FIG Working Week, Rome Part 2
Laser Scanning, Geodesy and Monitoring

In this, the second part of GW's review of the papers presented in Rome, **Richard Groom** focuses on laser scanning, geodesy and monitoring. The full papers can be downloaded from http://www.fig.net/pub/fig2012/techprog.htm

Datums and reference frames

With GNSS it has become possible to measure geodetic positions and the velocity of their movement due to tectonic effects with very high accuracy. Whilst this is immensely useful for scientists, it poses a dilemma for survey folk. How do we deal with the fact the every control point is moving with respect to the international reference frame? Several sessions at FIG Rome discussed this and other geodetic problems.

Peterson and **Sarib**'s paper "A New Geodetic Datum for the Northern Territory" (TS1B) looks at Australia's Northern Territory where there has been considerable investment in GNSS infrastructure both in the establishment of national continuously operating GNSS stations and territory-wide and local networks. They are now able to define a new accurate datum and see many benefits in this approach. Their argument is that customers will soon want centimetre level positioning, but clearly it is not practical to be forever changing the coordinates of points on the ground which, so far as most users are concerned, are not moving. The paper goes over the issues in detail and even puts a monetary value on the geodetic improvements – $3.5m.

TS02B featured a paper on dynamic datums by **Kevin Kelly** from Esri. The company is developing software to enable data from different ITRF epochs to be combined. The author points out that in this field, there is also a need for standardisation and that GIS is the obvious platform both for calculating transformations and for applying them.

Also in TS02B, **Stanaway** et al link international, regional and local reference frames. Secular movement can be expressed using a 14 parameter transformation: scale, translations and rotations with their velocities. But in this paper, the authors present a technique using nested grid (patches) to model local deformations caused by seismic events, where high resolution grids are used near active faults. This was also the subject of a paper in TS07L by **Grant** and **Crook**.

Monitoring

TS01F focused on dams. **Marco Di Mauro** and **Joel Van Cranenbroeck** stressed the value of co-locating deformation monitoring sensors, which measure the geometry of the outside of a structure with met sensors and geotechnical sensors measuring the inside. **Maria Henriques** et al, described the use of optoelectronic tilt sensors to measure inclination in the Cabril Dam, in Portugal. Measurements were made in conjunction with a temperature sensor. **Sunantyo Tarsisius** et al from Indonesia described the design and installation of multi-sensor equipment on Sermo Dam, Yoygakarta, Indonesia. The dam is measured using a combination of continuously operating GNSS receivers and a total station observing to prisms on the structure. In this case one GNSS station is co-located with the total station and the other with a back-sight reference prism.

Artur Adamek et al, looked at the possibilities of using laser scanning for inspection of concrete water dams. They concluded that laser scanning is currently only suitable as a supplement to conventional and photogrammetric methods of measurement. However, they see the laser intensity as a useful means of studying the condition of the concrete.

A major difficulty with monitoring is assessing what observed movement is significant. **Seyfullah Demirkaya** and **Muhammet Balcilar** from Turkey described how artificial intelligence can be used for this purpose. In an example they describe how, during a nine-year period of dam monitoring, the first seven years were used as a 'train and validation dataset and the following two years were treated as 'test' datasets. A comparison of the predicted model with actual observations in the test years showed a remarkable correlation.

In TS05F **Ceylan** and **Ekizoglu** described the creation of a "Dam Information System". The GIS holds bathymetric data as well as water temperature, dissolved oxygen, pH and water clarity in the water body and geology and vegetation around the lake.

Mining subsidence was a popular topic. **Hakan Akcin** et al (TS01F) describe the use of InSAR and GNSS to monitor ground surface subsidence arising from coal mining. The InSAR data came from the PALSAR and RADARSAT satellites. PALSAR uses L-band microwaves, which are less affected by vegetation and atmospheric effects than the C-band microwaves used by RADARSAT. This makes it easier to provide high coherence between master and slave images in densely vegetated areas. Unfortunately comparisons were made at different epochs so it is difficult to draw solid conclusions. The paper also mentions the value of contoured subsidence plots for planning the orientation of buildings. Along the contours is good, perpendicular to the contours is asking for trouble.

In TS03F, **Adrian** and **Gheorghe Radulescu** propose a "Structural Monitoring Handbook". It is a practical and useful read for anyone working in that sphere. Also in this session were a number of useful deformation monitoring case studies and a paper by **Zhang** and **Schwieger** who explore the possibilities for monitoring using low cost GPS receivers and communications via a

> *"... customers will soon want centimetre level positioning..."*

wireless mesh network. They report some encouraging preliminary results.

In TS05H, **Needham** and **Dash** describe the use of photogrammetry (with a Canon EIS 1000D DSLR camera and PhotoModeler software) for deformation monitoring of a destruction test on an overhead power line tower. Precision is in the 2–5 mm range.

In TS08B, **Bo** et al, show how crustal deformation can be monitored precisely with levelling and GNSS to give some advance warning of earthquakes. **Radicioni** (Italy) et al, compare long-term GNSS and SAR data for deformation monitoring of the Assisi landslide. GNSS can of course measure deformation in three dimensions whereas InSAR measures only the component along the line of sight to the satellite. The researchers calculated the line of sight component from the InSAR data. There is broad agreement, but they will be extending the research into other areas and comparing with levelling data.

In TS09I, **Frukacz** looked at the calibration of precise levelling rods: perhaps the driest of dry subjects! One interesting point though is that the mean error in determining the coefficient of thermal expansion is much lower for new barcode staves than for "classical rods in a wood lining". The author describes some anomalies, including a rod with positive corrections for readings up to 1.5m and negative corrections above 1.5m. The cause, he suggests, is deformation of the aluminium body of the levelling rod caused by fixing handles.

Guillaume et al, take us into the world of metrology for particle accelerators. QDaedalus is a total station modified so that the eyepiece image appears on a CCD sensor instead of a human retina. The instrument is trained to recognise targets so that it can operate without human intervention. QDaedalus is one of several methods used and described in the paper. Remaining at the precise end of the geomatics spectrum, **Meier** et al describe the use of hydrostatic levelling to monitor 192 high precision level sensors distributed around the circumference of the Swiss Light Source (SLS) accelerator simultaneously. The real-time results are used as a monitoring tool for re-alignment of the SLS.

In Session TS02F there were two papers on the lab measurement of beam deformation under load. **Ioanna Chounta** and **Charalabos Ioannidis** use an automatic photogrammetric technique while **Xiaojuan Qi** and **Derek Lichti** use range cameras (Swiss Ranger SR4000). A single range camera can perform 3D measurement of entire surfaces, they are compact and their cost is an order of magnitude less than a laser scanner. With the increasing use of non-metric cameras, lens calibration is important. **Pinar Karakus'** paper in TS02F was on the evaluation of distortion error using fuzzy logic.

Laser Scanning

In TS03D **Reiner Jager** et al describe SImulation of Multisensor Arrays (SIMA) software for the development and validation of algorithms for GNSS and MEMS based multi-sensor navigation platforms. **Winne Shiu** and **Kam Biu Tam**, from the Hong Kong Housing Department, describe a pilot study using mobile laser scanning to survey potential and existing housing projects. The system is not mobile in the accepted sense because there is no IMU and data is collected when the scanner is stationary. The system was tested when mounted on a car, scooter and even a roving person (see Figure 1). They concluded that the technique is suitable (with limitations) and in particular in providing source data for tree surveys.

Figure 1: The surveyor as a one-man band.

In TS07A **Bertacchini** et al describe the results of their investigations into the use of laser scanning to monitor landslides. They used total station and radar observations for comparison and conclude that laser scanning can be used for analysing slope instability. **Harmening** et al, consider the use of least squares co-location to determine a trajectory observed by GNSS and compare this method with other interpolation methods. **Sebari** and **Moutaouakkil** consider the use of laser scanning for volume calculation and compare with observation by total station. Laser scanning wins!

In TS08C, **Castagnetti** et al, use laser scanning to analyse the structure of Modena Cathedral. The survey revealed geometric anomalies which helped with the interpretation of previous deformation monitoring surveys. They used a Leica ScanStation2 and scan resolution of 8mm. Registration was carried out using at least three targets in each scan with the aim of achieving sub-centimetre accuracy in the overall 3D model. Verticality was analysed by cutting sections out of the model where required. Tilting of the outer walls and columns has been confirmed by comparison with the results of periodic precise levelling over 27 years, of monitoring points around the cathedral.

> *"Along the contours is good, perpendicular to the contours is asking for trouble."*

Chow et al, investigated the accuracy of the Faro Focus 3D and the Leica HDS6100 scanners (see Figure 2 over). They use the 'self-calibration' approach to determine systematic errors which they state "can drastically deteriorate the point cloud quality". Comparison showed what the authors describe as "significant systematic errors" in the Focus 3D. Even after self calibration, random noise is still higher than in the Leica instrument.

Hancock et al use laser scanning to detect fire damaged concrete. The results of their

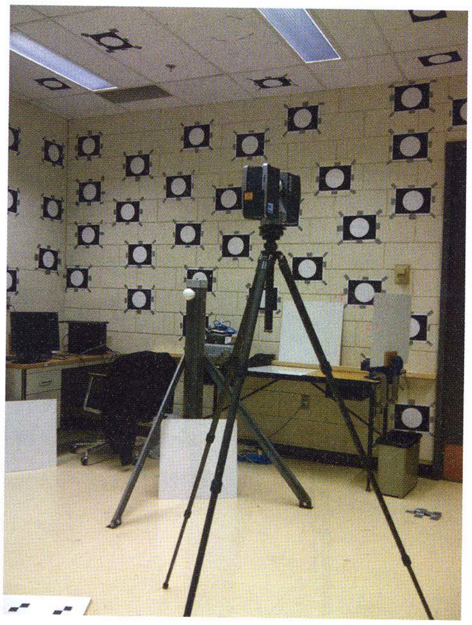

Figure 2: Laser Scanner Calibration Room.

> *"...the US is moving towards a datum realised through GNSS."*

preliminary experiments indicate that the intensity of the return signal might be used to determine the temperature to which concrete has been heated during a fire and assist in assessing structural damage.

Height

TS04B includes papers by **Avsar** and **Ustin** on analysis of the GRACE satellite's ten-day gravity data for analysis of mass changes within the Earth and water and ice on the surface. **Halicioglu** et al describe the use of a vertical zenith camera for determining astro-geodetic vertical deflections in Turkey and most obscure of all is a study of Stoke's kernel by **Rabehi** et al. However, with feet more firmly on the ground, the session also featured two papers on the North American Height Datum. Both **Shields** and **Gallagher** and **Roman** and **Weston** describe how the US is moving towards a datum realised through GNSS. Canada is going to adopt the resulting new datum in 2013 but the US will continue to collect gravity data with a view to publishing a centimetre-level geoid model in 2022.

In Session TS04K **Hanna** and **Bell** describe the use of discontinuous tide gauge records to determine sea level rise in New Zealand. They compared these with the continuous records maintained at the country's four main ports and found that the trends are consistent at 1.7 ±0.1mm per year.

Davis et al, describe the use of satellite altimetry to determine and monitor sea level in the Caribbean. The sea surface determined in this way has to be corrected by applying models of tidal variations, atmospheric pressure loading etc. To achieve sub-millimetre accuracy for annual rate of sea level rise, the authors acknowledge, is a challenge. When tested at tide gauges, the mean sea level generally agrees to 2cm with 5cm RMS. However, satellite altimetry works best in the open ocean, so the authors are looking at a means of integrating it with tide gauge data (see Figure 3). **Dodd** and **Mills** describe FIG work on establishing 'best practice' for ellipsoidally referenced hydrographic surveying. Separation models linking the ellipsoid and chart datum are proving to be the greatest challenge: challenges that have been overcome in the UK by the development of VORF and in the US by Vdatum.

UAVs

TS04H included a number of papers on data capture using Unmanned Aerial Vehicles (UAVs). **Dominelli** et al describe using an 8-rotor helicopter to record damage following the L'Aquila earthquake and production of photogrammetry. **Arthur** et al presented a method for automatic generation of orthophoto mosaics using the Scale Invariant Feature Transform (SIFT) approach to overcome difficulties that many commercial systems encounter with automatic image matching using UAV imagery, due to high variability between scenes. **Sun** et al have been working on integrating GPS, pressure and low cost IMU MEMS sensors on board small UAVs. At present computing capability on the UAV limits what can be done.

GNSS

In TS05B, **Blick** and **Donnelly** ask if it is possible to entirely replace the role of passive survey control stations with CORS in the context of the recent earthquakes in New Zealand. For a summary on the latest developments in modernisation of global GNSS services, refer to a paper delivered by **Lau** and **Roberts**. The paper also covers simulation tests including the new constellations and GPS frequencies. **Mader** et al describe the upgraded OPUS online positioning service, known as OPUS-Projects and **Maras** et al describe an online processing service called Selcuk, which they have tested using IGS station data. Finally in this session, **Martin** and **McGovern** (Ireland) presented a report on the performance of the Irish Network RTK services, which is essential reading for surveyors working there.

In TS06E, **Cranenbroeck** and **Lui** analyse the factors that cause CORS networks to succeed or fail. They take a high-level view of the products and ask various questions regarding the economics and sustainability of the technology, including the 'threat' posed by precise point positioning (see also *Precise Point Positioning v. GNSS*, *GW* September/October 2012).

In TS07H, **Kallio** et al look at GNSS antenna calibration. It is generally assumed that the published antenna calibration values for a particular model of antenna can be used for the individual antennas but, following an experiment using individually calibrated antennas from two manufacturers, the researchers found that there were residual errors, particularly in the L2 height component, of several millimetres. Their preliminary conclusion is that the differences are down to the 'near field' effect, caused by the difference between the antenna mounting used in lab calibration and the concrete pillars on which the antennas were mounted for the experiment.

Baiocchi et al describe an innovative method for GNSS data processing which they call a "multiconstellation" approach. The premise is that, by using GPS and GLONASS satellites, there are now sufficient satellites to divide the available satellites into two groups and use one group to compute baselines out from one station and the other to compute independently the remaining baselines in the network. Under current operating procedures, two observing sessions would be required to measure all available baselines, so there is potential time saving with the multiconstellation approach.

Zhang looked at surveying accuracy in terms of cost-benefit. For engineering applications it is reasonable to assume that higher accuracy surveying will result in higher surveying costs but lower engineering costs, but is the surveying cost less than the engineering benefit? An interesting question that is well worth exploring. **Zou** et al, describe the development of a GNSS receiver that can record data from a number of antennae, thus potentially reducing the cost of GNSS monitoring networks.

Session 09B was devoted to Precise Point Positioning (PPP). *GW* covered this in our last issue, in an edited version of a paper presented in Rome by **Chris Rizos** et al. **Vladimir Seredovich** et al from the Siberian State Academy of Geodesy gave a paper on GNSS precise point positioning (PPP) in Nigeria. With dual frequency and carrier phase observations standalone receivers can achieve post-processed positioning using the precise ephemeris with centimetre to decimetre accuracy. The authors used the technique to compute a survey station on Nigeria's Jebba Dam by submitting their data to the on-line GNSS computation sites, AusPOS and CSRS. The results agreed to within a few centimetres. A Trimble TRM41249 antenna was used to collect one-second data for six hours. The paper concludes that surveyors in Nigeria should embrace PPP instead of using existing geodetic control.

Alcay et al report on their investigations into the use of GPS with GLONASS for PPP using the magicGNSS web-based software for processing. They conclude that the addition of GLONASS observation data improves positioning quality. **Elsobeiey** and **El-Rabbany** introduce an improved PPP model which rigorously accounts for all GPS errors and biases including second-order ionospheric delay. In particular, they found that the NOAATrop model for tropospheric signal delay is superior to the widely used Saastamoinen and Hopfield models. **Sanlioglu** and **Kara** have analysed data for four IGS CORS and observed that the time series of the height component shows an annual variation which is proportional to temperature and inversely proportional to pressure.

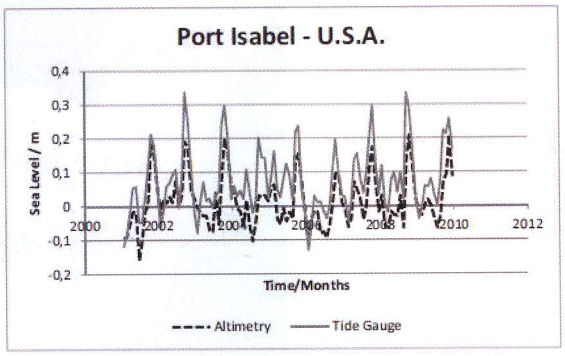

Figure 4 (a)- Sea level anomalies averaged over a month for Port Isabel 2001 – 2010 (Jaggan and Davis, 2012)

Figure 3: *Sea level anomalies averaged over a month for Port Isabel 2001-2010.*