

DIGITAL PHOTOGRAMMETRY AT THE SURVEY DEPARTMENT  
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**Summary**

The Survey Department in the Netherlands has continued to experiment with new photogrammetric techniques and systems since their successful GPS flight in Flevoland. This has resulted in the purchase of the DCCS system of Helava associates inc., a successful GPS laser test with the University of Stuttgart, practical experiments with existing digital matching techniques and the development of a GIS-prototype based on (future) digital photogrammetric products. This paper presents the results achieved on these topics, the practical experience gained with the DCCS system and the expectations of digital photogrammetry with respect to efficiency improvement and product innovation.

**Keywords:** Digital Photogrammetry, GIS

**Introduction**

Taking into consideration the number and variety of papers which have been published on the subject of digital photogrammetry, following the 16th ISPRS congress in Kyoto in 1988, we can only conclude that digital photogrammetry has made a major breakthrough. The content of these papers however mostly are focused on the theory of a digital photogrammetric technique, on the expected benefits and disadvantages of digital photogrammetry, or on the functionality and performance of commercial digital photogrammetric systems. With a few exceptions (Newby, 1991, Colomina 1991), the implementation and experience with digital photogrammetric systems in a commercial surroundings is rarely discussed. The Survey Department of the Ministry of public works, water management and transport has gained theoretical and practical experience with one of the precursors in digital photogrammetric systems, the Digital Comparator Correlator System (DCCS). The Survey Department is involved in a test on stereo matching techniques. Several institutes and companies were asked to participate and to test their matching algorithm on aerial photography of poor quality, namely a stereo model of the coastal area of the Netherlands. This stereo model consists of a sandy beach and dunes with marrow vegetation. The institutes are asked to generate a digital terrain model using their matching algorithms. The relative accuracy of the results and the absolute accuracy in comparison with a manually measured digital terrain model will lay the base for further research. The Survey Department also participates in research on the automatic extraction of roads in scanned aerial photography (De Gunst, 1991). In February 1990, a severe storm passed the Dutch coast. Lack of DTM overage of the dutch coast (length of 300 kilometres) complicated a fast assessment of the damage because the arisen bottlenecks

were not exactly known. An extra photographic flight and the current elaboration techniques would take too long. The coastal area of the Netherlands is almost every year harassed by severe storms. Keeping in mind the flood of February 1953, which cost the lives of 1835 people in Zeeland, and resulted in the construction of the delta works, the possibility of monitoring of the Dutch coast is desirable.

Recent developments in automatic DTM generation and Laser-altimetry, give well-founded hope that a faster procedure to monitor the coastal zone will become possible. Anticipating to the future developments in digital photogrammetry, a Coastal GIS-prototype has been developed.

This paper focuses on the experience which the Survey Department has gained with the DCCS-system and other new photogrammetric techniques, and our future expectations and demands of digital photogrammetry.

**Digital Comparator Correlator System (DCCS) at the Survey Department**

The Digital Comparator Correlator System (DCCS), designed for automatic aerotriangulation was already presented at the 1987 Conference on Fast Processing of Photogrammetric Data, in Interlaken (Helava, 1987). Therefore, the DCCS is a system designed for specific applications, with high performance and limited functionality (see also Dowman, 1991).

Together with the DSP1 system of Leica, the DCCS-system can be considered as precursors in commercially available digital photogrammetric systems. Hardware and software of the DCCS-system has been

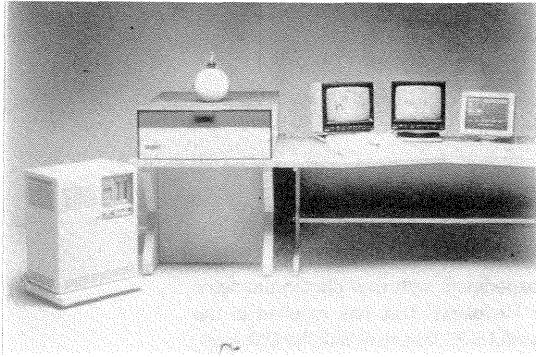


Figure 1. DCCS system

described in (Helava, 1988). Unlike fully digital systems, the DCCS-system consists of mechanical parts, namely a monocomparator. In contrast with the DCCS version of the Ordnance Survey (GB), the CCD-camera's are fixed to the comparator. The pixel size of the sensor is 0.014 x 0.017 mm. The X,Y-stage is movable on indication of a planning algorithm. With the earlier version of the DCCS, a diapositive was put on a fixed glass plate, while the ccd-camera's were driven to a specified position. This alteration and the detachment of the comparator from the main work-table has been made in order to stabilize the comparator. Another significant change in hardware has been made on the light source. The digital photogrammetric techniques for tie point selection and measurement (the interest operator), and for tie point matching (Hierarchical Correlation Relaxation, HRC) directly use the grey values of the digitised image segment. Optimal image quality therefore is necessary to ensure the performance of the digital photogrammetric techniques. A uniform light source illuminating the mensuration area is mounted above the input stage. This light source is an integrating sphere providing 98 % uniform light at its 2" diameter output port. The light is provided by a quartz-halogen light source introduced to the integrating sphere through fibre optics. The Survey Department already became interested in the DCCS system in 1989. This resulted in a practical experiment which Helava performed on a representative set of 1:5.000 aerial photography. In 1991, based on satisfactory results, we decided to perform a more extensive experiment of three months with the DCCS system. Several conditions were formulated to which the system had to meet:

- One photograph can be processed within 30 minutes.
- The overall accuracy must not exceed 6 microns RMS.

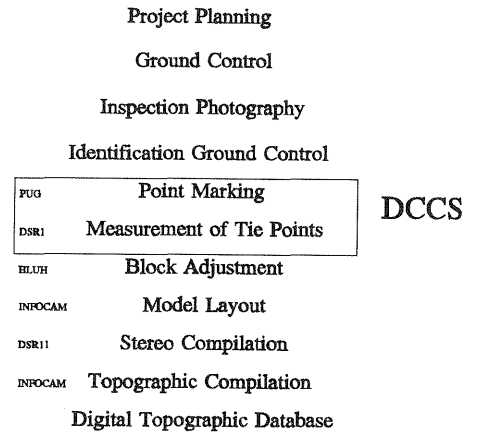


Figure 2. DCCS in the production process of the Survey Department

- Colour photography should not be a limitation.
- Strips with different angles can be processed.
- Aerial photography of poor quality can be performed without significant problems.

The DCCS was expected to replace our current triangulation process, which consisted of the selection and marking a tie point with a Wild PUG, and measurement of its stage coordinates with a Kern DSR1 analytical plotter (figure 2).

During the tests of three months, no serious problems occurred, but for an electric wire which was pinched because of the movement of the x,y-stage.

In these three months, both black & white and colour photography of good, average and poor quality (beaches at low tide !) were processed. In general, 1:5000 scale photography was used. The selected photogrammetric consisted of parallel and perpendicular strips.

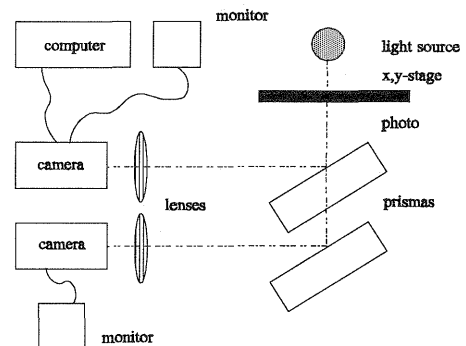


Figure 3. Monocomparator with light source and CCD-camera's

The results show that:

- The overall accuracies varied between 5.7 and 7.7 microns RMS.
- One black & white project of 90 photographs in 6 strips was processed at a speed of 4 to 5 photographs per hour.
- Colour photography were processed without serious problem at a speed of 3 to 4 photographs per hour.
- Aerial photography of poor quality and strips crossing at any angle do not raise significant problems.

The RMS of the y-parallax (after BLUH bundle block adjustment, without robust estimation) frequently exceeded the set condition of 6 micron. Downloading of the aerotriangulation results showed parallaxes between 0 and  $\frac{1}{2}$  of a measuring mark in an analytical plotter. These parallaxes still offer the operator the required stereoscopic view for further processing.

The single framegrabber of the CCD-camera digitizes small parts of the analogue colour photograph into digital image segments. The grey values of the digital image segments have a limited range. While a colour photograph consists of several photographic emulsions, digitization of colour photography using a single framegrabber degrades the image quality, degradation of the image quality slightly delays the DCCS-performance.

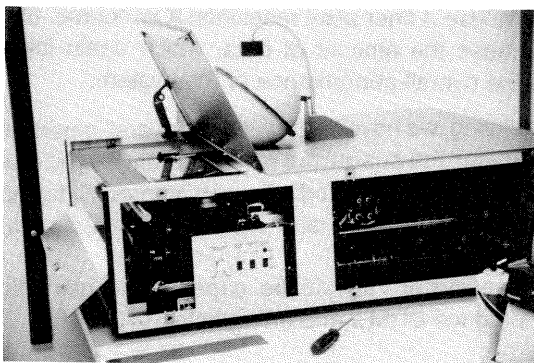


Figure 4. DCCS monocomparator with CCD-camera's and light source

The quality of the photography is decisive for the performance of the DCCS. It often occurs that DCCS-results from excellent photography in one strip are brought down by blurred photography in the next strip. On several occasions, different printing of photography might have improved the final results considerably. The DCCS functionality only covers 5 percent of the

overall production process at the Survey Department. The efficiency improvement, which can be obtained in comparison to the traditional procedures was rather impressive. As a result, the Survey Department decided to purchase the system at the end of 1991. At the beginning of 1992 the system was implemented in our production division.

#### Efficiency improvement with the DCCS

In comparison to so called fully digital photogrammetric systems, the DCCS shows some significant differences. Fully digital systems lack any opto-mechanical parts. The DCCS system however uses a highly-accurate monocomparator and two CCD-camera's, which requires the system to become calibrated once in a while. Fully digital systems process digital images, like satellite, airborne scanner images or scanned photographs. The DCCS-system uses one of the CCD-camera's to scan parts of the diapositive. Though it is possible to scan the full diapositive in black & white at a resolution of  $14 * 17$  micron (resulting in over 200 megabyte of data for a  $23 * 23$  cm photograph), in view of a faster throughput, only small patches of a diapositive are scanned.

What are the causes for the outlined efficiency improvement? During the test period, it became clear that fully automatic aerotriangulation with the DCCS is not possible. A fully automatic procedure frequently yield mismatches tie-points which are not usable in the following analytical process. A semi-automatic mode was chosen to be suited for our production process (Appendix A.). The obtained efficiency improvement in the semi-automatic mode, is caused by several factors. First, the time-consuming marking of tie-points on the photographic material can be skipped. Of course, this requires that an analytical plotter is used for further (stereo) compilation. This condition was easily met since the Survey Department has twelve Kern analytical plotters at her disposal.

Next, relative orientation, which normally is carried out by measuring significant terrain features in order to accurately measure the individual tie points, can be skipped. With the DCCS-system, selection of a candidate tie-point which already occurred in the last photograph is simplified by switching between the tie-point image of the current and previous (stored) photograph on the same monitor. In the next strip of a photogrammetric block, corresponding tie-point images of the previous strip are automatically loaded. The tie-points between strips are measured in a similar way as the tie-points within a strip. As a result, the DCCS will yield a stronger photogrammetric block with each tie-point measured in one uniform manner.

Finally, the operator is continuously able to evaluate the result of the individual measurement and the quality of the measured tie-point. A number indicating the strength of an automatically measured feature or the figure-of-merit of a match, is display on the alpha numeric monitor. During a triangulation project, the measurements of each tie-point can be compared and corrected using multi-image matching (adaptive least squares matching).

#### Requirements for a digital photogrammetric production process

As described in Dowman (1991), compared with an analytical plotter the DCCS-system is a digital photogrammetric system designed for specific applications with limited functionality but with high performance. One should therefore consider the DCCS to be one of several digital photogrammetric systems in a digital photogrammetric production process. The complete photogrammetric production process on one system does not seem to be useful, especially in larger companies.

The results of aerotriangulation lay the foundation for further stereo compilation. The DCCS can fully scan a photograph in black & white. The black & white digital images, together with the orientation parameters, can be directly input for automatic DHM generation and for black & white orthophoto generation.

The DCCS itself cannot be used efficiently for DHM-generation due to the limited number of elements per photograph which can be measured. Automatic measurement of DHM's, together with aerotriangulation, are two parts of the photogrammetric process, which, from the point of view of digital image processing, do not require the skill and experience of an operator (Ackermann, 1991). Several experimental results show a reliability of 80 %. The unreliable measurements have to be corrected on-screen by the operator.

Observation and correction of the corresponding terrain objects in the DCCS system should be performed by switching between the left and right image on one monitor. For the assessment of Digital Height Models (or Digital Terrain Models, although in general height information automatically generated do not take account for vegetation or man-made objects) and for stereo compilation, stereo viewing of the scanned stereo photography is essential. At several exhibitions high resolution monitors with stereo-viewing capacity are demonstrated. Its techniques vary from split screen (DSP1, DVP) to polarizing screens (and glasses, HAI500) or image shuttering techniques (ImageStation). Experiences of photogrammetric operators with

digital stereoscopy are unknown to the author but will become a decisive factor for its success.

The use of high resolution imagery immediately implies the necessity of mass computer power and huge data storage. These hardware requirements do not seem to raise any problems in the near future (see also Ehlers, 1991). Outstanding workstations of 1992 (MIPS and FLOPS is the new nomenclature) will be degraded into slow machines within a couple of years. A hard disc of 600 megabyte to one Gigabyte is almost standard nowadays. However, one stereo pair of 23 \* 23 cm aerial photography, scanned in three colours at a resolution of 10 micron, already requires almost 1600 megabyte of data.

A change in the state of mind is necessary to prepare the operator for the processing of digital images instead of analogue photographs, and prospect of digital photogrammetry. Implementation of the DCCS did not raise any problem on this aspect, because the operators use analogue photographs as input for the DCCS. In case of automatic DHM generation, the operator corrects unreliable measurements instead of performing the measurements by him or herself. Assuming that automatic DHM generation will use a digital photogrammetric system instead of an analytical plotter, equipped with CCD-camera's, The height measurements will be handed to the operator, without any physical contact with the original photographic material. A bigger problem might arise, when, eventually, the operator has to zoom-in several times on his digital stereo imagery to perform a large scale 3D mapping. When the pixel contours turn up, the stereoscopic effect will fade away. To avoid this, one could decide to use a finer pixel resolution. Off course, this will increase the amount of data, which again influences the overall-performance of the system.

Summarizing, we have distinguished several important demands for the successful implementation of digital photogrammetry in a production environment, taking into account the functionality (tie point measurement, scanning) of the DCCS:

- The system should be capable to automatic produce DHM's and orthophotos
- Therefore, stereo-viewing of digital stereo imagery is necessary
- Training of personnel is essential
- Mass computer power is requested for fast processing of digital imagery, which needs
- Huge data storage
- A cluster of digital photogrammetric systems is needed

## Expectations of Digital Photogrammetry

Based on the assumption that the above outlined functional and practical requirements can be met, what added value do we expect from digital photogrammetry? With the DCCS we can obtain an impressive efficiency improvement by measuring 3 to 5 photographs every hour instead of one an hour in the traditional way. To be able to justify the investment on DHM software and hardware, a similar profit is requested. The availability of such a fast system however enables to be more flexible on customer's demands for different types of products (profiles, break lines, fully DTM's, object heights etc.). Acceleration of the production process offers the opportunity of monitoring land resources and global changes. In february 1990 for example, after a severe storm harassed the Dutch coast, we were asked to assist in the assessment of the sustained damage along the coast. Although the weather conditions allowed to insert an extra photographic flight, the elaboration techniques of that time would take too long to measure height profiles perpendicular to the Dutch coast (with a length of 300 kilometres). At that time, the assistance of digital photogrammetric systems but also airborne scanning laser altimetry could have been of considerable.

The future of digital photogrammetry, regarded in the context of the growing awareness, demands for, and application of Geographical Information Systems and developments in Computer Technology, will be interesting. (Digital) photogrammetry might supply GIS in a flexible way with several up-to-date major landbase layers like Digital Terrain Models and Digital Orthophoto's and Digital Topographic Databases. With the advent of GIS, photogrammetry has become only one of the components of GIS, but certainly one of the most important ones. Based on a uniform georeference, GIS serves as an integrator between topographical and thematic information.

## Conclusion

In this paper we have outlined our first experience with one of the first commercially available digital photogrammetric systems, the Digital Comparator Correlator System of Helava a.i. The experience with and the purchase of the DCCS shape the beginning of Digital Photogrammetry at the Survey Department. Experiments with digital matching seem to be promising. Possible selection of the most interesting hardware/software package will be made in a similar way as we did with the DCCS. Further we have discussed the requirements for applicable digital photogrammetry. The future of Digital Photogrammetry seem to be

promising. Especially with respect to the integration with GIS, a large variety of digital photogrammetric products can become accessible for new and larger groups of users.

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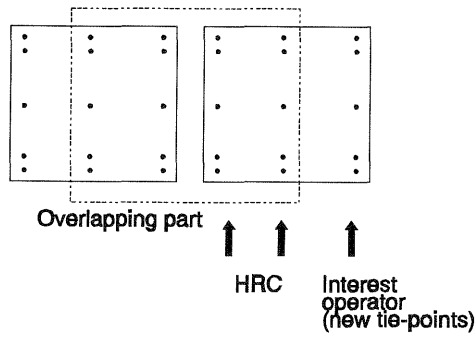
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Appendix A.

Digital photogrammetric algorithms to select and measure new and corresponding tie points



Semi automatic aerotriangulation with DCCS

