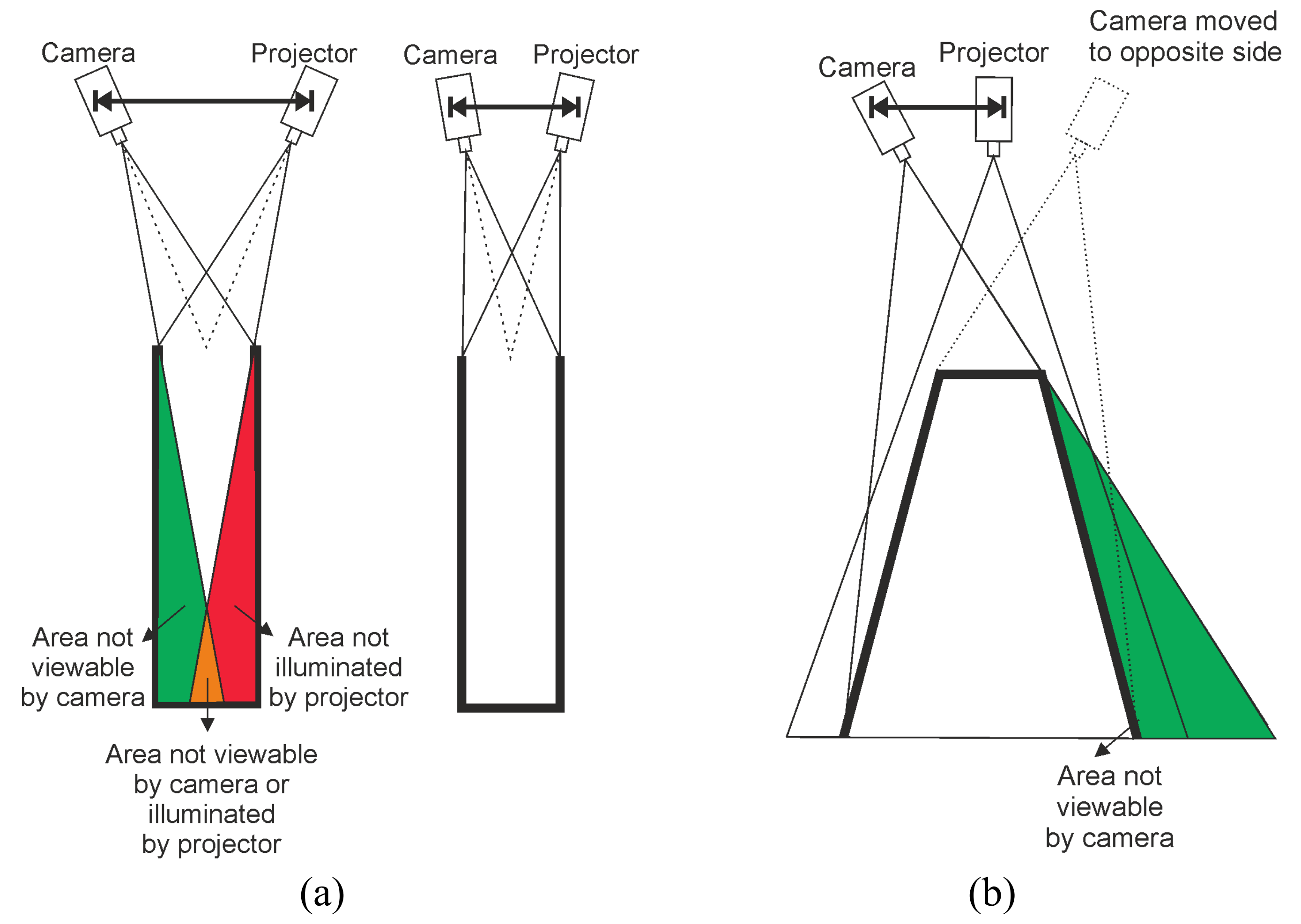

Figure 1. Sketches showing problems with measuring (a) a deep trench self-occlusion when the camera and projector are too far apart (b) a tall ridge self-occlusion whereby the camera cannot acquire the full illuminated field and has to be moved to the other side of the object [1].

Sensor fusion used for self-calibration

The ability to calibrate the system during the measurement process allows the camera and projector to become independent of each other and thus adjust their positions to accommodate for object-specific features, such as high aspect ratio occlusions, as shown in Figure 1. To accomplish this, we use a setup where we keep the projector and measured object static and rotate the camera around the object (Figure 2). An inertial measurement unit (IMU) with pose sensors mounted on the camera tracks it's motion and thus the calibration parameters of each measurement can be adjusted. Herein, we evaluate the accuracy of the LSM9DS0 IMU for the measurement of both a tall-ridge and a deep-trench self-occlusions.

References

[1] Stavroulakis P. I., Waterhouse D-S., Piano S., Leach R. K., 'A flexible decoupled camera and projector fringe projection system using inertial sensors.' *Optical Engineering*. 2017 (In press).

Experimental setup

The experimental setup used (Figure 2) consists of a Raspberry Pi camera mounted on an AM arch frame which can rotate around the object. A projector is set on a tripod and is static during the measurement.

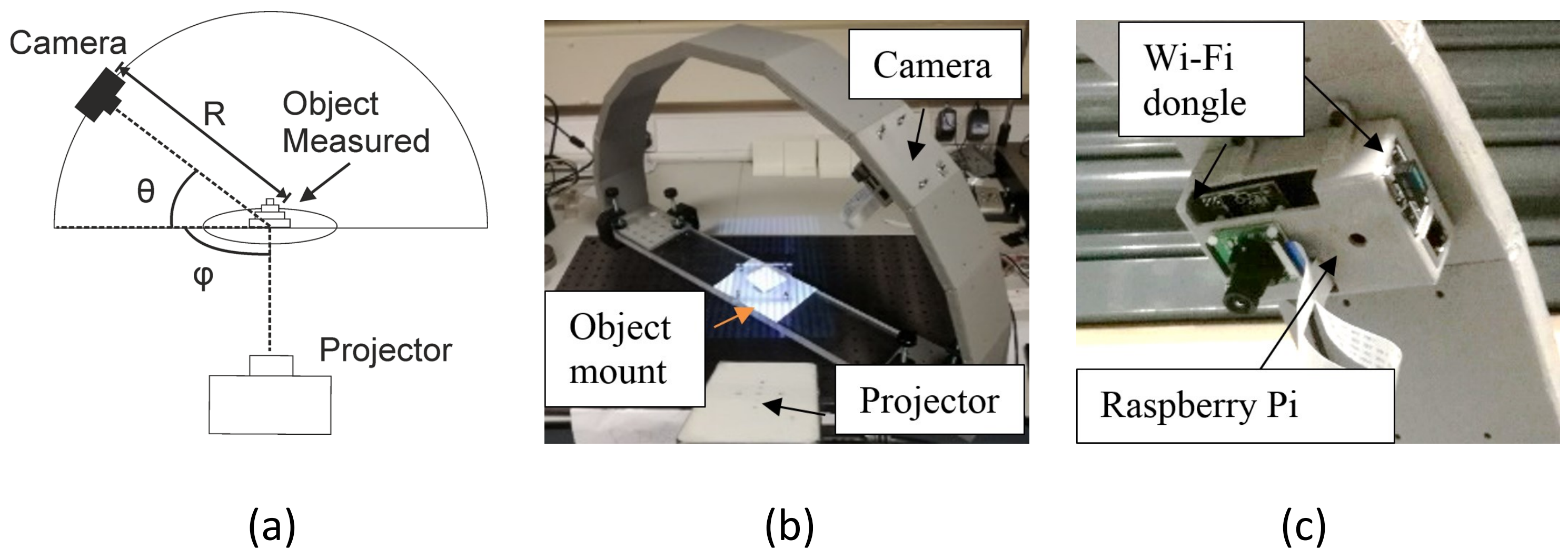

Figure 3. From left to right (a) schematic of the setup (b) photo of the setup showing the projector and measured object (c) close up of the camera. [1].

Results and discussion

The first example measured was that of a pyramid (Figure 4). Two point clouds were taken by rotating the camera by ~85°. The two point clouds were registered on the model of the object via ICP and compared to the sensor data. An error of 1.03°- was achieved which translates to a point cloud mean distance error of 18 µm.

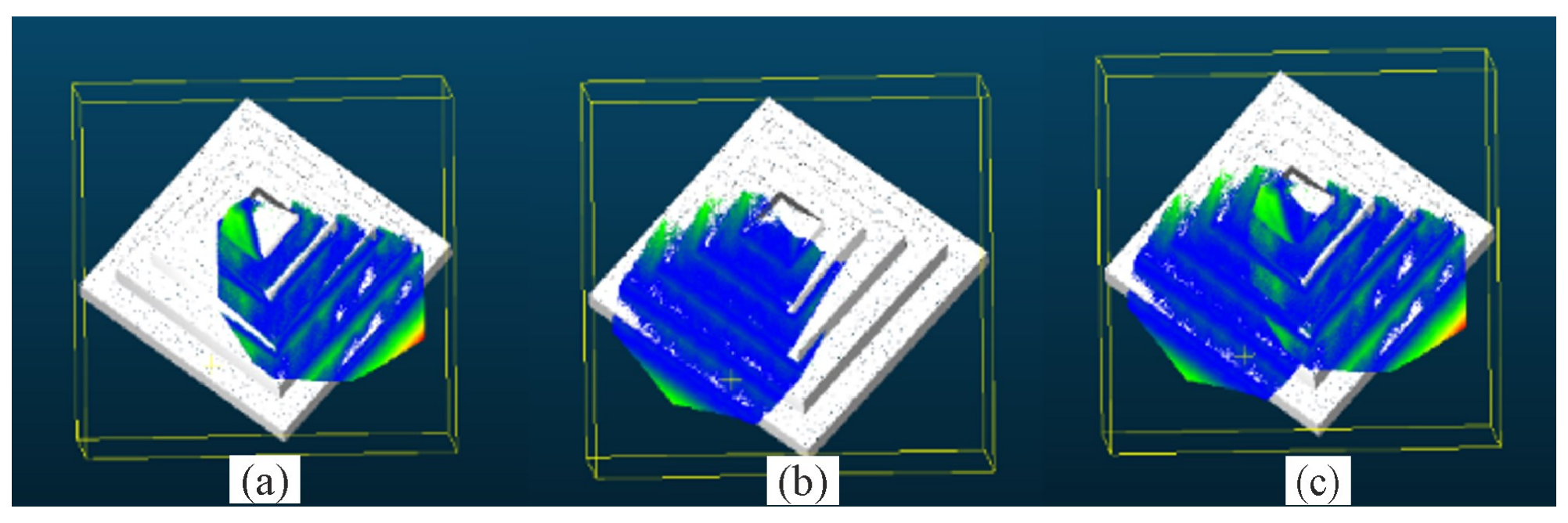

Figure 4. From left to right (a) point cloud taken from one side of the pyramid, (b) point cloud taken from the other side of the pyramid (c) result of registering point clouds together using IMU data. [1].

The second example evaluated was that of a deep trench self-occlusion on an object with parallel ridges (Figure 5).

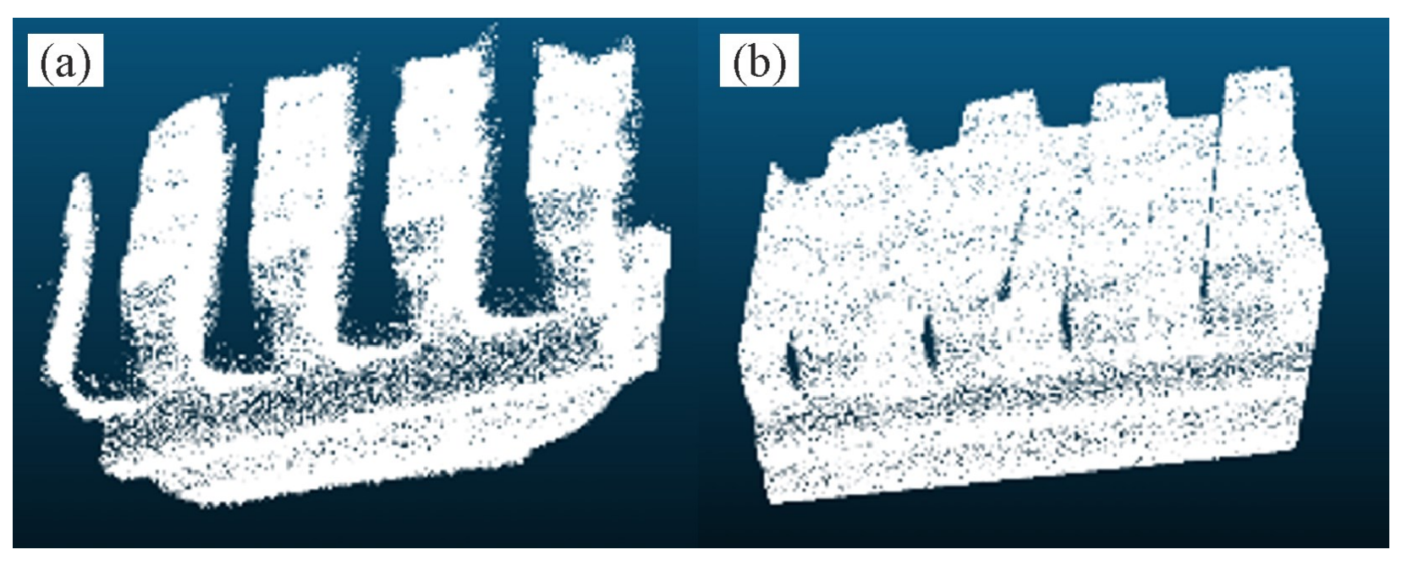

Figure 5. (a) Point cloud acquired when the angle between camera and projector is large and the bottom of the trenches could not be measured (b) point cloud acquired when the angle has been brought closer together and the bottom of the trenches was measured. [1].

It has, therefore, been shown that sensor fusion can assist both in automating the system self-calibration and allowing the measurement setup to adapt to types of object-specific self-occlusions in a more efficient way.

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