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3D Imaging, Metrology & Photogrammetry
Applied Coordinate Technologies

UCL

Photogrammetry in the Dynamite Project

UCL: Ben Sargeant, Stuart Robson, Charles Richards, IDEKO: Pablo Puerto, Asier Garcia Berdote, Ibai Leizea
CNAM: Joffray Guillory, Daniel Truong, Jean-Pierre Wallerand, LIRMM: Marc Gouttefarde, Technalia: Pierre-Elie Herve
PTB: Daniel Heißelmann, Florian Pollinger, Eva Rafeld, Matthias Franke, Kai Geva

The integration of metrology systems in production environments is a vital part of maximising their potential. Use of appropriate metrology adds traceability, enables optimisation of manufacturing techniques and provides fault detection. Improvements can then be made to products by taking advantage of tighter tolerances and alternative manufacturing techniques thus enabled. Dynamite is an inter-organisational project set up to develop and investigate metrology fundamentals to support modern factory environments that make increasingly heavy use of automation and digitisation techniques. UCL focused on the development and use of low-cost photogrammetric techniques using its in-house VMS (Visual Measurement System) software.

Capability Development

Initial work consisted of the development and testing of the capabilities of the photogrammetry system. Work focused on compatibility with other measurements systems, tracking of large numbers of objects and high speed measurement.

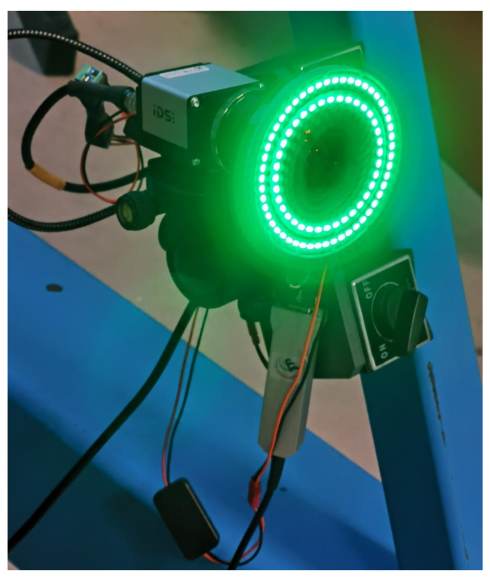

***Fig 1.** Camera setup*

Photogrammetry

Photogrammetry is a metrology technique which uses camera images to measure objects. Each image provides angular measurements of points on the target object and the information from multiple images is combined to triangulate the location of those points. The VMS system allows for online, in-situ, processing of these images, or for them to be post-processed. Figure 1 shows the type of standard camera setup used with Multi-camera VMS systems. An IDS camera fitted with a stable, fixed lens and a bright ring-light. This is connected to the processing computer, via ethernet or USB, and to a trigger system, to ensure images are taken simultaneously across all cameras. Throughout these tests, target-based photogrammetry was used to enable greater accuracy, and coded targets were used to enable measurement to be done automatically. Many of these tests were done in conjunction with IDEKO, who's VSET system uses similar targets. The VMS (upper) and VSET (lower) targets are shown together in Figure 2. Measured targets can be grouped and tracked as a single object, providing 6DoF (Six Degree of Freedom) locations. One of these objects can be designated as a reference frame, relative to which all other measurements are made. By choosing a stable reference frame a system can thus be made resilient to camera instability.

***Fig 2.** Coded targets*

Cross-Compatibility

Multiple measurement systems would be used across the Dynamite project and, in order for these to work together, common targets and artefacts were needed. Tests were carried out with the VMS and VSET systems to ensure cross-compatibility of their targets, and the artifact in figure 3 was created by CNAM. This artefact features targets from both photogrammetry systems, along with seven nests compatible with photogrammetry targets and targets for other systems. Additionally, the artefact was designed to either stand upright or be attached to a CMM.

***Fig 3.** Dynamite 6DoF reference Artefact*

Multi-object tracking

Photogrammetry has the potential to measure any number of targets, given sufficient time or processing power. To demonstrate this ability a demonstration was run of a system tracking 50 distinct objects across a range of sizes and speeds simultaneously. This included robot segments, motion stages, hand-held tools and spinning fan blades. Results were transferred to SA (Spatial Analyser) for ease of visualisation ,as shown in figures 4 and 5.

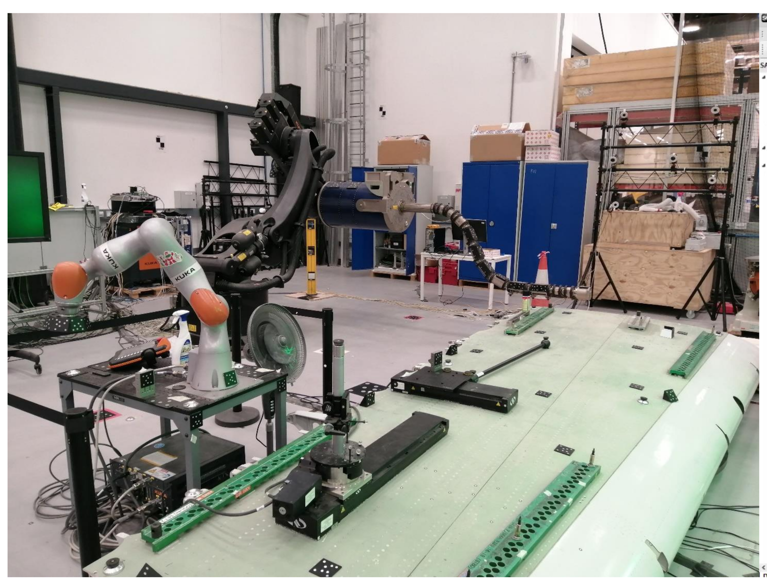

***Fig 4.** Objects to be tracked*

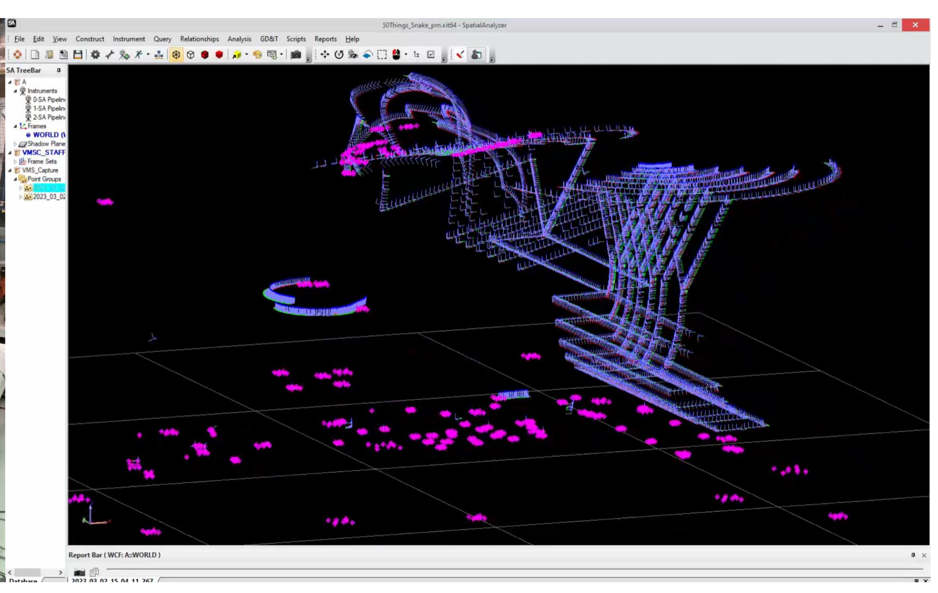

***Fig 5.** 50 Objects being tracked and displayed in SA*

High-speed measurement

Speed is an important element of manufacturing and it was desired to demonstrate the capabilities of low-cost photogrammetry in this area. For this, cameras with 10 megapixel Sony Pregius S global shutter sensors with 9mm Kowa lenses were used. These were run with 0.02ms exposure times, at 20 frames per second. To test this setup a Soraluce large milling axis machine was used, with support from IDEKO. With the setup shown in Figure 6, the spindle was rotated at 3000RPM, giving the targets on the spindle an average speed of 17.5ms². When traveling at this speed the system was able to achieve a standard deviation of 22.7µm spatially and 0.061° angularly when measuring the spindle in its central position. When moved within the systems operating volume of 0.5m³, gross outliers were observed in 0.88% of measurements. With these outliers removed a standard deviation of 37.7µm and 0.086° was observed across the entire volume.

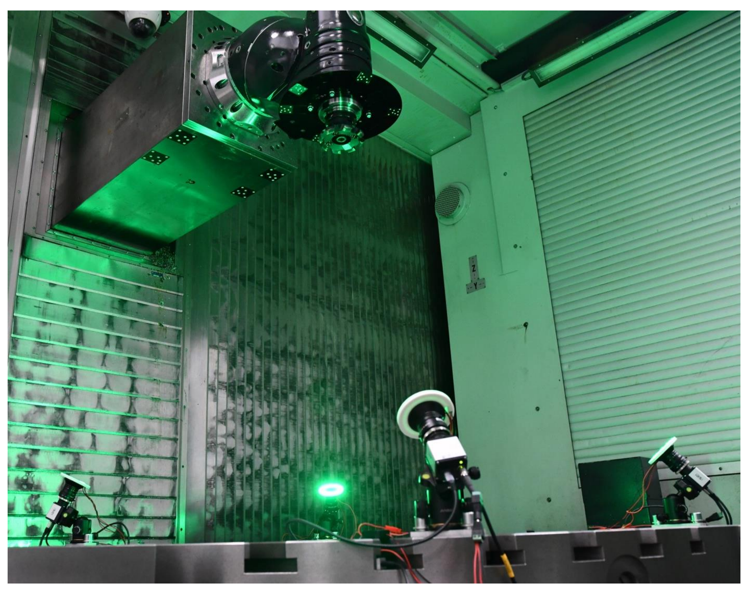

***Fig 6.** High-speed spindle tracking*

System cross-compatibility testing

As well as developing and testing the low-cost photogrammetry system, work was done to support and compare measurement systems in use by other members of the consortium. This work continued to use the camera systems deployed for high speed test, albeit with longer exposure times for better target detection over larger volumes.

Supporting the CNAM multilateration system

The multilateration system developed by CNAM is designed to coordinate n=2 spheres to the order of 10s of microns in large volume environments. In this project it was used to track a large volume cable robot manipulating a rigid body cube. The limitation of the multilateration system is that its lasers must be sequentially pointed at individual targets in order for a 6DoF measurement to be carried out. To assist with this, a rigid body cube was fitted with coded targets measured, using VSET, relative to the location of the glass spheres tracked by the multilateration system. The VMS system was then used to track the cube and give sub-millimetre estimates of the locations of the n=2 spheres over the robots 10m³ working volume. Sphere coordinates were transferred to the CNAM system, allowing the lasers to be accurately pointed.

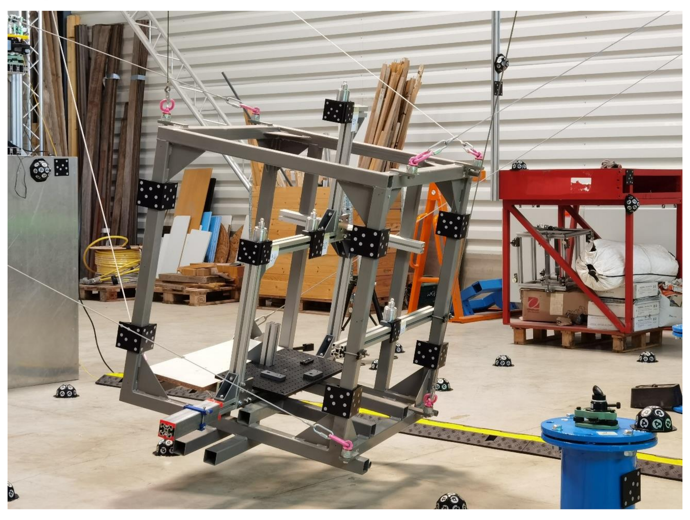

***Fig 7.** Tracked cube with targets*

Comparison of Measurement systems

Using the 6DoF reference artefact as a common measurement target a cross comparison was carried out. Initial tests at IDEKO used a small CMM to measure the artefact in different locations on the CMM table. This was followed by large CMM tests at PTB, where the artifact was mounted to the CMM and moved throughout its volume whilst being tracked. These results are still being processed, but highlight how measurement variance relates to distance from the sensors in photogrammetry. As an example RMS fit to the artifact reference coordinates varied from 0.08mm at 2m from the cameras to 0.15mm at 6m from them.

***Fig 8.** CMM testing at IDEKO*

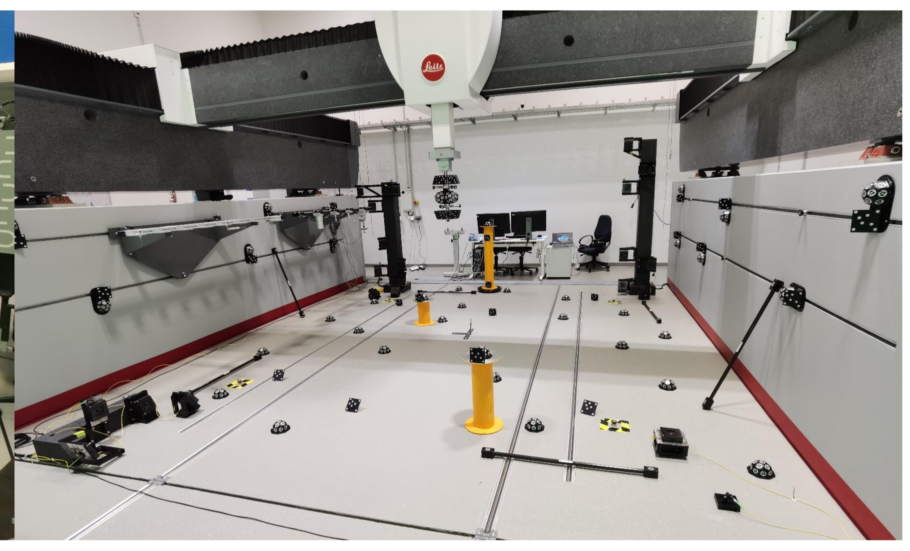

***Fig 9.** CMM testing at PTB*

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Contact:
Ben.sargeant.12@ucl.ac.uk