The evolution of stereo photogrammetry

by Harald Krahmann, HK Consulting

The evolution of photogrammetry remains an extremely interesting subject in spite of the fact that computer technology, software engineering and image processing today carry the image of progress. A bit of reminiscing on how today's state-of-the-art photogrammetry came about should therefore do no harm in our hasty times where the past is so quickly forgotten.

Reflecting on the past will be of more meaning to those who have lived closer to it than the younger generation of today who have to stand their ground and look ahead in a highly competitive professional market where keeping up with technological progress is the name of the game. But in this context, we should not forget our historical ranking in the international photogrammetric community, which can be traced back to Dr. H G Fourcarde who, with his intensive research into stereo photogrammetry, left his mark in the history of the profession.

His historical camera and stereo comparator can still be viewed at the University of Cape Town. Moreover, in later years, the participation of many overseas VIPs at our numerous CONSAS (Conference of South African Surveyors) conferences in Durban, Cape Town, Johannesburg and Salisbury (Harare) also bears testimony to our high international ranking.

Photogrammetry in the sense of the word refers to extracting measurable information from photographs, be it for topographic or terrestrial surveys, cartography or in architecture and astronomy. Photography as such was invented in 1839 but it took until 1858 for the first aerial photograph on record to be taken from a balloon.

Already in 1833, it had been realised that three-dimensional perception was due to a parallax effect resulting from comparing the views of an object under two different angles, hence our own three-dimensional perception. At first photo theodolites served topographical surveys particularly in difficult mountainous terrain. Then in 1915 Dr. Oskar Messter, the co-founder of Zeiss Aerotopograph, presented the first aerial camera designed for taking series of aerial photographs with a selectable forward overlap.

The evolution of aerial cameras

Progressively optics were improved with regard to resolution, aperture ratio and chromatic correction and distortion. In the early sixties, a distortion-free aerial camera lens with less than 4 microns distortion brought a significant increase in the accuracy of block triangulation and plotting. Then forward motion compensation (FMC) was introduced to eliminate residual image blur. The introduction of a precision grid plate into the camera optics to serve as a stringent reference was established, but did not find general acceptance. Also automatic exposure control was provided.

The problem of camera orientation with regard to verticality of the optical axis at the instant of exposure saw many attempts to a solution such as a supplementary Horizon Camera and the coupling to a gyroscope. Eventually the answer was found with a gyro-stabilised camera mount, which soon became a standard requirement. Then there was of course the introduction of the global positioning system (GPS), which substantially improved aircraft navigation during flight missions.

The industry eventually settled for a standard photo format of 23 x 23 cm together with a 15 cm wide-angle camera lens. The original format was 18 x 18 cm, but even a format of 30 x 30 cm had been realised. At one stage, however, also super wide-angle optics came into use to provide for larger cover and to save on ground control for aerial triangulation.

In this context I might mention a rather unique local project in which I was directly involved. It concerned the combination of three 60 cm long focal length RMK 60/23 cameras in tandem...
Incidentally, in 1983 a standard RMK 30/23 was the first camera in outer space on board the Columbia Space Shuttle from where it took a first series of some 1000 colour and infrared colour photographs of the Earth’s surface from an altitude of 250 km. At the extremely small scale of 1:183 000 a resolution of 20 to 30 m on the ground was established, at the time a remarkable achievement although not comparable with today’s high-resolution satellite imagery.

**Analogue plotter solutions.**

A single photograph is always a two-dimensional presentation of detail in a central projection. It is affected by focal length, camera tilt, lens distortion and of course, in aerial photography a terrain-dependant variation in scale. With rectifier projectors, tilt and scale can be controlled but not the central projection. For establishing cartographic control points from large photo mosaics, a slotted template method was developed as a first attempt at aerial triangulation from large blocks of aerial photographs. It was an ingenious way of overcoming, at least partially, the problem of perspective distortion by meaning the position of specified control point from four overlapping photos.

When viewing two overlapping photos with an overlap of usually 60% in a stereoscope, plotter or projector, a three-dimensional stereomodel is observed. The orientation of the photos relative to each other and the subsequent absolute orientation of the resulting stereomodel to known ground control points, presented an intricate challenge to many an instrument designer. An exciting era began with many ingenious designs of plotters seeking a mechanical solution to the complex problems.

The most elaborate of these was an opto-mechanical solution realised in the concept of the Zeiss Stereoplanigraph. In practice, however, a less costly mechanical space rod solution found preference and dominated the market. Stereoplotters were classed in first and second order where first order models provided for ‘base in - base out’ observation to facilitate strip-wise aerial triangulation for subsequent block adjustment with relevant software programmes.

The origin of precision stereo photogrammetry can be traced back to the introduction of the Stereo Comparator in 1901 by Carl Pulfrich from Carl Zeiss in Jena and simultaneously by Henry Fourcade at the University of Cape Town as already mentioned. The concept found wide application not only for cartography but also in architecture and astronomy. In later years, the design was perfected by adding grid plates, the ability to serve as a reference and electronic data capturing functionality. In this way it became an instrument of highest precision for aerial triangulation. A first of these, a Zeiss PSK Precision Comparator was acquired by the then Trig Survey Office in Cape Town.

The orthophoto era

All along the conversion of the central projection of a photograph into an orthogonal projection, as required for mapping, posed an unresolved problem until Zeiss presented their first GZ 1 Orthoprojector at the ISP in Lisbon in 1964. The problem was solved by scanning and reproducing an oriented photograph in narrow 4 mm parallel strips at an equalised scale that were continuously varied to match the relevant height above ground.

This was achieved by synchronising the travel of the floating mark in a stereoplotter with the exposure slit of the projector in a meandering path allowing the operator to continuously vary the scale of projection by keeping the floating mark in the coupled stereoplotter to the ground. In this way, a uniform projection scale was achieved, thus voiding the effect of perspective obliquity. The resulting orthophoto resembled
a map in true scale while at the same time also showing all photographically resolved detail.

For the operator it was a strenuous task to continuously keep the floating mark on the ground. This technology opened a complete new era in photogrammetry. A first test run was conducted by Dr. Brucklacher from Zeiss and covered the steep slopes of Devils Peak in Cape Town. It was a formidable task successfully mastered. I might add that I was subsequently instrumental in providing the local industry with four GZ1 projector systems in different configurations in the years that followed.

The analytical era

It might seem odd but photogrammetry originally sought mechanical solutions to bypass tedious survey calculations. This changed drastically when computer technology and electronic hardware advanced to a stage where an analytical concept, as had already been visualised by Helava in 1957, could be realised.

In this concept the plate carriers were no longer tilted but were moved horizontally by servo drives into x and y positions relating to the floating mark and simultaneously considering orientation and correction parameters. These parameters were established with photogrammetric software routines forming part of a fully computerised system.

The analytical era started in earnest with the ISP in Helsinki in 1976 where several solutions to such a new system were presented with the Zeiss Planicomp C 100 in the forefront. One of the first of these on our continent was acquired by the Orange Free State roads department in 1980. The analytical approach also found application in the extremely complex design of the Zeiss Z2 Analytical Ortho Projector. It was a standalone instrument with the systematic strip exposure and all relevant orientation parameters controlled analytically and thus not requiring the continuous assistance of an operator.

The digital era

A first step towards truly digital photogrammetry was the introduction of precision scanners to digitise aerial photos in a high resolution for subsequent digital processing on relevant workstations. The processing of vast amounts of data today seems to have no restrictions with the ever-increasing power of computers and so there seems no end to the development of further comprehensive processing systems, be it for geographic information systems (GIS) or any other practical application.

In the meantime, a substantial number of digital cameras of various concepts are in practical use. In addition, digital satellite images are readily available. New technologies such as light detecting and ranging (lidar) laser scanners and side-looking airborne radar (SLAR) have found their niche in the market. We have come a long way from the first bird's-eye view photographed from a balloon in 1858 to today's satellite imagery. However, photogrammetry remains a fundamental cornerstone for most new technologies, in spite of more descriptive terminology in use such as image processing, GIS and geomatics.

Contact Harald Krahmann, HK Consulting, Tel 011 792-8491, krahmann@deunet.co.za

Fig. 5: The auditorium at the first Conference of South African Surveyors at Natal University in Durban.