OMC Technical Brief - Photogrammetry

Photogrammetry uses one or more cameras to measure the location of common points in images by triangulation

What does it do?

Photogrammetry systems measure to points by optical triangulation seen from more than one camera view in a volume from (0.1m - 30m^3). Typical accuracy is in the range 10 to 100 microns per m^3. The cameras can either be in a fixed configuration where the measurement system can be treated as black box requiring little operator expertise or a single roaming camera can be used to take multiple images from a variety of viewpoints. One of the key capabilities is to provide multiple measurement at one instant in time and for this process to be repeatable as often as 100 times per second. As a result a photogrammetry system can be used to measure deformation of structures under loading or provide guidance to robots for assembly operations.

Where are photogrammetry systems are used?

Photogrammetry systems can be applied to a wide range of tasks. They can be embedded in applications for instance to measure the location of holes in a car body being manufactured or in a system to measure the surface shape of a component or man made structure such as a car body or antennae. Photogrammetry can also be used as a portable CMM to measure jigs or to check the geometric manufacturing quality of components. The main advantage is to be able to measure a large number of points relatively quickly without touching the object at the point of measurement.

Why use this technique?

There are two main functional capabilities. The first is the measurement of the size and shape of a complete object – a structure such as an antenna, a gantry, or a jig, for example. The purpose of the measurements might be to check conformance to design or to record as-built dimensions. In some cases the structure might change shape and multiple measurements will reveal deformation or allow measurement of stress. The second functionality is to measure the relative orientation of one or more objects with respect to each other. In this situtation the measurement system could be used to report the location of components that require assembly or the position of a tool with respect to a workpiece.

The time required to perform measurements with a single camera off-line system will vary from job to job but in most cases the data capture time is relatively short and measured in minutes rather than hours. Processing of images and computation of results may take a few seconds to a few minutes. Analysis of collected data may take much longer. For the fastest multiple camera systems: image capture can take place in as little as 1/10,000 of a second and can be repeated as fast as 100 times per second. Processing of images to produce 3-D co-ordinates may take place on-line or off-line. For a system embedded in an application 3-D data production 25 times per second is feasible. However, systems using larger images will often be slower with measurement repeat rates of the order of seconds.

The accuracy obtained by photogrammetric systems is related to the number of pixels in the sensor and the size of the object e.g. a bigger sensor will produce more accurate results for the same size object. For a given camera, natural features such as edges produce the worst results due to apparent location changes with viewpoint, this is difficult to compensate for unless the environment is carefully controlled. Retro-reflective targets provide the highest accuracy as, when used with correct lighting, they are much brighter than even white objects and are largely position invariant to rotation. A typical professional system can produce 0.05 mm accuracy over a 5 metre object.

What are photogrammetric systems used for?

The list of uses to which photogrammetry system have been put is very wide, for instance:

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alignment tasks in shipbuilding, production of architectural models of buildings or facades, archaeology surveys, medical e.g. human body scans for back problem or gait analysis, missile or plane tracking, antenna measurement, checking aerospace manufacturing jigs, verification of the design of manufactured structures, virtual reality and entertainment.

How does it work?

A number of features are identified in one or more images. Sometimes naturally occurring features such as edges are used, but for high accuracy measurement strongly contrasting features such as: projected spots of light; self-illuminating targets (light emitting diodes); or retro-reflective targets are used. The method provides results with accuracy between 1 part in 5000 to 1 part in 100,000 of the largest dimension of the object being measured. It can be applied to objects ranging from a few millimetres to many metres in size. The main steps in the measurement process are illustrated in the following figure.

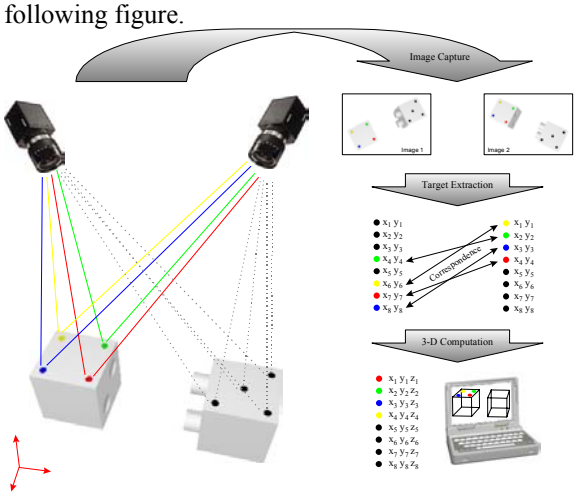

Illustration of the photogrammetric measuring process

To operate it is necessary to determine: where the cameras are and in which direction they are pointing; the camera specifications; some measurements in the object space to give scale; and a datum definition. This information may be collected as part of the measurement process, or as a series of steps e.g. camera calibration, physical set-up, and measurement. There are two methods of operation: single-camera, where the operator takes a number of images (typically between 5 and 100) of the object being measured from differing viewpoints; and multiple-camera, where typically 2 to 4 cameras are used.

What are the benefits?

The benefits of photogrammetry systems are:

- Multiple point measurement at one time with on-line systems
- Mulitple point measurement over a short period of time with single camera systems
- High relative accuracy
- Range can be scaled up or down depending on the application
- The object is not touched during measurment

What are the limitations?

- ***geometry*****,** clear lines of sight are required to each camera, when more than one is used these will usually occupy a large volume compared with the object being measured,
- ***set up*****,** before measurement can take place the system must be initialised and if necessary cameras calibrated prior to use,
- ***complexity*****,** these systems have many degrees of freedom and a reasonable level of expertise is needed to get the best results, and
- ***cost*****,** there are few off-the-shelf systems so the expense can be high. Typical commercial systems cost in the range £30,000 to £250,000.

When to use a photogrammetric system?

It used to be said that the time to use a photogrammetric system is when you cannot use anything else. This is no longer entirely true, but photogrammetry still has a reputation for being difficult to use. This is partly due to one of its chief advantages which is the flexibility to configure it in many different ways and partly due to software which involves least squares estimation and statistics. However, large improvements have being made as software is made more user friendly, computing power increases, high resolution digital cameras replace analogue cameras, and coded targets are used to make setting up easier. Photogrammetric system should be considered when the particular benefits of a self-checking, high-accuracy, high-speed, multiple-point, measuring system are required.

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