

OBJECT MONITORING/RECONSTRUCTION WITH AUTOMATED IMAGE-BASED MEASUREMENT SYSTEMS

Alexander Reiterer
Institute of Geodesy and Geophysics, Engineering Geodesy
Vienna University of Technology
Email: alexander.reiterer@tuwien.ac.at

Abstract: The increasing number of objects involved in deformation processes in highly populated areas has increased the demand for rapidly working and easily usable deformation and measurement systems. This demand is associated with a higher degree of automation of monitoring, analysis and interpretation. There are various different sensor systems on the market that can be used for object monitoring. During the last years, research in the area of image-based measurement systems has gained an increasing interest. Unfortunately, most of such systems required artificial targets defining object points. To overcome this restriction the texture on the surface of the object can be used to find interesting points. However, well-trained “measurement experts” are required to operate such a system. In a complex image-based measurement system, the selection of suitable sensor units or suitable measurement modes is a highly non-trivial task. To make the measurement system easily applicable even for non-experts, it can be extended by a suitable decision support system. The following paper presents such a automated image-based measurement system currently under development.

1. Introduction

In science and industry increasingly 3-D representations and monitoring of objects in the built environment are needed with high accuracy. Meanwhile a greater number of optical 3-D measurement techniques is available: laser scanners, photogrammetric systems, measurement robots, theodolite measurement systems [6]. In comparison with laser scanners and measurement robots theodolite measurement systems measure objects with higher accuracy, compared with photogrammetric systems in many cases they can easier be used for on-line measurement processes. This will especially be the case, if the theodolite measurements can be performed with a high degree of automation. This will be possible, if the images of the telescope’s visual field is used in a more flexible way.

Such a image-based measurement system should be capable of applying knowledge within a visual input to discriminate decisive from irrelevant information, to find out what needs to be attended to, and when, and what to do in a meaningful sequence, in correspondence with visual feedback. Therefore, successful visual interpretation includes fusion of visual features, applies reasoning and inference for prediction and verification, and requires context recognition to focus attention on promising information.

We report on the architecture and functionality of the such a image-based measurement system, especially on the potentiality of automation – the concept of a knowledge-based decision system, its development stage and the promising results obtained in experimentation.

2. Image-based measurement system

A image-based measurement system (Figure 1) is a combination of different components: image sensors (image-based tacheometers or videotheodolites), a computer system, software (e.g. control system, image processing, etc.), and accessories.

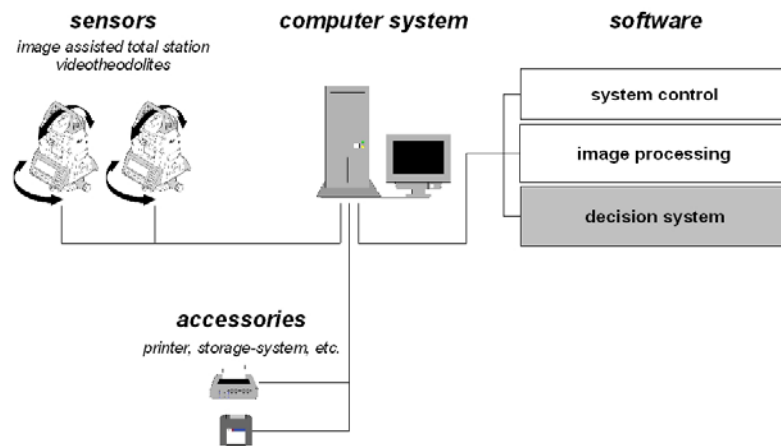


Figure 1: Abstracted architecture of a image-based measurement system.

Recently, research interest in the area of image-based measurement systems has been increased. Most notably the works done by Walser [21, 22], Wasmeier [23] and Topcon [20]. The central topic of all these image-based measurement systems is the calculation of 3D object coordinates from 2D image coordinates for subsequent processing steps.

Image-based tacheometers/videotheodolites have a CCD camera in its optical path. The images of the telescope's visual field are projected onto the camera's CCD chip. The camera is capable of capturing mosaic panoramic images through camera rotation, if the axes of the theodolite are driven by computer controlled motors. With appropriate calibration these images are accurately georeferenced and oriented as the horizontal and vertical angles of rotation are continuously measured and fed into the computer. The oriented images can then directly be used for direction measurements with no need for object control points or photogrammetric orientation processes.

In such a system viewing angles must be addressed to CCD pixels inside the optical field of view. That means, especial calibration methodes have to be used, an autofocus unit has to be added to the optical path, and special digital image processing procedures have to be integrated.

An optical system for such a system was developed by Leica Geosystems [21, 22]. It is reduced to a two-lens system consisting of the front and the focus lens. Instead of an eyepice a CCD sensor is placed in the intermediate focus plane of the objective lens. The image data from the CCD sensor are fed into a computer using a synchronized frame grabber. For the transformation of the measured image points into the object space the camera constant must be known¹.

¹ In an optical system with a focus lens the camera constant, however, changes with the distance of the object. The camera constant can be derived from the focal length. This can be performed automatically if an encoder measures the focus lens position relative to an origin, which is chosen when focusing to infinity.

Points of interest can be identified with interest operators (IOPs) (e.g. Förstner operator [4] or Harris operator [8]). Interest operators permit the location of a wide field of different points with subpixel accuracy: points on lines or edges, centres of symmetrical figures, intersections of lines, edges, etc.

In a complex measurement system with many algorithms for image processing and interest operators, the selection of suitable algorithms, their order of application, and the choice of input parameters is a non-trivial task. To provide automated support, a suitable decision support system has to be integrated in the system (see Figure 1).

A decision (support) systems is a specific class of a computerized information system that supports engineering, business or organizational decision-making activities. Such a system consists in its plainest form of three main components, namely an input component, decision algorithm(s) and an output component.

There exist various approaches for the implementation of decision support algorithms (module-oriented systems, object-oriented systems, knowledge-based systems, neural networks, software agents, and others). One of the most suitable and common used approaches for (automatic) decision making are knowledge-based systems (rule-based). This technique has been developed more than thirty years ago and has some exceptional advantages in comparison with conventional approaches.

Gonzalez et al. [5] have formulated three fundamental concepts which distinguish knowledge-based systems from conventional algorithmic programs and from general search-based programs: (1) the separation of the knowledge from how it is used, (2) the use of highly specific knowledge, and (3) the heuristic rather than algorithmic nature of the knowledge employed.

The first underlying idea is the most important and leads to one of the biggest advantages of knowledge-based systems compared to conventional software. The fundamental concept of the separation of domain-knowledge from reasoning mechanism makes it easy to modify or extend the knowledge. In modern information technology changes occur frequently and knowledge has to be updated; ease of modification is a very important feature in these situations.

Knowledge-based systems (KBS) are complex computer software products that can be viewed from the perspective of an end user or from the perspective of a knowledge engineer. From the point of view of the user a knowledge-based system consists of an intelligent program, a user interface and problem-specific database. The system is a black box that operates based on unknown algorithms. From the developer's (knowledge engineer) view the system consists of two components: an intelligent program and the development shell. The development shell is a set of tools that assist the implementation of relevant knowledge.

In image-based measurement systems all decisions have to be done on the basis of the captured image or on values which represent this image. Using the whole image as input is, because of processing time, not suited for an on-line measurement system. For this reason appropriate values which represent the captured image should be used (image analysis).

3. Processing chain

The central topic of all image-based measurement systems is the calculation of 3D object coordinates from 2D image coordinates for subsequent processing steps, like deformation analysis or object reconstruction. A system which works on-line has the additional task to

provide all results nearly in real-time (“pseudo real-time”). For such a system several procedures can be developed – Reiterer [15] has developed the following processing sequence (Figure 2):

- image(s) capturing,
- image analysis,
- image preprocessing and image enhancement²,
- image analysis,
- point detection,
- point filtering.

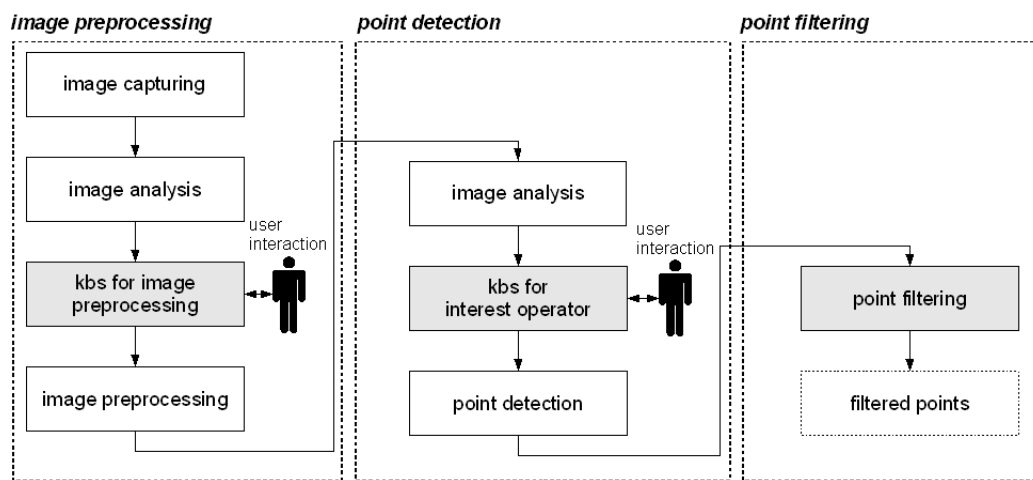


Figure 2: Processing sequence and data flow [15].

This procedure is based on point detection by means of interest operators and subsequent point filtering. This means that the point detection is not strongly application-oriented (point reduction to relevant points for subsequent processing steps is done by special filtering).

A more intuitive procedure could be based on “application-oriented point detection”. The main goal of such a sequence is to use knowledge about the object (so-called “*model-knowledge*”) and about the intended subsequent processes. From this viewpoint, a processing sequence could be sketched as follows: the master sensor (in a multisensor system one of the image-based theodolites) “scans” the object; on the basis of these captured data a *image understanding system* (or a *cognitive vision system*)³ analyses the whole scene. The resulting description of the object is used by a knowledge-based system for several decision-makings like the choice of regions of interest or the choice of suitable object points for subsequent processing steps (e.g. deformation analysis). Additional features extracted by image analysis and by user-questions can influence this process. The development of such a measurement

² Experiments [16] have shown that a necessary precondition for the successful application of algorithms for finding interesting points is the “quality” of the image. It is often required to improve the visual appearance of an image. This can be done by image preprocessing and enhancement processes. Furthermore, flexible image processing makes the measurement system more independent of variable illumination during image capturing.

³ *Image understanding* and *cognitive vision systems* perform information processing on multiple levels of abstraction, such as in low-level feature extraction, feature grouping, object and scene recognition.

