Event Report

EuroSDR / ISPRS Joint Workshop on Oblique Cameras and Dense Image Matching
by Paul R. T. Newby, Fellow of ISPRS; Editor Emeritus, *The Photogrammetric Record*
Based on a shorter report published in *The Photogrammetric Record*, 30(152) (December 2015)

Well, that was interesting and fun! After all the years of "Remote Sensing and Photogrammetry", this was a real photogrammetric meeting, full of international experts whose main preoccupations still include accuracy, calibration, deformation, distortion, even earth curvature, and, above all, geometry! [This has only taken us from A to G … I could go on.]

The EuroSDR / ISPRS Joint Workshop on Oblique Cameras and Dense Image Matching took place at the Ordnance Survey (OS) Head Office in Southampton, United Kingdom, on 19th and 20th October 2015. Registrants, 95 in number, came from 23 countries, including a sprinkling from outside Europe, and seem to have been considerably more numerous than the organisers and sponsors expected! There was a reasonable balance between national mapping and cadastral agencies (NMCAs), academic R&D and private sector companies. The organisers included Fabio Remondino (President of ISPRS Technical Commission V and Chairman of EuroSDR Commission 1, Bruno Kessler Foundation (FBK), Trento, Italy), Norbert Haala (University of Stuttgart, Germany) and Markus Gerke (Co-chair, ISPRS WGIII/4, ITC / University of Twente, the Netherlands).

After a brief welcome by our host, David Holland (Ordnance Survey), Fabio Remondino introduced the meeting by thanking the sponsors, led by Leica Geosystems (Hexagon Group) and supported also by Aerowest, IGI, Microsoft UltraCam (Vexcel Imaging)), nFrames, Pix4D and Visionmap. Remondino's overview of the past ten years of change in our field set the scene: the improving quality of digital images, the development of oblique multi-camera systems and their acquisition by photogrammetric production organisations in the public and private sectors, innovation in dense image matching algorithms and ongoing changes in production flowlines at the NMCAs. As leaders in R&D responding to these opportunities, ISPRS and EuroSDR have jointly set up two linked "benchmarks", on high density aerial image matching http://www.ifp.uni-stuttgart.de/ISPRS-EuroSDR/ImageMatching/index.html and on multi-platform photogrammetry http://www2.isprs.org/commissions/comm1/icwg15b/benchmark_main.html . These two projects provided the overarching theme for the Workshop. The visual aids used for most of the presentations can be found on the EuroSDR website http://www.eurosdr.net/workshops/eurosdrisprs-workshop-oblique-cameras-and-dense-image-matching .

Remondino went on to chair Session 1, *Benchmarks, oblique sensors and workflows.* Markus Gerke presented preliminary results of the multi-platform photogrammetry benchmark, beginning with a reminder (from Boston, USA, 1860) that oblique airborne photography is not in itself new, but that exploiting it in the 21st century requires a difficult change of mindset after a century of predominantly vertical (now apparently known as "nadir") imagery. It is clear that multiple oblique views, now typically using a "Maltese Cross" or "penta" (five-image) configuration, mitigate the problem of occlusion and can improve height accuracy, especially if far greater overlap (up to 80% both along and across track) can be afforded. The potentially better intersection geometry is yet to be fully exploited and tie point matching between different viewing directions is proving more difficult than expected. A comment from the floor emphasised the difficulty of handling the complex and currently poorly understood distortion effects, including atmospheric effects, compared with the well understood radial and symmetrical case of nadir imagery. Norbert Haala then introduced the benchmark on high density aerial image matching. This is about geometry! The ultimate focus will be on complex urban environments although the first of the three experimental datasets issued for the benchmark covers a semi-rural area; the third goes all the way, over a dense urban area of Zurich and including oblique imagery. The digital surface model (DSM) product is expected to give way to the point cloud, although comments from the floor disputed this. Recognising the excessive

weight of data in any useful point cloud, the potential end product may be a filtered and "meshed" version, perhaps to become known as a digital image model (DIM). [The linguistic purists' battle against the use of "mesh" = German *Masche* instead of the once-preferred but longer English "triangular irregular network" (TIN) seems to have been lost, on the evidence of this meeting, and I am bound to admit that "mesh" now serves a useful purpose.] Mathias Motz and Rene Rothe (Leica Geosystems) then brought the practical perspective to oblique sensors, workflows and information with a masterly and highly informative sales pitch centred on the RCD30 Penta Oblique camera system with five 80 Mpixel CCD camera heads and the HxMap (pronounced "hexmap") production workflow software suite.

Session 2, *Advancements in data acquisition and processing* was chaired by Haala and repeatedly emphasised current progress in the resolution and ground sample distance (GSD) of digital imagery and in the automation of its processing. Konrad Wenzel (nFrames, Stuttgart) led with "Flight planning for city acquisition at high resolution". [We editorial pedants risk losing this battle of words, but in a subsequent conversation I learned that Wenzel is actually very interested in the developing terminology of our discipline and moreover has no wish to acquire cities, only customers and prestige for his young company.] To achieve his aims, his quest is for best practice, balancing quality and productivity: efficient **data** acquisition involves minimising the number of flight lines while providing adequate overlaps for the individual cityscape; efficient processing requires automation with a minimum of manual editing. These points were repeated often throughout the meeting but will not be repeated for successive speakers. Yuri Raizman (VisionMap, Tel Aviv, Israel) introduced his company's "A3 Edge for oblique and dense DSM – practical case study" including the LightSpeed processing suite and example models from Chile and France. Michael Gruber (Vexcel Imaging/Microsoft UltraCam, Graz, Austria) presented "UltraCam Osprey – nadir meets oblique". He emphasised that software is the key technology which enables today's exploitation of the over-100-year-old principles usually attributed to Scheimpflug (one might add: "following Carpentier's British patent of 1901"). He stressed numerous practical considerations from colour balancing, de-hazing and water masking across multiple images, through to the handling of earth curvature, all with the ultimate aim of true 3D (including the space under bridges and arches) rather than conventional 2.5D modelling.

Session 3, *NMCA experiences*, chaired by Francesco Nex (ITC/Twente) brought the first day to a close. Host David Holland presented "Ordnance Survey's experience in creating dense point clouds and 3D building models from oblique imagery". Experiments have been performed using the test area of Bournemouth in order to examine the considerations affecting the possible introduction of such products: what formats do users need; is oblique aerial or even terrestrial imagery really relevant; can data from multiple systems and sensors be economically integrated; can multiple uses (two examples: change detection and specialised information such as street furniture) be drawn from the same raw data or any intermediate or final products; can processes be sufficiently automated to render the products economic? If this point is reached (and without multiple uses and sufficient automation, OS experience to date is negative) how are such products to be stored, managed and filtered for a range of users? This was an enlightening presentation but it is clear that the goal of fully 3D geographical data is still some way from practical, cost-effective, realisation. Dare one introduce the "Holy Grail" metaphor to surveying and mapping yet again, or would that guarantee only a quest without end? Very similar considerations affect Ordnance Survey Ireland (OSi): Andy McGill's presentation "LOD2 from vertical and oblique imagery" again emphasised cost-effectiveness, and therefore automation, in support of the objective of moving from 2.5D to 3D while updating the existing topographic database and eliminating historic legacy issues of accuracy in urban areas of Ireland. Here, in the face of the fickle Irish weather which is all part of the special environment in which OSi must operate, Dundalk provided the test bed thanks to good conditions on the day the chosen system was available. I would add that it remains to be seen whether the Level of Detail (LODx) model hierarchy, a recent borrowing from computer graphics, will stand the test of time in the context of the resolution, style and content of geographical information, or

whether some more directly relevant measure will be devised to replace the traditional and perfectly understood **scale** of maps and vertical aerial photographs.

A pleasant social evening ensued, in the impressive if slightly faded ambience of the Grand Café, originally the splendid ballroom of Southampton's South Western Hotel, where doubtless many of the first-class passengers on the *Titanic* spent their last night on shore in 1912. Little was made of this interesting history by our generous hosts for the evening, Leica Geosystems: perhaps too many negative modern metaphors spring from that ill-fated voyage, but Southampton has learnt to live with its history and prizes its heritage.

As a Hampshire local I returned safely home for the night, and immediately briefed Mrs Newby, who knows a thing or two about oblique aerial photography among other matters, regarding my day. Quick as a flash she asked "so is that the same as the old Trimetrogon?" and "do they fire the cameras simultaneously?" I had to reply "yes, but now there can be up to five cameras" and "funny, nobody mentioned that all day, but I guess they must try to". This exchange provided me with a helpful opening to the discussion in Session 4 next morning, *Advancements in data processing (I)*, chaired by Markus Gerke, in which the first speaker, Lisa Chen (Pix4D, Lausanne, Switzerland) spoke on "An oblique-imagery case analysis of Pix4Dmapper densification result" and **did** mention the need for synchronised exposures as well as rigorous calibration of camera rigs. She challenged our assumptions about flight planning by showing a "multiple circular" flight consisting of a tight series of equal and overlapping circles over downtown Nashville, USA. Pix4D is a software company concerned chiefly (though not exclusively) with surveys using UAVs and digital cameras, each of a wide range of sizes. Chen gave considerable detail on the processes involved in the dense image matching, editing and quality management. In discussion, Mrs Newby's sensible question provoked an interesting range of assertions and detailed responses from the floor, ranging from "exposures must be simultaneous" to "software can take care of any amount of time difference" to "lack of synchronicity greatly weakens the bundle adjustment solution". [For those too young to recall the Trimetrogon three-camera rig (vertical and sideways-looking, extending to the horizon), this was a military reconnaissance tool which was eventually used for the first mapping of vast areas of desert and polar regions. The view to the horizon assisted orientation but rendered the more distant part of the scene otherwise unusable; nevertheless in areas with good visibility and minimal population or detail, the number of flight lines required for preliminary mapping was greatly reduced compared with pure vertical photography.]

Mathias Rothermel (nFrames, Stuttgart) then presented "Oblique image processing in SURE: first experiments and results". He gave a lot of frank detail about stereomatching and "surface meshing" and the challenges involved in making use of multiple images to produce acceptable views of building façades. He became my clear winner for the most entertaining new piece of jargon of the meeting (perhaps of the year to date): "loopy belief propagation". Regrettably I cannot tell you what this means (unless it is simply what we used to call an iterative adjustment process), but I have no doubt that he could. Hans Joachim Benfer (Aerowest, Dortmund, Germany) spoke on "True orthophotos and dense point clouds from multi-perspective aerial imaging – opportunities and challenges in practice", from the perspective of a private company in the real world trying to develop modern products which will actually earn money by finding, attracting and retaining clients. His splendidly detailed and lucid presentation covered the handling of images from the firm's IGI Quattro and Penta DigiCAMs to produce, inter alia, true orthophotos (with roofs placed in correct geometrical relationship to building footprints) and RGB point clouds, both of these being merely by-products of dense image matching. He pointed out that most potential customers do not yet have the software even to allow them to view, never mind manipulate, the amount of data in dense point clouds, and emphasised the age-old need to educate clients in what they can, and cannot, expect to achieve with the products. The disciplines of delivering, storing, backing up and eventually updating the volumes of information now entailed in 3D GIS have yet to be worked out. Automation will eventually reduce the price, speed up processing, render update more practical … and further increase data volume.

Session 5, *Advancements in data processing (II)*, was chaired by David Holland. Jens Kremer (IGI, Kreuztal, North-Rhine Westphalia, Germany) led with "Dense image matching with Penta DigiCAM images – experiences and options". He remarked that his presentation would not chiefly concern data processing but the whole flowline from mission planning through their modular sensor management system to the hardware of aerial sensor systems and mobile mapping solutions. The first of these items becomes far more complex and important where one is aiming to secure the correct overlaps between multiple nadir and oblique images. The camera systems sound impressive and are soon to employ large-format CMOS rather than CCD sensors in order to secure more rapid exposure repetition rates. IGI's eventual data processing module, IGI Match, is powered by nFrames's SURE. He pointed out practical aspects such as the conundrum of how to display five images in sensible orientation; it is not yet clear what clients want, but certainly standardisation is required! Chris Longworth (Blom UK (the former Simmons, then Blom, Aerofilms), Cheddar, UK) spoke on "Experiences with techniques for 3D modelling from oblique imagery in Blom". As former Pictometry franchisees still active in oblique imagery developments and production for city modelling, the company has gained extensive experience, especially in providing multiple levels of detail for navigation purposes. Isabella Toschi (FBK, Trento) then presented "Experiences with oblique datasets: AT, dense matching and building modelling". By using multi-camera bundle block adjustment, she demonstrated the behaviour of different oblique imaging platforms in real-world conditions, including the influence of the additional, oblique cameras on image block generation, dense image matching and 3D building model construction.

The final (and longest) session (6) *R&D and experiences* was chaired by Andy McGill and seemed to become increasingly highly technical and difficult for this reporter to follow. Wojciech Ostrowski (Warsaw University of Technology, Poland) introduced "Quality assessment for dense image matching on oblique images – experience in Poland". Seven Polish cities have been surveyed using IGI Penta DigiCAMs in conjunction with laser scanning, leading to valuable experience of the possibilities and challenges of oblique imagery. Mozhdeh Shahbazi (Sherbrooke, Quebec, Canada) spoke on "From sparse matching based on evolutionary search to dense matching based on intrinsic curves – preliminary results", with the aim of developing UAV-based high resolution imaging and mapping flowlines using photogrammetry and computer vision to generate 3D point clouds for open-pit mining applications. Karlheinz Gutjahr (Joanneum Research, Graz, Austria) continued with the admirably short title of "3D mapping with RSG", the Graz remote sensing software package developed progressively since the 1980s to cover many different kinds of imagery right through to radar interferometry. Now tackling dense image matching using the benchmark datasets, he acknowledged the need for severe "thinning" to deal with the information overload resulting from point clouds derived from oblique images. Finally, Willi Karel (TU Wien, Austria) presented "Analysis of oblique image datasets with OrientAL". As another true photogrammetrist taking part in the image orientation benchmark, his preoccupation with the elimination of blunders and outliers enters new territory with the excessive numbers of tie points generated by multi-image datasets; the mixture of nadir and oblique images means that "tiepoint decimation" is by no means straightforward nor easy to automate.

Fabio Remondino brought the successful meeting to a close by proposing continuing ongoing collaboration in the run-up to the next two relevant meetings, EuroCOW which will be held in Lausanne for the first time (February 2016) and the ISPRS Congress in Prague (July 2016). The tradition of EuroSDR / ISPRS joint meetings is clearly alive and well, as is the Ordnance Survey's support for them, which incidentally enables participation by a significant number of OS staff, who would clearly not have this opportunity to attend meetings elsewhere in Europe in such numbers. The visitors in turn greatly appreciated the generous hospitality and welcome provided by OS. I became quite nostalgic for the corresponding event, on Updating Digital Data by Photogrammetric Methods, which, as a member of Ordnance Survey at the time, I was privileged to organise at Christ Church, Oxford University in September 1991.