Report on 54th Photogrammetric Week (PhoWo) at the University of Stuttgart, Stuttgart from 9-13 September 2013.

The 54th Photogrammetric Week was once again managed very ably by Professor Dieter Fritsch, Head of the Institute for Photogrammetry and Remote Sensing at the University of Stuttgart. Invited speakers presented papers in the morning sessions, and the 'Open PhoWo partners', comprising the major companies which market equipment and software for the photogrammetric industry, presented workshops on their equipment and software in the afternoons. The Open PhoWo partners included Hexagon, Trimble, IGI, Microsoft Vexcel, BAE, and VisionMap which was a new partner on this occasion. The theme of the conference was *'From High Definition Point Clouds to Virtual Reality Models'*. During the conference the Carl Pulfrich Award was presented to Nicholas Coops (Canada) and Norbert Haala (Germany).

The opening included a musical presentation and a welcome speech by Professor Alfred Kleusberg the VP Teaching and Rectorate representative of the University of Stuttgart. Welcomes were also given by Professor Dieter Fritsch and Professor Chen Jun, President of ISPRS.

Uwe Franke from Daimler Research gave the opening keynote presentation entitled *'How Cars Can See'*. The research, which has received multiple awards, is designed for pedestrian avoidance and control in traffic. Calibrated cameras are mounted on the windshield 22 cm apart. Processing is based on semi-global matching (SGM) incorporating FPGA hardware and fast algorithms for computer vision methods such as optical flow. The 6-D vision (2×3D) estimates position and motion of all tracked objects within 20ms, which is twice as fast as a human can react. Stixels act as super pixels. It has been tested on 1 million km on roads and has shown to operate effectively at night. Precision of matching is 0.3 pixel; it could be 0.1 pixel, but that would be pushing limits. Optical flow estimation can result in a precision of be better than 0.1 pixel. There is a zero error expectation with the system.

The first morning then comprised presentations on the latest technology developments by the Open PhoWo partners. They are summarised as follows.

Jack Ickes (Hexagon Geospatial Division) – from sensor to information – the evolution continues. He presented the latest details on Hexagon's imaging systems. 272 million km^2 have been flown and ortho images delivered for the NAIP program in USA in 4-5 months, seamlessly merged using Hexagon's imaging devices. Recent systems include ADS100 with 20,000 pixels and 5 µm pixel size, TDI, FOV of 77°, 8 cm GSD at 1000 m. RCD30 has oblique sensors. The DMCIIe has a redesigned sensor head. The ALS70-SP3 version has increased sensitivity especially for LiDAR detection of powerlines to overcome saturation of the ground when detecting powerlines. Geosoft has been acquired, including their Pegasus software and workflows have been strengthened and restructured, through collaboration with GeoCue. The company tridicon has also been acquired for managing oblique 3D views. UAS applications are in collaboration with Aibotix. The next 2 years will be more dynamic.

Ralph Humberg (Trimble - Director Innovation Geospatial) – *Connecting the dots and points in the geospatial world.* Developments in Inpho's software for UAV/UAS were described. It integrates aerial photogrammetric software, as 'shrink-wrapped for surveyors' as an end-to-end system. Point clouds have a central role especially for aerial photogrammetry. The biggest steps forward have been taken in fast loops between photography and feature extraction.

Albrecht Grimm (IGI) – IGI – history – present – future. He briefly described historical work in photogrammetry. Then he presented details of CCNS-5 (version 5) which is designed for multiple sensors; continued with Lite Mapper as the IGI LiDAR system and the new Penta DigiCam with 5 cameras, 4 of which are oblique sensors. GyroCopters/Cavalon are preferred to UAS and can operate with 5 cameras and laser scanners for city modelling, if desired.

Alexander Wiechert (Microsoft Vexcel) - UltraCam and UltraMap – an update. He referred to Microsoft Vexcel's successful sales of 238 UltraCam cameras and installation of 48 upgrades. He reviewed the developments since 2003 to the current UltraCam Eagle, and the soon to be available Osprey with oblique cameras, and in October the Hawk which will replace UltraCamLp. The Osprey with forward/backward and left and right cameras will be available in mid-September. UltraMap includes dense matching at 300 points/m^2. The ortho pipeline includes Dragonfly.

Stewart Walker (BAE Systems) – The product pipeline of BAE Systems for photogrammetry and remote sensing. He said that version 5.6 of SOCET Set is the last version of this software. SOCET GXP V4.0 replaced it in 2012. GXP Explorer is available for searching for data while GXP Enterprise Solution software suite and GXP Web Viewer are current versions. A large number of sensor models are available. There are strong links to Esri and other 3rd party companies.

Adi Gozes (VisionMap) - VisionMap sensors and processing roadmap. She described the A3 Edge camera with GSD of 7.5 cm and 6 cm and FOV of 106° thus providing high productivity. The software is fully automatic for aerial triangulation and orthophoto production. Dense point clouds can be produced by ifp's SURE software incorporating SGM (260 points/m^2).

Konrad Wenzel (ifp, Uni Stuttgart) – SURE – the ifp software for dense image matching. He described the development of the SURE software for the dense image matching incorporating SGM in a modified way. tSGM uses less memory and is used for multiple stereo models with noise suppression and storing of precision of points. It is scalable, parallel, and robust with default parameter setting. The company 'nFrames' has been formed to market the software. The intention is to use plug-in libraries. A Web site is available through University of Stuttgart.

The topics discussed in the following presentations came under three headings: *Data Collection from Air, Space and Ground; Advanced Methods of Computer Vision and Photogrammetry; and Solving the Future Mapping Problems: All About 3D Modelling*.

1st topic: Data Collection from Air, Space and Ground - An Update

Dieter Fritsch (University of Stuttgart) Oblique image acquisition- potential, experiences and recommendations. Mapping organizations have less staff and more work, so automation of processing is essential. Benefits of oblique cameras are that they image points on facades. Four systems for acquiring oblique images have been described at PhoWo. Images in the first test were taken with a GyroCopter giving point densities of 400 points/m^2. The data can be used amongst other applications, for detecting unregistered buildings. Oblique images have different geometry so the question is, how does SGM work with oblique images? The test carried out with DigiCam images resulted in 60% success with image matching. Overlaps were about 60%, but 75% overlap was needed. A new study was undertaken involving 41 stereo models from a VisionMap camera with a GSD of 6 cm, overlaps of 55%/45% and oblique angles of 25°-45°. Aerial triangulation was done by VisionMap. Matching success depended on the intersection angles, but accuracy was generally satisfactory at about 5 cm for intersection angles > 20°. The conclusion is that SGM can work for oblique images, resulting in an average accuracy of the order of 4 cm with 75% overlap along track and 60% cross track. Points should be visible on at least 3 images.

Rudiger Wagner (Hexgon) - Urban mapping applications. The Hexagon RCD30 is available as trio or penta cameras. Workflows for oblique images have now been developed, with distributed processing provided by GeoCue. Visualizing the results from SGM has presented problems. 3D maps are required because of the extent of urban developments. Hexagon has acquired tridicon for 3D city modelling from oblique images - OAPM is fully automatic for generating point clouds using multi spectral images. Data from UAVs and floor plans can also be added for BIM.

Yuri Raizman (VisionMap). High throughput aerial photography, ortho and 3D processing. The VisionMap A3 Edge mapping system was compared with other aerial camera systems in terms of FOV, overlaps, GSD, flying ceiling and productivity. The system can achieve imaging of 7,000 km^2 per day. Processing is an end-to-end system by Lightspeed software which can process 250,000 frames in a block: 6 such blocks would cover the whole of Germany. A second camera, A3 Core, is also available with smaller FOV.

Michael Gruber (Microsoft Vexcel) - Oblique image collection - challenges and solutions. The Osprey camera comprises a nadir image and 4 oblique cameras. It has compact design with, for example, 10 cm nadir images and 7 cm to 12.5 cm GSD for the oblique images on flat terrain, based on 5.2 µm to 6 µm pixel sizes respectively. Details were given of focal lengths for each of the cameras and examples of images were shown. Occlusions occurring have to be overcome with mobile cameras at street level. Flight pattern could be 75% along the flight and 60% across the flight line. Microsoft Vexcel's calibration range has been extended for oblique images. UltraMap software will include oblique images in the workflow which is in course of preparation.

Jens Kremer (IGI) - contour flying for airborne data acquisition. The approach is designed to overcome the effects of changes in GSD and overlaps due to flying with variable heights above the terrain. He discussed pros and cons of the process. IGI can supply tools for planning and implementing contour flying based on a DEM of the site, from for example SRTM data. It is necessary to limit decent and climb rates so the flying height changes are averaged out, because it is not possible to follow every height change of the terrain. The pilot would be guided by the CCNS-5 (version 5) which displays graphical elements on the screen as shown in the presentation. An example was shown of flying virtually over Lantau Island in Hong Kong which has height variations of 800 m above sea level and the flying height could be varied to achieve consistent GSD over the island.

Peter van Blyenburgh (UVS International) - RPAS - The European approach and the way forward. The acronym RPAS (remote piloted aircraft systems) is now accepted by ICAO which is also developing procedures for RPAS. The keyword is 'aircraft'. RPA or OPA (optional piloted aircraft) are additional terms. The mass of RPASs can vary between 17 g and 14 t and examples of RPAS were shown. Various flight control systems may operate, but they must be VLOS (visual line of sight). In Europe UAS < 150 kg are under national controls apply, while those > 150 kg are under European control.

The UVS International Web site contains significant information on RPAS. The photogrammetric community needs to be recognized as a participating group in RPAS.

Werner Mayr (GerMAP GmbH) - Unmanned aerial systems - for the rest of us. Available UAV/UAS/RPAS were described including weights, types, wingspan, autopilot, endurance, start/landing procedures, types of cameras, elements of autopilot, rudder control etc. All produce very good results. Software is available for producing maps. Permits in Germany limit certain parameters for flying, such as flying height below 100 m. His company is developing new planes, which were on display, with different wing spans, eg 1.5 m, 2 m and 2.8 kg, and a 3rd with 1 m wingspan with suspended mount.

Michael Cramer (ifp) - The UAS@LGL BW project - a NMCA case study. At the Rostock conference on UAS the previous week, the question was asked whether UAS could satisfy NMA (National Mapping Authority) needs. Some thought that they could be used for 'hot spot' mapping. The state of Baden-Württemberg use UAS for imaging for land consolidation. A test area was flown of more or less traditional aerial photography, incorporating also an image over a Siemens star to test the image quality with GSD less than 5 cm. Structure from Motion method was used to extract tie points. There were few ground control points. Full in-situ camera calibration, and PixUAV and Match-AT were used for image matching, the latter resulting in matching to an accuracy of less than 1 pixel. The relative accuracy of results derived by SURE software was better than that obtained using PIX4UAV. The conclusions were that UASs do satisfy the specifications for photography on demand for NMAs, providing also flexible acquisition, but harmonized procedures are needed.

Andreas Schilling (University of Tuebingen, Germany) - Another step towards measuring the world from the air: model-based 3D real-time simulation of micro-UAV. The standard scenario for airborne testing of UAVs is manual control and off-line evaluation. Therefore why simulation? Simulation is cheaper, ground truth is available, and results can be reproduced. Various situations can be simulated. The method requires devising equations and integration of stages. Some software can be used for real tasks. The block diagram for the process was demonstrated. Real and simulated scenes appear very similar.

Uwe Soergel (IPI Leibniz University of Hannover) - The TanDEM X mission: data collection and deliverables. The characteristics of SAR interferometric image acquisition were described and the accuracy of the TanDEM X mission was presented as a function of the location, noise, and number of looks. There is a mathematical relation for the accuracy of elevations. The data is collected with small and large baselines for determining elevations. Multiple looks improve accuracy, 15-25 looks being recommended. This defines the elevation post interval of 12 m. During year 1, a baseline of 200 m was used, in year 2, a base-line of 300 m was used and in years 3 and 4, the problem areas are determined for further processing. The orbits of the two satellites follow a helix form to avoid crossing. Dedicated phases are assigned to certain geographic regions. Baselines vary from 200 m to 600 m along track and 0 to 1000 m across track. Water bodies require masking out. 1st and 2nd coverages have been completed: 3rd and 4th covering difficult areas, such as deserts and Antarctica are still to be done. Products will include elevations with accuracy < 10 m, but the goal is 4 m for slopes < 20° and 8 m for slopes > 20°. Commercial sales commence in 2014 through Astrium.

Juha Hyyppa (Finland) – Unconventional Lidar mapping front air, terrestrial and mobile. Second generation UAVs and LiDAR systems are now being used. Identification of trees species is now the challenge, there being 3 or 4 species in Finland requiring identification. Hyperspectral LiDAR is being used to test classification accuracy. They use multi-sensor data on ground together with UAV data to determine reference data. Mobile mapping is in its second generation on a backpack with an accuracy of 2 to 3 cm, which is dependent on the GNSS system. Systems also combine vehicle based and backpack for mobile LiDAR. Multiple scans around trees are used to determine DBH with an accuracy of about 2 cm. Other applications of LiDAR include determination of road lighting needs and crop inventory.

2nd Topic: Advanced models of computer vision and photogrammetry

Luc van Gool (Belgium) - Image based 3D city modelling and mobile mapping. The aim is for 4D city models. General statements were made about the task of deriving city models: image based systems are operational while recognition of urban objects is partially solved; work is still needed on scalability; inverse procedure modelling is required, as it focuses on automatic learning, but is not currently part of their approach. Mobile mapping includes multiple images that can also sense and avoid aircraft. Recognition of traffic signs is available as well as scenes while driving. 3D can assist with recognition. Inverse procedural modelling uses rules, e.g. consequent rules, with features taken from a library. A high level of detail is possible. Structure from Motion using 3D point clouds is a bottom up approach, while style grammar is top down. Building component detectors need also to deal with occlusions. Style grammar is not trivial to produce for large spaces. A cut down from point cloud density is needed to provide robustness in processes. Advanced style grammar is required for large areas, using style classifiers and machine learning. Examples include segment classification, MRF, optimization at various levels, low, medium and high.

Martin Schaich (Germany) -Combined 3D scanning and Photogrammetry surveys with 3D data base support for archeology and cultural heritage: a practice report on Arctron's information system aSPECT3D. The software (www.aspect3D.de) is designed for a documentation system, and produces 3D details by structure from motion software from University of Graz, and also SURE software from ifp. A free of charge viewer is available.

Andreas Ulrich (Riegl Austria) - Sampling the world in 3D by airborne Lidar - assessing the information ground content of point clouds. A description was given of LiDAR as a sequential sampling based on a footprint size which limits the resolution and thus impacts on the information content. Full waveform sampling provides the best target resolution. Density and quality of LiDAR is dependent on distance to points and points/m^2. Up to 12 pulses in flight are now possible. Figures demonstrated the PRF v flying height and increasing pulses in air as PRF increases. Scanning speed should avoid overlapping of footprints, but this is difficult with high PRF. Demonstrations were given of point densities for single and dual scans for variable terrain heights. The figures demonstrated that dual scans cannot always be kept out of phase if elevations vary significantly. The new Riegl Q780 provides for more efficient scanning.

Samuel Bärisch (GAF Germany) - Dense 3D Photogrammetry. GAF in cooperation with DLR have used SGM for processing Indian satellite data. Very high resolution images with GSD of 0.5 m and 11 or 12 bit dynamic range are derived from very agile satellites that travel about 200 km in 10 s. Horizontal accuracy derived from these images is 5 to 8 m. For determining elevations, GAF prefers to have 5 overlapping images, but 3 is a trade-off, i.e. nadir, backward and forward with matching based on forward and backward. More images avoid occlusions, but it is not always possible in all parts of the world. GAF will also accept images with 10° off nadir. Tests show accuracy of CE90 of 3.4 m and after eliminating bias CE90 of 0.6 m. They have experimented with the implementation of SGM with up to 6 images. Water masking is done semi-automatically as well as void filling. Cost is Euro 50-70 per km^2.

Norbert Haala (Germany) - The landscape of dense image matching algorithms. There is an increasing number of solutions for SGM. Papers are available on the TU Vienna Web site for the recent EuroSDR workshop where results of the EuroSDR were presented. Limitations are occlusions which can be overcome with highly overlapping images, such as 80% along flight and 70% across the flight direction. A control base image is used for matching to it. Tests were undertaken for EuroSDR to investigate effects of different land uses and block configurations. The block size was limited to reduce work for the participants. Two test areas were used, one in a semi-rural area and the other in an urban area. DEMs were evaluated based on the computed median for the 10 participants, since even LiDAR was inadequate for the evaluation. The details are available on the PhoWo Web page. Large discrepancies occurred in shadows and on steep slopes. Vertical accuracies were close to sub-pixel. Softwares are still under development.

Phillipe Simard (SimActive, Canada) - Dense DSM Generation using GPU. He described software for image matching by optimized GPU code. They can process images from all sensors including pushbroom sensors, satellite images using RPC, and non-metric images on UAVs, on multiple PCs and GPU. Photogrammetry is a good candidate for GPU processing since all cores must do the same operations. There is no guarantee that it will perform faster since I/O is the bottleneck. They have now achieved a 3 times improvement in speed using the GPU. DSM spacing is the same as that of the original data. A top down approach is used in which elevations are estimated and back projected onto the data to find the match. It results in good density in all areas using 100 cores on the GPU. Processing time is 7.9 min per frame for GSD of 19 cm. For satellite data with 0.5 m GSD, accuracy is 0.28 m and RMSE is 0.73 m based on selected control points.

Panel discussion

Participants: Dieter Fritsch (Moderator) Samuel Baerisch (DAF), Jurgen Dold (Hexagon), Luc van Gool (University Leuven), Juha Hyyppa (FGI, Helsinki), Daniel Thalmann (EPFL, Lausanne, Nanyang Technological University, Singapore), Andreas Ulrich (Riegl, Austria)

Questions were posed to each of the participants. Significant conclusions from the discussions are:

- Some aspects of computer vision are not realistic, whereas photogrammetry is an application with its feet on the ground. Computer vision is becoming more realistic with applications such as car surveillance, bundle adjustment etc.
- In computer vision, bottom up approach is not necessarily the correct approach, and researchers need to look at new approaches
- Photogrammetry and CV collaboration has only just scratched the surface. We need efficient grammars for different situations, applications oriented grammars. We will have different grammars for the same operations and be able to convert between them. Updating will also be important.
- Vision for bringing Photogrammetry and CV together - go to each other's conferences.

- Hexagon will not change its policy of supporting 2 camera systems. It is optimistic of future developments including its mobile system -Pegasus- which is now a complete system.
- Recent developments in airborne LiDAR include higher altitude, dual scanners, backward looking, green laser systems for rivers and coastlines, multiple wavelengths at 1.0, 1.5 and 2.5 µm. Also there are integrated cameras. Very dense sampling will be possible, perhaps 100 pt/m^2. Hard surfaces accuracy will be up to 10 mm. This will depend on GNSS system.
- Other developments in LiDAR include 400 MHz PRF, autonomous driving, LiDAR in backpacks for forest inventory, but developments in mobile LiDAR have not been as fast as expected.
- In crowd generation, key words are simulation and prediction for any human situation.
- The next market for GAF is development of software for next generation satellites such as Skybox involving 6, 20 or 24 satellites, and high resolution frame based imaging systems.
- Developments for the future are expected to be sensor integration and integration of workflows, mobile LiDAR for indoors and integration of indoors and outdoors, automation of many processes. This will impact on all imaging. Almost real-time processing of LiDAR will be possible.

3rd topic: Solving the Future Mapping Problems, all about 3D Modelling

Daniel Thalmann (EPFL Lausanne, Nanyang Techn. Univ. Singapore) - Towards virtual life in 3D cities. Daniel demonstrated crowd simulation of up to 35,000 people. People have a variety of appearances, clothing, accessories simulated crowd scenes. Motion planning is required for collision avoidance and group adhesion based on a navigation graph. Distant people are only shown in 2D, while those closer in 3D. 3 levels of people are considered in scenes; group adhesion is used for 2-4 persons. Processes to consider are speed adaptation, waypoint adaptation, e.g., those intending to enter a shop or looking at places. Patches - objects stay in patches or are stationary. Need to define real trajectories. Combining cars with people is possible. For interactive design they have used Kinect from Microsoft. It should be possible to add true city models into scenes, but it would create problems in terms of processing requirements.

Martin Fellendorf (TU Graz, Austria) – Digital terrain models for road design and traffic simulation. Neither Germany nor Austria have adequate DTM data for road design. Switzerland has better data. The information from aerial photogrammetry is not good enough for road design since an accuracy of 10 cm is required for determining cut and fill, while cross sections are required to accuracy of about 1 cm and must be done by field survey. He wants to link highway design with traffic flow simulation, also to reduce fuel consumption and exhaust output. He is moving from traffic flow simulation to VR by combining traffic flow with VR scenes, including people, which is computer intensive. Next developments will be energy based vehicle navigation to minimize time and increase energy efficiency, which is a function of vehicle dynamics, street surfaces etc. Heights are needed to 10 cm on a 5 m grid.

Martin Ritz (Fraunhofer Institute for Computer Graphics Research, Darmstadt, Germany) – CultLab3D – Fast and economic high quality 3D digitizer of cultural heritage artifacts. Digitizing cultural heritage objects in 3D, e.g. Nefertiti as in Berlin, has been limited to small objects. There is no strategy for digitizing objects in museums and barely 1% of 3D objects have been digitized. ENUMERTE is an EU project for digitizing cultural heritage objects. 34% of museums can do 3D digitizing and 23% have long term strategies for digitizing. Polymetric 3D scanners require manual positioning of objects in the scanned which is about 85% of the scanner time. 300 scans at 15 µm take 36 hours computing time. Victoria and Albert Museum (UK) state that it would take from ½ to 20 hours to digitized various objects in its collection. Museums in Berlin have 6 million objects and are adding 120,000 objects to its collection every year. An automated scalable system is required. He described the challenges including selection of the technology, workflows, guidelines and best practices. The vision is for a fully automated system for digitizing that also obtains properties of the objects, based on an iterative 3 stage scanning process with each pass acquiring additional information.

*Livio de Luca (CNRS UMR MAP, France) - 3D modelling and semantic enrichment in cultural heritage I*nformation depth in architectural representation, scale certainty, traceability, coherence and intelligibility are required. He demonstrated geometry v semantics for 3D extraction of columns in buildings. Reasoning is required for shape analysis, but this is not solved yet. General principles require managing multiple representations and analysis of representations.

Marinos Ioannides (Cyprus Technical University, Cyprus) - From point clouds to triangular meshes. He uses Voronoi triangle to obtain 3D intelligent virtual models and showed examples of documented sites.

Stephen Lawler (Microsoft, USA) - 3D mapping and photogrammetry. With increased scale of computing the trend is to move to higher levels of information organization with real time read/write to Web servers. There is an explosion of data. Indexing is an issue, and filtering of noise is required. Communications are changing to natural communication methods such as touch, image recognition, OCR, Kinect, gestures and motion detection. Inventions will come from physical and digital world convergence. Augmented reality will become personalized and contextualized. Wearable computing devices, sensors, smart phones, and tablets can be expected. 'Internet of things' breathes digital life into the physical world of things. Maps will need to change to full 3D with rendering, be alive from multiple sensors and dynamic. Resolution will need to be very high with high rates of changes. Structural collection, Web indices, crowd sourcing, machine learning and big data, are all developments in the digital world. Microsoft's Photosynth will have a new version in the Fall. Maps will become more immersive, the 3D world will be represented more realistically from different perspectives. Windows 8.1 will include new facilities for 3D visualization. Computing will involve multiple nodes extending to billions of fully connected nodes, giving an end-to-end approach - from sensor, acquisition of data to user experience.

Slides of the presentations are available on the PhoWo web site. The full proceedings have been printed and are also available in digital form from ifp Stuttgart.

The 55th Photogrammetric Week will be held from 7-11 September 2015.

John Trinder
UNSW, Australia
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