A Report on the ISPRS Commission V 2010 Symposium

Close-Range Imaging & Measuring Techniques

Close-range non-topographic photogrammetry used to form a very minor part of the overall science of photogrammetry. However, with the advent of digital imaging and laser ranging and scanning, the subject has been completely re-vitalized. Now it is quite definitely in the mainstream of the science with numerous commercial, industrial and scientific applications – as demonstrated at the recent ISPRS Symposium held in Newcastle.

By Gordon Petrie

Introduction

During each four-year period between its full-blown International Congresses, each of the eight technical commissions of ISPRS holds a major mid-term symposium between the previous Congress (the last of which was held in Beijing in 2008) and the next Congress (which will be held in Melbourne in 2012). ISPRS Commission V is concerned with close-range imaging and measuring techniques and their applications and is currently held by the U.K. for the current four-year period (2008-2012). Thus the Commission's mid-term symposium was held in the city of Newcastle-upon-Tyne in north-east England between 22nd and 24th June 2010. The event was extremely well supported with more than 240 participants and over 100 technical papers being presented over the three-day duration of the meeting. The symposium was held in the excellent conference facilities that are available within St. James' Park, the very modern stadium that is the home of the Newcastle United football club [Fig. 1]. The actual meeting was organised in exemplary fashion by Professor Jon Mills (President of Commission V) and his team from the geomatic engineering section of the School of Civil Engineering & Geosciences of Newcastle University.

The detailed scientific activities and technical developments of Commission V are conducted by its six working groups (WGs) and by the two inter-commission working groups (ICWGs) that it shares with Commission I (which covers airborne and spaceborne imaging). The two largest of these working groups are WG V/1, which covers the systems, best practice and applications of vision metrology, and WG V/2, which is concerned with cultural heritage data acquisition and processing and its applications. Both of these large working groups had been allocated three technical sessions over the course of the meeting, each session allowing four or five papers to be presented. However this did not begin to cope with the large number of papers – 39 in the case of WG V/1 and 30 in the case of WG V/2 – that had been submitted to and accepted by these working groups. As a result, a large number of these papers were only presented in the lunch-time poster sessions. This was rather unfortunate, given the quality and interest of many of them, especially on the cultural heritage side.

WG V/1 – Vision Metrology

Currently there is a high level of interest in industrial metrology in general and in the specific applications of vision metrology for quality control, deformation monitoring and reverse engineering purposes. As one would expect, current vision metrology systems are based almost exclusively on digital camera technology. The resulting images allow the dimensions of industrial components to be measured to a very high degree of accuracy, often employing retro-reflective targets. The use of this type of target allows both their location and the actual measurements to the targets to be made in a highly automated manner, often using template matching techniques. The specific applications that were described at the symposium were extremely varied – including (i) the development of a robot-guided multiple optical sensing system to inspect the cylinder heads of automobile engines; (ii) the testing of textile-reinforced concrete components both for crack detection using photogrammetric methods and for the inspection of their internal structure using the images acquired by a scanning electron microscope; (iii) the industrial testing of marble tiles using images acquired by a tri-linear CCD colour scanner; (iv) the modelling and the detection of deformations in tunnels; and so on. The full list of industrial applications that were covered by this working group was really very impressive.

At one time, it was difficult to find many applications of close-range photogrammetric techniques outside (i) architectural photogrammetry, which involved the use of metric film cameras, and (ii) accident recording, which was based on the use of specialized stereo-cameras and stereo-plotting instruments. Now there are an almost bewildering range of possibilities being offered through digital imaging. Most of the applications make use of digital SLR cameras and consumer grade digital cameras rather than cameras that are designed specifically for photogrammetric applications. This meant that a considerable number of the WG V/1 papers were concerned with camera calibration and with the camera configurations, orientation strategies and processing algorithms that are required in the often unusual circumstances of specific vision metrology applications.
**WG V/2 – Cultural Heritage**

With regard to the WG V/2 programme, it was very obvious from the large number of papers and their content that the development of the new digital imaging and laser ranging and scanning technologies are having a huge impact on the recording, measurement and analysis of cultural heritage sites and objects. Indeed architects, archaeologists and museum curators are now using these technologies quite widely on their own account besides employing professional surveyors and photogrammetrists to undertake these tasks. A new technique that is engaging the attention of a number of institutes and practitioners in both WG V/1 and WG V/2 is **polynomial texture mapping** (PTM). This uses multiple images captured by a fixed camera but with a moving light source to capture the different reflectance properties of a given surface that are acquired on successive exposures. This allows the construction of a detailed surface model of the object that is being photographed. Within the cultural heritage domain, the PTM technique is beginning to be applied to a wide range of architectural features and archaeological objects. The use of **hand-held laser scanners** to create 3D models of museum artefacts and objects such as sculptures is also becoming widespread [Fig. 2].

**WG V/3 – Terrestrial Laser Scanning (TLS)**

This working group had 14 papers, nine of which were presented in the two sessions that had been allocated to the group, while the remaining five were poster papers. By far the largest number of papers that were given within this group were concerned with the application of terrestrial laser scan data to help solve **engineering problems**. These included the monitoring of the exterior fabrics of buildings (including, once again, historic buildings) and various other structures such as bridges and certain large modules forming parts of offshore platforms.

Further papers in this engineering subject area were concerned with indoor surveys within buildings and with the application of laser scanning to hydraulic modelling. Another much smaller group of papers were concerned with instrumental aspects of terrestrial laser scanners, including their self-calibration and their performance in different atmospheric conditions. Finally there were also a couple of papers that were concerned with algorithmic aspects of TLS. These covered (i) the automated extraction of break lines; and (ii) the automatic feature matching of the images captured by digital frame cameras with a 2D representation of a 3D point cloud that had been acquired by a terrestrial laser scanner. Once again, without question, the TLS technology is now very well established and, as the symposium papers showed, it is becoming a standard method to be used in numerous different civil engineering applications and situations.
This working group covers both image-based and range-based 3D modelling. Ten papers were offered in its programme, most of them at a very high level of quality and interest. Nine of the papers were presented by this working group. One of them was given in WG V/3. Another was concerned with kite aerial photography (KAP) and could well have been included in the ICWG I/V programme that will be discussed below. Four of the six papers from a German source came from Jade University in Oldenburg and was concerned with the geometric calibration of non-standard cameras, including fish-eye cameras. The remaining paper from a German source came from DLR (German Space Agency) Germany, with four of them originating from DLR (German Space Agency) and Humboldt University in Berlin. These were heavily oriented towards traffic applications, including the tracking of nearby objects while driving; real-time navigation of robotic vehicles; and traffic monitoring. The remaining papers were concerned with different aspects of camera calibration. This included one of the DLR papers that outlined a unified approach to the calibration of non-standard cameras, including fish-eye cameras. The remaining paper from a German source came from Jade University in Oldenburg and was concerned with the geometric calibration of thermal IR cameras – a topic of extreme interest to the present writer since he and two of his graduate students have in the past undertaken similar research work in Glasgow. Still another calibration paper came from the University of Nottingham in the U.K and was concerned with the effects of temperature changes on the calibration of digital SLR cameras. A really important paper was yet another by Prof. Fraser from Australia which considered the self-calibration of the long focal length lenses that are available with digital SLR cameras. Small changes to the normally used calibration model overcome the instabilities and poor accuracy values that are often encountered when calibrating cameras using these long focal length lenses. It is also worth noting that a paper from the University of Berne given in WG V/6 that was concerned with the repeated calibration of SLR cameras over a period of time should really have been included in this group of papers. In summary, this working group contributed a really interesting and valuable set of papers to the symposium.

**WG V/6 – Earth Sciences Applications**

Rather surprisingly, there were only six papers presented by this working group, one of which was in fact concerned with TLS and could (or should) have been given in WG V/3. Another was concerned with kite aerial photography (KAP) and could well have been included in the ICWG I/V programme that will be discussed below. Four of the six papers were given within a single session, with the remaining two being poster.

**WG V/3 – 3D Modelling**

This working group covers both image-based and range-based 3D modelling. Ten papers were offered in its programme, most of them at a very high level of quality and interest. Nine of the papers were presented in its two sessions, while the tenth was a poster paper. Quite a number of the papers were concerned with developments on the algorithmic side, including one from Prof. Clive Fraser and two colleagues from the University of Melbourne on the use of improved feature-based matching for automated surface reconstruction using a convergent camera network. Two other papers in this group (from UC London and TU Dresden respectively) were concerned with the speeding up of the computational process needed to carry out image matching and to construct 3D tree models, in each case through an appropriate sub-division of the task and the use of parallel processing. However, two among the several excellent papers really caught my attention. One was by Dr. Remondino from the Bruno Kessler Foundation and his two collaborators from Milan Polytechnic which set out in a very clear way the whole process of the automated 3D reconstruction of blocks of close-range photographs, often with a complex geometry, using feature based image matching. The other, from a group at Turin Polytechnic, outlined the methodology used and the experience gained in undertaking rapid surveys and 3D modelling of archaeological excavations. This technique uses a Canon EOS small-format digital camera mounted on a pole and boom that is set at an angle over the excavation site [Fig. 3]. In turn, the pole is mounted on a tripod with wheels that is placed in a location external to the actual site being surveyed and allows the camera to be placed in the appropriate position to take the next overlapping photograph. The whole system mimics the classical aerial photographic configuration used for mapping purposes, and provides very large-scale photography as required for the recording of archaeological excavations. Furthermore it does so in a flexible and convenient manner and at a low cost. DEMs and orthophotos can be generated rapidly from the resulting images using the automated procedures that are commonly used in aerial photogrammetric operations nowadays. As I can testify from my own experience, it is great fun and very satisfying to undertake this type of archaeological surveying and mapping work!

**WG V/5 – Image Sensor Technology**

Eight papers were presented by this working group, five of them in the single session allocated to WG V/5, while the other three were delivered as poster papers. No less than five of the eight papers came from Germany, with four of them originating from DLR (German Space Agency) and Humboldt University in Berlin. These were heavily oriented towards traffic applications, including the tracking of nearby objects while driving; real-time navigation of robotic vehicles; and traffic monitoring. The remaining papers were concerned with different aspects of camera calibration. This included one of the DLR papers that outlined a unified approach to the calibration of non-standard cameras, including fish-eye cameras. The remaining paper from a German source came from Jade University in Oldenburg and was concerned with the geometric calibration of thermal IR cameras – a topic of extreme interest to the present writer since he and two of his graduate students have in the past undertaken similar research work in Glasgow. Still another calibration paper came from the University of Nottingham in the U.K and was concerned with the effects of temperature changes on the calibration of digital SLR cameras. A really important paper was yet another by Prof. Fraser from Australia which considered the self-calibration of the long focal length lenses that are available with digital SLR cameras. Small changes to the normally used calibration model overcome the instabilities and poor accuracy values that are often encountered when calibrating cameras using these long focal length lenses. It is also worth noting that a paper from the University of Berne given in WG V/6 that was concerned with the repeated calibration of SLR cameras over a period of time should really have been included in this group of papers. In summary, this working group contributed a really interesting and valuable set of papers to the symposium.
papers. The most interesting paper (at least to the present writer) concerned the photogrammetric determination of the velocity of surface features on the San Rafael Glacier on the North Patagonia Glacier in Chile carried out by a team from TU Dresden. This used a small-format digital camera to acquire monoscopic images automatically at timed intervals together with an ingenius use of various photogrammetric techniques to establish the velocity values. Another paper from a Spanish group gave details of the procedures that were used to map a rock glacier comprising a body of rock and sediment that is being transported by underlying ice, again using the images acquired by a small-format digital camera. The TLS application involved measuring the transport of sand over a period of time along a beach on the coast of Holland, while the KAP application involved the mapping of a crater lake in Turkey. A final paper involved the use of photogrammetric methods to establish the volumes occupied by the canopies of tomato plants and their corresponding leaf area index. Values. By any definition, this did not seem to qualify as an Earth Science application! My own personal opinion is that this working group has a lot of work to do to bring it up to the level of activity of most of the other groups. There is plenty of activity going on within this particular application field, but this was not evident at this symposium.

**ICWG V/I – Mobile Mapping Systems**

This group had seven papers, four of which were presented in the single session allocated to this group, with the remaining three being offered as poster papers. Two of the papers were concerned with the modelling of trees and with measuring the defoliation of trees from mobile laser scanning data. The remaining papers were a quite diverse group, mainly from academic institutions, that were concerned with mobile scanning configurations; the merging of data sets; the refinement of 3D building models; and the extraction of road edges using mobile laser scan data. When one considers that mobile mapping is currently one of the most vibrant areas and probably the fastest developing segment of the surveying and mapping industry, it was really disappointing not to have any of this huge professional activity reflected in the working group’s programme at this symposium. Some reports from the Tele Atlas, NAVTEQ and Google companies, which are massive users of mobile mapping technology, or from the numerous service providers that supply the image and range data of the road and rail infrastructure that is needed for engineering maintenance and management purposes would have been much more relevant and brought this group’s activities into the real world. To your reporter, the programme that was offered by this working group simply dealt with peripheral matters rather than the mainstream activities and applications of this exciting technology.

**ICWG I/V – Unmanned Airborne Vehicles (UAVs)**

This working group is concerned with the use of unmanned airborne vehicles for imaging, mapping and monitoring applications. Of the five papers that were presented, two from the universities of Essex (U.K.) and Padova (Italy) were concerned with the actual development of unmanned airborne platforms for use in imaging operations. The former utilized a powered parafoil configuration [Fig. 4(a)], while the latter used a powered single-rotor model helicopter [Fig. 4(b)]. A third paper reported on the joint development and integration (i) of a six-rotor mini-drone (by the Flemish VITO research organisation) and (ii) of a novel hyperspectral imager based on the use of a Fabry-Perot interferometer (by the Finnish VTT research organisation) [Fig. 4(c)]. The first of the two remaining papers was concerned with application of UAV technology for the monitoring of the very large and dangerous Super Sauze landslide [Fig. 5] in the French Alps that was carried out principally by a group from the University of Stuttgart using a quad-rotor mini-drone [Fig. 4(d)]. The remaining paper from the ETH in Zurich covered the successful use of UAVs in Bhutan, Peru and Honduras for the recording of archaeological excavations. The first of these utilized a quad-rotor mini-drone, while the other two projects in Latin America made use of a petrol-engined mini-helicopter. The users of UAVs are all enthusiastic and are having a great time, besides achieving useful results. However the regulatory side of operating these very small UAVs within the context of stringent national air traffic control and safety procedures appears to be a thorny and as yet unresolved question in many developed countries. This uncertainty is now stunting the growth of what, over the last few years, was a rapidly expanding and highly useful professional activity.

**Special Sessions**

There were also three special sessions to cover topics that did not fall into the areas of the working groups. The first of these had three papers that covered human body measurement and motion analysis. The second session comprising six papers gave a platform for students to present papers on a wide variety of topics. The third session was concerned with range imaging cameras. The development of this technology appears to have reached the stage where it has caught the attention of the close-range photogrammetric community, such that eight papers were presented on this topic at the Newcastle symposium. Four of these were given in the single session allocated to this topic; the other four were poster papers.

Each range imaging camera has an illumination unit comprising an array of LEDs that can emit amplitude modulated (AM-CW) signals. These strike the objects within the camera’s field of view and the reflected signals are then picked up by the pixels in the camera’s focal plane array. Each pixel can measure the phase shift of the received signal and hence derive the distance to the recorded object, together with the signal amplitude, from which an intensity (grey scale) value may be derived. All of the pixels in the focal plane array acquire this data simultaneously at video frame rates (30 to 40 frames per second). This results in a three-dimensional model of the object field being derived directly from a single camera station. This contrasts with the two or more images acquired from different locations that are required to implement stereo-photogrammetric methods, followed by a substantial data processing stage to form the 3D model. Several of these range imaging cameras are now available commercially from Mesa Imaging (SR3000 & 4000 models) in Switzerland [Figs. 6 (a) & (b)], PMD Technologies (CamCube) in Germany [Fig. 6(c)], and Canesta (CADP2000 & XZ422 models) in the U.S.A. [Fig. 6(d)].
At the present time, these cameras have a rather poor resolution and a very small format size – in the order of 200 x 200 pixels – together with a limited range of 30 m or less and a measuring accuracy of several centimetres. However it is hoped that these limitations will be overcome as the technology develops. Indeed cameras with VGA image formats and resolution values (640 x 480 pixels) are expected to become available in the medium term. All of the papers presented in this part of the symposium were concerned with the calibration of these new cameras and with establishing the characteristics and accuracy of the resulting coordinate and image data. Within this latter context, most of the authors were concerned about the errors in distance that can occur due to the multi-path effects that take place, mostly within the range imaging camera itself. These result in an individual pixel receiving signals from two or more (e.g. foreground and background) objects simultaneously causing errors in the measured range to a specific object. It really is a most interesting and potentially useful technology combining both imaging and ranging that is however only in the very early stages of its development.

**Conclusion**

This was a really excellent symposium, very well organised and with overall a very high standard of presented papers. The symposium fully reflected the fact that, with the widespread adoption of digital cameras and terrestrial laser scanners, this area of close-range photogrammetry is really buzzing – with numerous interesting applications in a wide range of disciplines. The complete set of papers is available for download from the ISPRS Commission V Symposium site at the University of Newcastle - www.isprs-newcastle2010.org/papers.html

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**Event**

The SR3000, and the SR4000 range imaging cameras, that are produced in Switzerland by Mesa Imaging. (Source: Mesa Imaging)

The CamCube range imaging camera which is manufactured by PMD Technologies based in Siegen, Germany. (Source: PMD Technologies)

The XZ 422 range imaging camera is manufactured by Canesta Inc. in the U.S.A. (Source: Canesta)

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