55th Photogrammetric Week (PhoWo) at the University of Stuttgart, Stuttgart, 7-11 Sept. 2015.

The 55th Photogrammetric Week, with the theme '*Excellence in Photogrammetry, Computer Science and Geoinformatics*' was once again managed very ably by Professor Dieter Fritsch, Director of the Institute for Photogrammetry (ifp) at the University of Stuttgart. Invited speakers presented papers in the morning sessions, and the 'Open PhoWo partners', comprising the major companies offering market equipment and software for the photogrammetric industry, presented workshops on their equipment and software in the afternoons. The Open PhoWo partners this year included Hexagon, Trimble, IGI, Microsoft Vexcel, GerMAP and VisionMap. During the conference the Carl Pulfrich Award 2015 was presented to Dr. Christoph Strecha, the developer of Pix4D software.

The first morning comprised:

Dieter Fritsch, ifp Univ. Stuttgart, Stuttgart, Germany - Some Stuttgart Highlights of Photogrammetry and Remote Sensing. As this was Dieter's last PhoWo event at which he is Director of ifp, he presented a review of some of its achievements. The Institute was established on 1 April 1966 by Professor Ackermann and contributed to bundle adjustment software (PAT-B), image correlation, GPS based aerial triangulation and many other developments. Professor Fritsch took over as Director of the Institute on 1 June 1992. Contributions thereafter have included laser scanning with GPS/IMU, 3D city models, generalised camera calibration and certification, close range photogrammetry, and mobile mapping. A total of 775 papers have been published over the period of the last 23 years. Podcasts of lectures are available since 2006. The 50th anniversary of ifp will be celebrated on 8 April 2016.

Self-calibration Additional Parameters (AP) have been normally used for film images, but do they work for digital images? There have been some criticisms of the self-calibration approach since the methods have no theoretical justification. Should AP continue to be used and if so, which ones and are new parameters available? Challenges in the selection of AP include those related to GNSS/IMU misalignments, shift parameters, and interior orientation parameters. Several tests on the Vaihingen/Enz test site used film and digital cameras and the classical definitions of Aps, such as the sets of Ebner and Gruen. The reformulation of new families of AP incorporated the principle defined by Weierstrass's theorem, that any misalignments and/or distortions can be approximated by an appropriate polynomial. For example, the Legendre function and Fourier series can be optimum functions in this sense. He used both formulations for tests using the DMC and UltraCam images with 60%/20% overlaps, using 66 Legendre and 16 and 48 Fourier parameters. The results achieved 0.2 GSD for x,y and 0.4 GSD for z with AP and with 4 GCPs. Hence the solution performed very well based on the proposed formulations of AP. There was less correlation between the parameters compared with those for film images. The Fourier series with 16 parameters are theoretically preferred and should be included in all bundle block adjustment for digital images. References are available.

History of SURE software. Professor Fritsch described the project undertaken on the Amsterdam façade, which involved 1.1 billion points derived by image matching. The SURE software for image matching, originally developed at ifp, is now available through nFrames GmbH company. It enables true orthophotos production and improved texturing of 3D models.

Geoprocessing of WorldView-2 images. The normal approach is to use the RPC. Solving for the 80 RPC requires 40 GPS. Epipolar images were produced, a DSM obtained and results compared with the output from a DMC camera and airborne lidar. RMSE results were 1.4 m for roofs and 2.1 m on the terrain surface. The process has yet to be optimised.

Presentations on the latest technology developments by the Open PhoWo partners.

John Welter, Hexagon Geospatial Division, Heerbrugg, Switzerland - Sensors to Solutions – Data to Information.
The sensor portfolio includes: DMCIII, ADS100/120, RCD30 and the penta/oblique RCD30. DMCIII has 50% more CMOS pixels. ADS100/120 now also has 120 mm focal length. Software includes improved HxMAP workflow, RealCity, Leica Building Finder. Lidar includes bathymetric offering amongst 4 systems, based on modular solutions. Mobile mapping includes Pegasus:Two and Backpack systems. Railway and CPR solutions are also available. UAV systems include the Swiss based Aibotix drones and the Dragon 50, which can fly at 10,000 feet ASL and are intended to differentiate from the normal market. HxIP is a unique program for professionals based on a subscription service similar to Apple iTunes.

Tobias Heuchel, Trimble, Stuttgart, Germany- 'Providing Accurate Answers Fast is Crucial – An Overview.
Trimble has expanding solutions for photogrammetry and remote sensing. Land mobile mapping Mx7 includes 6 cameras 360° coverage, GNSS and laser scanners. 3 lidar systems are available for aerial mapping. For UAS, the new high precision UX5, ZX5 modular, UX5 with Sony 36 Mp camera, with 3 lenses which can achieve GSD as small as 1 cm. gBOX GNSS receiver, and GNSS inertial combination. Trimble imaging software is available for frame and pushbroom sensors. Remote sensing software includes eCognition and SATMaster.

Philipp Grimm, IGI, Kreuztal, Germany (IGI – Integrated Geospatial Innovations) 'Expanding Solutions for Photogrammetric and Remote Sensing Professionals.
SMU-2 mobile mapping control rack; Quattro DigiCam with various capabilities, large format, CMOS sensor in multiple configurations. Workflows include IGI Match with SURE for textured matching. Navigation in absence of GNSS was tested for measuring tunnels for underground railways. GCPs were measured at every 150 m and an accuracy of 2.2 cm was obtained.

Alexander Wiechert, Microsoft Vexcel, Graz, Austria - UltraCam and UltraMap – An Update
4 cameras are available with various capabilities and prices. Eagle has various lenses and is upgradable, now comprising 2300x14700 pixels. Osprey has been upgraded with increased coverage for the nadir camera. Osprey Lite is also available with RGB only. UltraMap is available in various modules and versions – colour matching on colour images. Very good visualisation tools for many tasks and editing 3D data. Next year will see the release of 3D TINS.

Werner Mayr, GerMAP, Welzheim, Germany - UAVs for Production.
He showed various types of UAVs for different payloads. G130 fixed wing with 130 cm wingspan, G180 fixed wing for 1.2 kg payload, G212 with suspension mount; G400V vertical take-off with 4.2 m wingspan and 3.7 kg payload; the company use multi-copters provided by other companies that are used for surveillance.

Yuri Raizman, VisionMap, Tel Aviv, Israel VisionMap - A3 Edge – A Single Camera for Multiple Solutions.
The A3 Edge has 2 telescopes with FOV of 110°, acquiring 700 Mp for vertical and oblique images. Several versions are available, some for manned aircraft and for UAS. Lightspeed photogrammetric software is provided for processing. The system can image up to 11,000 km/hr with high flying height and has the highest orthophoto production rate of 9000 km^2/day. An example was shown of results of aerial triangulation without GCPs accuracy with an accuracy of 20 – 50 cm. Thermal imaging is also available.

Chance Coughenour, ifp Univ. Stuttgart, Stuttgart, Germany - The Marie Skłodowska-Curie ITN-DCH Project – Overview and Scientific Work.
The digital heritage project plans to integrate all types of data for several case studies. Archaeological sites include Asinou (Cyprus), Donaustauf Castle (Germany) which is said to date back to 500BC, Ilmendorf (southern Bavaria in Germany) and Carnuntum (Austria) outside Vienna. Virtual reconstruction is done in cooperation with 7reasons (Vienna).

1st Topic: "Remotely Sensed Data Acquisition – An Update

Fabio Remondino, Fondazione Bruno Kessler, Trento, Italy - Oblique Aerial Imagery – A Review.
The systems available for oblique imaging were reviewed, including sweeping, 3, 4 and 5 separate cameras. The Maltese-cross layout providing 5 views is the most common configuration with RGB and sometimes NIR in the vertical. Pros – multi views, wide coverage, possible automation of processing. Cons – occlusions, but the data can lead to 3D views with texture. 3D cadastre may also be available with various levels. Problems: flight planning, processing because of convergent images increases processing time.
A simulated flight plan with high tilt angles of 45° was tested demonstrating the high redundancy of homologous points. Flight plans were tested with 60/40 and 80/80 overlaps. The highest redundancy led to highest accuracy. Workflow would rely on GNSS/IMU data. For matching, images with the same tilts were used.
An ISPRS/EuroSDR bench mark test is being undertaken with GSD 10 cm and more than 1000 images. Area 1 – Dortmund, Germany with 1200 images. Area 2 - 900 images. Tests ran on the data. Nadir compared with oblique images – 6x less tie points. There were only a few matches across obliques. Self-calibration is mandatory. 80/80 gave the best results. The results of a questionnaire to users and mapping authorities have been published in GIM Vol 28 (12) 2014. Vendors and users generally agreed on answers – identification/mapping tasks have priority, oblique images are best for identifications of features. Maximum GSD was 19 cm, but they prefer 10 cm. Overlap of 60/60 was preferred.
Conclusions: Oblique images will probably become standard, but will not replace nadir images. There are many applications. The mapping agencies are adjusting so as to cope with oblique images. They need a new approach for flight planning and processing the images. Additional costs may be compensated by benefits of denser point clouds, higher reliability and true orthophotos. New solutions are needed to derive structure information.
Open issues – scales and radiometry changes, correct identification of points, processing time, fusion of points and interpretation of details. Competitors are UAS close to features on the ground.

Georg Bareth, Univ. Cologne, Germany - 3D Data Acquisition to Monitor Cropping Systems: Sensors and Methods.
Motivation: Precision agriculture for estimation of biomass for crops such as rice, maize, grasslands. Limitations of remote sensing are clouds, repetition rates, resolution, costs. Opportunities available for airborne systems are field borders and resolutions. Self-driving spraying devices are now available. Objective is to acquire 3D data of plant height for biomass estimation which is a key parameter. Hyperspectral data is an option for chlorophyll determination. Nitrogen index (NNI) needs to be optimised. All types of sensors are in use for precision agriculture, especially TOF (time of flight cameras), and ultrasonic sensors, N sensors to measure nitrogen content. Multi-temporal crop surface models are measured many times during crop growth. Hence it is possible to calculate plant growth during a period in the growth season and consider stress on plants. TLS data is derived of the fields by oblique scanning with RTK GNSS. Also multi-copter UAV with RGB sensors are used. SfM is used for matching points for 2.5D surface models using low cost cameras. Very reliable measurement of plant height obtained is possible using lidar and UAV systems and also against

manual measurement. Biomass determined with R^2 of 0.84 derived from UAV. Plant height is a key parameter. Measurements are made of grass height using rising plate meter compared with UAV results. Conclusion: plant height as a robust estimator of biomass based on TLS/UAV, worked well for crop surface models (CSM).

Wolfgang Wagner, TU Vienna, Austria - Big Data Infrastructures for Processing Sentinel Data
The amount of data being derived from new satellite systems requires large infrastructure. Sentinel 1, 2, 3, and 6 are important new sensors and will provide the best available data. ESA is taking leadership in EO. Sentinel-1 is a game changer with 20 m resolution, temporal resolution of 3 days in Europe, excellent quality, highly dynamic for land processes. Sentinel-1 will acquire 1.2 PB data in 7 years. This is a new era in data acquisition. A PB is a point of the earth for every 10 cm. 1 PB would take 64 years processing for 1 computer, so super-computers are required for Sentinel data. Moore's law will hold for a number of years (doubling CPU capacity every 2 years) and therefore new infrastructure will be required to bring users and their software to the data. A consequence is that cooperation is needed and specialisation. There is a business case for private sector involvement, such as Google and Amazon Web services. Google Earth Engine is involving 3 countries US, Europe and Asia. This is progressing with 'Googlish' which runs on the Google Earth Engine with an image oriented data structure. European Observation Data Centre (EODC) was founded in May 2014 as a PPP. It is a community facilitator, cooperative framework involving 13 countries. It is building up the infrastructure, initially with 4 PB. Operations commenced in June 2015 with a computer cluster, with 54,000 acquisitions of data or about 40 TB. Experimentation has commenced with data with 312 nodes on a super-computer resulted in obtaining output in 45 minutes.
Conclusions: EO is entering the era of big data. Developments are along the lines of private, general purpose computing or building new dedicated EO data centres.

Norbert Pfeifer, TU Vienna, Austria - Lidar: Exploiting the Versatility of a Measurement Principle in Photogrammetry
Cameras determine angles and directions with processing subsequently. Lidar measures angles and range and the solution is simultaneous. Wavelengths characteristics define reflectances. There are challenges in processing bathymetric lidar. The water surface must be identified and modelled, and the effect of Snell's law must be applied. The footprint of bathymetric lidar is much wider than for terrestrial applications of airborne lidar – 60 cm for green laser but it depends on the flying height. The question is how the larger footprint relates to the bottom of the water? This has not been evaluated, but accuracy could be 15 – 20 cm. Time series changes in river banks can be determined. Full waveform lidar exploits radiometric and geometric measurements. Grasslands have been classified by decision trees with an accuracy of 75%, equivalent to competing methods such as using hyperspectral data.
Photon counts are suitable for large flying heights, including those from space. Simulations of returns of the footprint with conventional detection have been tested. Spurious photons may also be detected.
Using UAV as a platform for lidar, the results look as dense as TLS with very small footprint and for modelling tree diameter. (see GIM 2015 – Mandlburger et al)
Conclusion: Lidar provides more than directions and hence additional observations for classification of objects. Lidar from space requires correct interpretation of point clouds which needs knowledge of footprint size. Very highly dynamic lidar point cloud acquisition requires refined models of objects.

Norbert Haala, ifp, Univ. Stuttgart, Germany - Image-based 3D Data Capture in Urban Scenarios
Representation of spatial data in 2.5D is unsatisfactory, so what is the appropriate representation of 3D structures? Hence he discussed the conversion of 2.5D to 3D. Point clouds are known in our

field, but not voxels. He related depth maps and point clouds. Tests were undertaken of real-time visualisation using OpenSceneGraph software and hierarchical adding/removal of triangles, which are also 2.5D. Depth maps and meshes can be integrated and transformed to object space. Conclusions: multi-view stereo is complex. 3D meshes can be used and true 3D is possible.

Ismael Colomina, GeoNumerics S.L., Castelldelfels, Spain - On Trajectory Determination for Photogrammetry and Remote Sensing: Sensors, Models and Exploitation
Two messages were provided: sensor orientation/positioning have made tremendous progress and navigation technology needs to be used properly. Trajectory is a function of time, navigation is real-time orientation. He described the Galileo navigation system, measurement accuracy and multi-pathing. GNSS infrastructure in future will involve 30-40 satellites to be seen simultaneously and 12 signals, which means about 1000 channel receivers. There is a revolution in MEMS, which are cheap and with low noise. A simulation study showed accuracies of 2 cm horizontal, 5 cm vertical and attitude at about 0.03°, which includes the revolution of low cost precision time keeping at 1 µs in 24 hours. Good timing results in good vertical accuracy. The conclusion is that there is ongoing progress in motion sensing.

Heiko Hirschmueller, Inst. Robotics, DLR Oberpfaffenhofen, Germany Computer Vision for Mobile Robot Navigation
Navigation on Mars has been autonomous because of the time of communication at such distances. The robot system uses passive stereo matching. Outdoor scenes are typically well structured. The pipeline involves left and right images, stereo matching using SGM because dense matching is required and implemented on a FPGA, which is also the Daimler solution for autonomous car driving. Visual odometer using wheels and tracking of natural features, all 6 DoF being determined. Robustness is more important than accuracy. Visual odometry and IMU enables real-time control of the robot. Odometry takes about 20 ms which is too long, hence the need for IMU. For mapping and path planning, transferability is based on roughness, steepness and obstacles etc.
Search and rescue applications. He displayed the DLR Crawler with stereo cameras and IMU. The Pelican flying system includes cameras, IMU, FPGA, but no GNSS, with everything done on-board. Depth maps and voxels are used. He demonstrated a flight outdoors to indoors to outdoors. It was also tested in a dusty mine. A light weight rover unit (LRU) has been developed as a prototype. Roboception(.de) GmbH is a spin-off company from DLR for commercialising of developments in robots. Detailed errors and confidence provided for every pixel with SGM.

2nd Topic: "Advanced Modelling in Photogrammetry, Computer Vision and Computer Graphics"
Christian Heipke, Leibniz Univ. Hannover, Germany – Image Analysis Based on Probabilistic Models
Tasks in image processing include geometric parameter estimation, image classification which may involve machine learning and image interpretation, object extraction and tracking. Strategies for auto recognition of objects in sensor data require knowledge about objects. There are model and statistical based approaches which learn from examples, or analysis based on similarity of features in feature space. Problems are complexity and transferability. Probability approaches can produce provable results. Examples are MLC, logic regression and random field. Non-probabilistic approaches are support vector machines and random forests.
Markov random fields consider context. Class labels of neighbouring nodes are not independent, hence smoothing is involved. There is a dependence of the classes in the simultaneous classification of all pixels. Conditional random field (CRF) (Kumar and Hebert 2006) includes associate potentials and interaction potentials. CRF is a better approach for classification tasks and can be formulated by the Potts model. Some examples were described to demonstrate the method. Land cover analysis resulted in 85.5% accuracy, but problem was the need for training data. Road extraction – 3 vertical layers created, some with occlusions and some without - accuracy was 85% while accuracy from random forests was 83.4%. The approach is suitable for multi-temporal and multi-resolution data

and data with different scales. Success depends on proper feature selection. Few but expressive features are often sufficient. An approach is required for auto feature extraction. Global context also needs to be defined, eg roads are parallel to buildings. Hierarchical models could also be considered. The use of higher order also has potential, ie pixels further way from the central pixel. Can errors in training data be modelled?

Helmut Mayer, UniBw Neubiberg, Munich, Germany - From Orientation to Functional Modeling for Terrestrial and UAV Images
UAV images can be used to produce fully 3D models of buildings, since there are objects that are not available in 2.5D. A 3D model of a building is 800MB, so it is necessary to produce functional models. For orientation, a high level of completeness and precise orientation by combining RANSAC is needed, least squares image matching, triplets based and hierarchical fully automatic linking. Corresponding pairs found by SIFTGPU. Minimum number of pairs using minimum spanning trees (MST). Accuracy is much better than VisualSfM and much faster. Scalable 3D modelling - used divide and conquer scheme with adaptive splitting of 3D voxels. Disparities were modelled using total variation (TV). Window size is based on threshold for TV. Relation of disparity to TV learned for data. Fully 3D data is demonstrated in examples. For buildings, it is necessary to detect vertical planes using statistical sampling of roof nodes and selecting best ones. For façade interpretation he uses catalogues of doors, windows etc.

Konrad Schindler, ETH Zurich, Switzerland - Recent Developments in Large-scale Tie-point Search
Image sets are unordered, especially crowd sourced images, as well as those from consumer UAVs. It is not possible to predict photos with homologous points. The task is to find points and determine correspondences, which is the bottleneck. A possible solution is to speed up parameter modelling by reducing the number of images by eliminating the redundant images, reducing the number of connections, that is, find multi-view correspondences directly. To reduce the number of images, select threshold by feature pyramid, try to recover features that do not match. A simple solution is to learn from training data, which descriptors will match, but the threshold needs to be selected with care otherwise too many features will be lost. Savings in computing time depend on details in the images. Match graph – set up a network, find clusters in images using one representative, restrict the number of images to the minimum dominant set and then bring in others later. Clustering can be brittle and low accuracy is likely. Restrict number of image pairs, gradually building up surrogate pairs, select the most similar images using a single measure. This tends to give better networks, but increases costs. Search structures ('vocabulary tree') can make the process more efficient. For efficient multi-view matching, if vocabulary is large enough eventually most words appear at most once in an image. Need initial values which should be based on pairwise matching. The approach is limited to 100,000 images because of the size of the memory. Which method should be used? It is horses for courses. Think of the goals, completeness v accuracy.
If done correctly there is almost no too big data set. 100 million unordered images can be processed in 5 days on 1 computer. A review paper will appear in ISPRS Journal next year.

Luc van Gool, Univ. Leuven, Belgium - Real-time Photometric Stereo
Photometric stereo using light domes, multiple images illuminated by lights on a dome with rotating table. His system was only operational in the laboratory, so a single camera portable system was developed with 260 LEDs. Differences in shades on objects lead to stereo. Lambertian reflection is not assumed so as to obtain closer to true reflections. The illumination, local albedo are known, hence reflectances can be determined if at least 3 lights are available. With multiple lights it is possible to solve the non-linear problem. Hence 3D reconstruction is possible in real time. Digital representation enables viewing details of objects on stone, coins, paintings, insects, metal plates with engraving. A new portable dome is available, for objects of 10-15 cm. Processing is done in 10

minutes; success is improved by camera settings. GPU implementation should speed up the solution by about 1000 times, with each pixel executed on each thread of GPU.

Michael Klein, 7reasons, Vienna, Austria - The 4D-CH Calw Project – Spatio-temporal Modelling of Photogrammetry and Computer Graphics
The company specialises in visualisation by transferring images into media production. The EU 4D-CH project acquires images from the wild and feed them into a pipeline for 3D/4D reconstructions. Calw, a medieval city in Germany from about 830 AD, serves as testbed for the 4D-CH World project. Point clouds, generated by SURE using aerial photos of a 2012 photo flight with 10cm GSD, a height map including roof heights was derived from the existing TIN LiDAR DTM. Building texture was obtained from images. Unwrapped diffuse and normal map textures were developed. To fill lack of information, a generic grammar based modelling approach was used to overcome time-consuming manual work and editing. Some problems still exist. The output was described to present the information to the public in modules on an internet platform, augmented reality, virtual reality etc.

Daniel Thalmann, Nanyang Tech. University Singapore - Hand Motion and Grasping: Capturing, Recognizing and Synthesizing
Virtual images need details of hands that are accurate with deformations and coordinate complexity. Hand motions and deformations vary a lot, such as grasping. It is formulated according the size of the object, situations, weight of object. Some objects have handles (tubular structure). If tubes are available, it is possible to add fingers as well. Reaching involves all joints. Smart objects are those where the object helps the person to use it, eg door, drawer, lamps. The fusion of hand and body also needs to be formulated as well as gesture recognition. This can be done by regression forest and fusion using PCA.

Hans-Gerd Maas, TU Dresden, Germany - Photogrammetric Techniques for Spatio-temporal Analyses of Glacier Motion Patterns
Greenland has about 20 large glaciers. If all the ice melted, the sea level would rise 7 m. The Jacobshavn Isbrae glacier is moving at the rate of 20 m per day comprising 110,000 km^2 with 35 m^3 of ice bergs. The glacier has retreated more than 20 km. In the past the velocity was measured at 20 m/day but NASA measured it at 35 m/day. Mechanisms need to be determined for change, melt, water flow, movement on water beneath the unstable glacier. Satellite images can be used for some aspects of the glacier, but not the effects of tide for which hourly images are required using close range photogrammetry and image sequences. Least squares matching, shadow correction, continuity constraints, targets for correct camera motion to obtain the correct trajectory. Georeferenced movement was about 40 m/day (SD=8cm) which is correlated with tides. Speed increases after carving. They determined the trajectories and considered the contributions of tides which varied over years. The dynamics of GLOF (Glacier Lake Outburst Flood) were observed for an early warning system. The project demonstrates the potential for photogrammetry for many different types of projects.

Manfred Buchroithner, TU Dresden, Germany - High up and Deep below – Dynamic 3D Cartography at the Roof of the World and in Sea-Level Caves
Stereo cameras were used to measure glaciers in Tibet at an elevation of over 5000 m ASL. The purpose was to generate a time series of images (> 6000). Earthquakes shifted the cameras and this movement had to be corrected. Orthophotos were produced and the snow line determined. There was complete ablation in winter. They also visited a monastery that could be threatened by a GLOF. The valley was mapped using satellite images and DGPS measurements in the field.
The Kast cave system in Borneo was mapped because of its economic importance. A quadcopter was used and a Faro lidar scanner to scan the caves at various levels. Automatic analysis of the

caves was done to extract birds' nests. A 3D model of the caves was produced using a 3D printer with different levels displayed by different colours.

George Vosselman, Univ. Twente, The Netherlands - From Nationwide Point Clouds to Nationwide 3D Landscape Models
In 2010 the Netherlands initiated the development of 3D geo information. There had been various initiatives by various cities, but the data was incomplete and in different models. Therefore it was proposed to produce a model of the whole country. TOP10NL data base at 10:000 is open data while the AHN-2 elevation data base was determined by airborne lidar. Two generations of data at 8-10 pts/m^2 amounting to 600 billion points, also open data, were classified as ground/non-ground. A 3D surface model was required without gaps, modelled at LOD1 (flat roofs), which is the simplest model. Modelling is based on many rules in converting 2D to 3D. Tiling and parallel processing were required using a supercomputer to process the 30,000 1 km^2 tiles. Software from ITC was transferred to the supercomputer and processed in 1 month with 100 cores. The data was displayed with buildings as LOD1, bridges in 3D. Initially 90% of details were successful, but now 97% are complete. LOD2 would be useful being based on roof topology graphs. Correction of errors could be by interactive means but this would take a long time. It is suggested that error types should be recognised and a library of errors and a recipe of corrections listed. If this procedure does not work, then manual editing will be required. At present 95% of buildings are correct. LOD2 would require 13 days processing + 2 years interactive editing. An alternative is to acquire high overlap images for dense matching, but the cost would have to be funded by the national mapping agency.

Clive Fraser, Univ. Melbourne, Australia - Advances in Close-Range Photogrammetry
Evolution of close range photogrammetry (CRP) was given. 1. Conversion from film to digital. 2. Manual to automatic measurement and orientation. 3. Manual feature extraction to automatic 3D point cloud detection. CRP is now in the digital era with coded targets, feature based matching/SfM, automatic orientation. SfM is only used for point extraction followed by dense image matching. Automatic camera calibration has enhanced access to CRP. Bundle adjustment plus self-calibration for refined network, determination of 3D points with final block adjustment. Workflows are needed from semi-automatic to completely automatic with various scenarios available, but flexibility is needed.
Manual measurement using targets is still used (not obsolete) as in US for traffic accidents (>2000 operations) where an accuracy of a few cm is adequate. Photography is a permanent record; targets are used sometimes as in accident scenes with poor geometry, ie ill posed. Hence special solutions are required. Using images in court can be an issue. Simple diagrams are provided from images. Target based measurements are required for aircraft manufacturing which have high tolerance levels. Specialised photography with is used with 22,000 targets projected onto the aircraft component. Auto orientation, targetless, with 250k points in dense matching, examples are available from PhotoScan. What was achieved from SfM? A powerful technique for point correspondence, but less precise for matching, 0.03 pixel for targets compared with 0.3 pixel by feature matching. RANSAC approached can be used for filtering matches, obtaining initial values and dealing with many points in the point cloud. UAV data is not adequate for courts yet, since it is a blackbox solution. Auto camera calibration with/without targets gives the same accuracy due to the large number of points (20 v 55000).

Nadia Magnenat-Thalmann, MiraLab, Univ. Geneva, Switzerland - Image-based 3D Avatar for Virtual Try-on Applications (http://www.miralab.ch/nadia-magnenat-thalmann/
Digital humans are used for fashion industry. Free form interactive modelling, templates and precise surface structures are acquired. 80 pictures are taken simultaneously using Agisoft PhotoScan software. Problem is solving clothing research, mechanical properties of cloth, collision detection and response. Interaction of external forces on the cloth needs geometric modelling and

visualisation. Start from sketches of patterns to display models and then animated models. 'Try on' of watches, rings on fingers etc were displayed. Various steps are needed to generate whole body of a specific size, using Kinect. She demonstrated construction of the person with clothing of different sizes, styles and on different devices.

Thomas Ertl, VisUS, Univ. Stuttgart, Germany eoVis – From Terrain to Tweets and Movements
Stuttgart Powerwall project.
Want a 6 m x 2 m display at 50 dpi. 16 x 4k projectors each with 9 Mp with a transfer rate of 20 GB/sec. There are many applications. Visualisation has an important role in exploiting data and its spatial properties. Visual Analytics is visualising very complex data relations. It commenced about 25 years ago. Is anything new? Yes. Terrain view techniques, geodata for situation awareness; focus on Twitter using tweets; look for spatio-temporal anomalies using keywords; data enrichment to understand urban dynamics; tracking ebikes; drilling down for temporal analysis; unknown correlations and deep insights about the semantic realm.

Kurt Rothermel, Inst. Distributed Systems, Univ. Stuttgart,Germany - Public Sensing – Using Your Mobile Phone for Crowd Sourcing
Phones are powerful sensors in the sensor network. By 2019 there will be 11.4 billion mobile devices. Google developed a device for $500 that can be programmed for the user's requirements. Mobile devices are good for crowd sourcing since there is no upfront cost. OpenStreetMap (OSM) now has 4.8 million GNSS points and about 30,000 active users. TomTom navigation uses 6 billion records, which are collected daily. Waze by Google has 50 million users for road condition monitoring, as in Boston. Challenges – hiding complexity, type of operations, user accessibility – privacy, energy requirements, quality of sensing. Some solutions are virtual sensors, abstraction, but they depend on the set of virtual sensors. Model driven sensing can be used in which required data is modelled. It can be used to evaluate the quality and fill gaps in sensing. Online learning of the models only takes a few minutes and saves energy. In the Com'N'Sense project at Uni of Stuttgart, users collect trajectory information. An example was shown, in which persons with IMUs on their shoes collected trajectories along floors and rooms for mapping a building. IMU has lots of drift so traces need to be corrected. Some parts of the building were mapped well, but need indoor grammar, production rules, probabilities and heuristics. A model driven strategy helps the crowd sourcing data collection process to come out with realistic indoors mapping.

3rd Topic: "Excellence in Geoinformatics"

Liqiu Meng, TU Munich, Germany - Mobility and Visuality of the Digital World
Locations are digitised, which is a function of resolution and then update frequency, and stored. Price is usually based on unit area. Mobility is one important aspect of humans. Visuality drives cartographic design. Many examples were shown of displays of visualisation.

Lutz Pluemer, Univ. Bonn, Germany - Early Identification of Plant Stress in Hyperspectral Images
The purpose is to make the unobserved observable using hyperspectral images. Need non-parametric classification, such as SVM with various kernels. This minimizes the risk. Identification of diseases early on different crops is necessary. Curve of sensitivity to wavelengths varies when plants are diseased. Unsupervised learning is used for senescence. Clusters are derived by Simplex Volume Maximization.

Monika Sester, Univ. Hannover, Germany. - Interpretation of Moving Point Trajectories

Since people are moving everywhere, the measurement of the movements have to be made with respect to check points. Status sensors observe moving objects. Movement can be constrained by roads, or temporary or permanent blockages, or by behavioural movement. Interpretation of the underlying infrastructure can be determined, such as the features, rules, behaviour etc. Challenges are: not all roads are used in the same way. To recover roads, a probabilistic model was used. Traffic regulations can be extracted from trajectories, eg no-right/left turns, based on sensors in cars, including on brakes, blinkers, motor characteristics, energy consumption. Drivers display similar behaviours hence rules can be extracted, trajectories clustered and patterns found. This could assist traffic planners to review rules. Interpreting a typical behaviour can also be achieved eg, when a driver is lost, by analysing typical/atypical behaviour. Group patterns can be determined for soccer players. Use constellations of observers to watch sequences of movements every second. Do sequences recur? This is a sequence mining approach but not so easy to interpret. Summary, there are many challenges in analysing trajectories, including data volumes, analysis methods, ownership and privacy.

Thomas H. Kolbe, TU Munich, Germany - CityGML goes to Broadway
He described an open data portal of New York City which has over 1300 data sets available, many in 2D and 3D. No uniform coverage exists or consistent coordinate reference systems. CityGML v2 is a standard. It has been adopted by cities in Europe, Asia but not in USA. The process was to decompose the city data model ontologies and exchange formats. Challenges were in generating the 3D data, road geometries, coordinate systems, huge volumes of data. A processing workflow was developed from the open data to CityGML transformation to produce the 3D city DB, and export the data. The data in feet were converted to metres, DEM was derived from the 3D data, solid building models generated, road models displayed in LOD0 and LOD1. A histogram of road models led to buffering. Road junctions needed to be treated in 3D. There were 3.5 million objects, 1.6 TB data compressed to 79 GB. This is openly available on TUM web site. This is the first open city data of a large city.

Ralf Bill, Univ. Rostock, Germany - Geoinformatics and e-Science
Characteristics of Science – eScience is the science of the future. Data is used by researchers so they need skills in using it, searching for it, applying it, etc. There are various components of eScience – hypothesis and model development, free availability, different data and states of research data, storage, local without being publicly with meta data, archived selected information, virtual research environments. Examples are virtual spatial data such as virtual topographic maps.

Dieter Fritsch's Open Farewell, ifp, University of Stuttgart 'More Than Five Decades of Geodesy and Geoinformatics'
On the Wednesday afternoon a special session was held in recognition of the achievements of Dieter Fritsch who will retire at the end of September. Speeches were given by the Rector of Stuttgart University, and many other academics from the University and well as the PhoWo partners. The true outstanding achievements of Dieter Fritsch were revealed at this session. He certainly has had a stellar career at Stuttgart University, which included Director of the Institute for Photogrammetry for 23 years, but also many administrative roles including Rector and President for 6 years. Very herty congratulations to Dieter Fritsch on an outstanding career.

The full proceedings have been printed and will be available in digital form, as well as slides of the presentations from IPF Stuttgart at http://www.ifp.uni-stuttgart.de/phowo/index.en.html.

The 56th Photogrammetric Week will be held from 11-15 September 2017.

John Trinder, UNSW, Australia October 2015