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An analysis of the prospects for digital close-range photogrammetry

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In this short paper an analysis is performed of the prospects for digital close-range photogrammetry with respect to current and future applications and equipment. While much progress has been made in the past decade, an expansion of photogrammetric methods is likely in the future to feed the rising demand for high-precision three-dimensional measurement.

1. Introduction

Digital close-range photogrammetry (DCRP) is maturing. Any definition of DCRP must cover the areas of high-precision measurement using targets, lower-precision measurement using feature-based methods, machine vision, and include the use of expensive digital workstations. This paper is concerned solely with low-cost, high-precision, targeted point, 3-D measurement, where the measuring process may be on- or off-line. An analysis of some of the advances in tools and techniques is performed.

2. Applications of digital close-range photogrammetry

The applications of DCRP methods are becoming highly varied. In comparison to film-based photogrammetry there are many more applications that can be considered. At the same time digital imagery is gradually being used to replace film in many of the conventional tasks. Examples of some current applications of DCRP can be determined from recent conferences (Zurich, 1993; Boston, 1994; Melbourne, 1994). These examples are summarised in Table 1.

3. Components of digital close-range photogrammetry

If the wide diversity of applications illustrated in Table 1 can be tackled using digital photogrammetry, the questions arise: what are the current limitations of the method and in what directions will future equipment allow developments to be made? In the remainder of this short paper an assessment of some of the key components is given. Reference is made to what is possible with current equipment and what is likely to be achieved with advances in the technology available in the near future.

3.1. Cameras

Many significant advances in camera technology have brought photogrammetric techniques to the point where they are beginning to be employed routinely. In the early eighties cameras were usually of the Vidicon variety where the scale of the image could be varied by electronic drift or a potentiometer. Frame-grabbers were well equipped if they could deal with a 256 kilobyte image, but even this was often achieved in 64 kilobyte chunks. Such CCD sensors as there were at this stage had poor signal-to-noise ratios and were highly susceptible to blooming (charge overflowing from one pixel to the next), sometimes stretching across the whole image. Over the past ten years CCD sensors have developed to a stage where blooming has been significantly reduced and sensor resolution has increased incrementally to where it is today: routinely (in the Kodak Megaplus 1.4) 1317 horizontal by 1035 vertical pixels (Kodak, 1994a) and exceptionally in the multiple tap 5000 horizontal by 5000 vertical pixel sensor made by Dalsa (Dalsa, 1994). While such sensors are still not available with ideal characteristics, the intermediate-resolution sensors (pushed forward by the drive towards high-definition TV) are no longer expensive or of dubious quality. A

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TABLE 1

Recent applications of digital close-range photogrammetry

Application	Task	Traditional photogrammetry	Dim. (m)	Acc. (mm)
Aircraft	Part measurement	Yes	3 × 3 × 1	±0.15
Space	Landing navigation	No	Variable	Variable
	Satellite components	Yes	2.5	±0.08
Nuclear	Flange positioning	Yes	1 × 0.5 × 0.5	±0.06
Automotive	Car	No	3 × 2 × 1	0.12
Medical	Patient monitoring	No	2 × 0.5 × 0.5	0.014
	Body surface	Yes	0.7	0.1
	Surgical	No	0.5	1.5
Aeronautics	Wind tunnel	No	9	10
Robotics	Navigation	No	NA	NA
	Robot gripping	No	NA	NA
	Tracking	No	NA	NA
	Calibration	No	0.3	0.03

NA = not applicable.

number of schemes have been developed to extract higher resolution such as micro-scanning and macro-scanning of a lower-resolution sensor. Images of 20,000 by 20,000 pixels have been claimed (Lenz and Lenz, 1993). However, such systems are not appropriate for measuring time-varying phenomena.

A camera which is providing a significant instrument for photogrammetry is the DCS 200 model from Kodak using a Nikon camera body (Kodak, 1994b). Such cameras use high-resolution CCD sensors in colour or black and white. The early results obtained by such cameras have been of the same order of accuracy as that achieved by small or medium format film cameras. The biggest advantage of the DCS 200 is its portability. Unlike most CCD cameras, it can be used in a manner that most photogrammetrists are familiar with. Furthermore, many of the problems that occur because of an inadequate means of signal transfer between a typical CCD camera and a frame-grabber have been eliminated because both are combined in the camera which can store up to 50 images.

A split may be developing between the type of camera required for off-line photogrammetric measurement and those for methods which are of necessity on-line. Both will benefit from improvements in camera technology over the next few years. It is likely that cameras for off-line photogrammetry will in the future be able to store many hundreds of high resolution images to provide a fast and efficient means of data capture, and allow processing of these images by a remote computer for processing on site or back at the office. Such methods are currently being used, for example by Beyer (Imetrics, 1994), and will no doubt be taken up increasingly by conventional photogrammetrists and end users as the software aspects are improved and simplified. The capabilities of cameras for on-line measurement have yet to be determined but are likely to have the analogue-to-digital conversion stage on board the camera with digital data transfer between camera and computer. For example the Pulnix 9700 camera offers eight bit wide digital information direct from the camera (Pulnix, 1994).

3.2. Frame-grabbers

With the exception of cameras like the Kodak DCS 200, the usual configuration used in digital photogrammetry is a single frame-grabber which collects images from a number of cameras. It is also usual for the images to be stored on the frame-grabber for subsequent analysis. An extreme example of this approach is the 4Meg VIDEO Model 12 from EPIX that has up to 256 megabytes of data storage (EPIX, 1994). However, this may all be about to change. A number of exciting prospects are emerging based around two developments of hardware.

The first is an improvement in the options for data transfer within an IBM compatible computer. Up until relatively recently the transfer of information into a computer from a frame-grabber has been via a 16 bit wide bus. The extended version of this bus to 32 bits has not been generally accepted but has highlighted the requirement and possibilities for faster data access which has now been met by the PCI and VL busses. Expensive frame-grabbers using either of these technologies are currently capable of storing single images from a single camera at near to frame rate. Cheap frame-grabbers (costing less than 200 pounds sterling) are able to collect and store quarter-size images in real time. However, frame rate storage of multiple camera images is a development that will enable many real-time applications to be considered. A variant of this approach is hardware JPEG compression and storage of images which reduces the data transfer rate to a level where it is not critical, even for storage direct to hard disk.

The second development is that of Digital Signal Processors (DSP). These devices are extremely powerful when used for simple repetitive operations such as image processing. While the clock rate of the device may be comparable to or slower than a conventional computer, a DSP is capable of performing multiple operations in a single cycle. A number of manufacturers are providing frame-grabbers with integrated DSPs which will allow real-time or near real-time processing of images (EPIX, 1994; Dipix, 1994; Imaging Technology, 1994). Again, such systems are not yet able to process multiple images at the same time without high cost penalties.

In conclusion, for future applications of DCRP the hardware side is gradually providing the equipment necessary for fast 3-D measurement.

3.3. *Algorithms*

It is clear that algorithms still have further to go in terms of easing the process of 3-D measurement for non-photogrammetrists or in achieving real-time 3-D measurement using multiple cameras and large numbers of data points. Such work must extend further into the areas of photogrammetric network design and deal with the wide variety of surfaces, shapes, textures, and sizes that occur in practice.

4. The future of digital close-range photogrammetry

4.1. *Real-time photogrammetry*

All the developments mentioned so far in this paper (high-speed and high-resolution cameras, high-throughput data busses or data processors, computers, and algorithms) must be brought together to achieve real-time photogrammetry, that is measurement and data storage over long periods at frame rate. When this occurs, a number of hitherto difficult or impossible tasks will be feasible, for instance: real-time dynamic monitoring; high-density 3-D measurement; high-precision 3-D measurement; and automatic inspection.

4.2. *Off-the-shelf photogrammetry*

The consumer market has a dramatic effect on the development of high-quality goods at reasonable prices. The 3-D measurement area is too small to drive the market, but photogrammetrists should be able to exploit products which have been developed for the mass market. For example, the video recorder, and the video itself have been analysed and used by many for some simple tasks. More recently, the Kodak DCS camera, developed for journalists who require digital images to transfer quickly to newspapers, has been used to good effect by photogrammetrists. It may also be predicted that the move towards high-definition TV will also bring a new generation of high-resolution sensors into the consumer market and hence into use by photogrammetrists. Finally, a new product written for Microsoft Windows called "Photomodeler" (Photomodeler, 1994) provides for non-photogrammetrists the means to produce 3-D models given a number of views of an object. This software package assumes no photogrammetric knowledge and sells for 750 pounds.

5. Conclusions

Much progress has been made in DCRP since the Vidicon camera was used to collect images and perform photogrammetric measurements. However, it would appear from the survey conducted within this paper that the number of applications is increasing. Many of these applications are not feasible using film-based methods and will only be achieved with the increased speed of computers and special purpose hardware which will be available in the future. Like the subject field of optics which was considered to have stabilised and not to be an interesting area to work in before the advent of fibre optics, lasers, optical computing, etc., this area of photogrammetry is currently set for an increased potential due to the opportunities discussed briefly in this paper.

References

Boston, 1994. Videometrics III. SPIE, 2350, 364 pp.

Dalsa, 1994. Product Information. Dalsa Inc., CCD Images Sensors, 605 McMurray Road, Waterloo, Ontario N2V 2E9, Canada.

Dipix, 1994. Manufacturers literature. Dipix Technologies Inc. Vision Products Division, 1050 Baxter Road, Ottawa, Ontario K2C 3P1, Canada.

EPIX, 1994. Manufacturers news letter, Epix Vision, solutions to tomorrow's imaging today! Epix Incorporated, 381 Lexicon Drive, Buffalo Grove, IL 60089, USA.

Imaging Technology, 1994. Manufacturers literature. Imaging Technology Incorporated, 10 Commerce Way, Woburn, MA 01801-9811, USA.

Imetrics, 1994. Imetrics TP210SB Three dimensional industrial measurement system. Imetric, Rue du Bourg 9, 2892 Courgenay, Switzerland.

Kodak, 1994a. Kodak Megaplus Camera Model 1.4 (M1 Sensor), Eastman Kodak Company, Motion Analysis Systems Division, 11633 Sorento Valley Road, San Diego, CA 92121-1097, USA.

Kodak, 1994b. Manufacturers literature. 'Kodak' professional DCS 200 digital camera. The Kodak Information Centre, 10 Cornfield Lane, Eastbourne, East Sussex, BN21 4NE.

Lenz, R. and Lenz, U., 1993. New developments in high resolution image acquisition with CCD area sensors. Optical 3-D Measurement Techniques II. Pub. Wichman, Karlsruhe, Switzerland, pp. 53–62.

Melbourne, 1994. Close Range Photogrammetry and Machine Vision. Int. Arch. Photogramm. Remote Sensing, XXX, Part 5, 495 pp.

Photomodeler, 1994. An all round viewpoint. Personal Computer magazine, December, p. 84.

Pulnix, 1994. Video products short form catalogue and reference chart. Pulnix head office, Takenaka Systems Co. Ltd, 2-1, Narano-Cho, Shinomiya, Yamashina-Ku, Kyoto, Japan.

Zurich, 1993. Optical 3-D Measurement Techniques II. Wichman, Karlsruhe, 626 pp.