IMPLEMENTATION OF DIGITAL PHOTOGRAMMETRIC TECHNIQUES AT THE SURVEY DEPARTMENT

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Commission IV, Working Group 4

KEY WORDS: Experience, Organization, Development, Integration, Hardware

ABSTRACT

One decade ago big chances were predicted in using photogrammetry in changing from analytical to digital methods. These techniques would deliver opportunities for fast automatic generation of digital elevation models (DEM's), semi-automatic mapping procedures and automatic triangulation.
During the last years, the Survey Department (MD) of Rijkswaterstaat has carried out many projects and pilot studies in the field of digital photogrammetry. These projects directed the MD to use digital photogrammetry for accelerating aerotriangulation processes, for doing lower accurate mapping with cheap pc-systems, and generating new products like high dense digital elevation models, orthophotos and bird's-eye-views.

1. INTRODUCTION

One decade ago the time was ready for operationalization of digital photogrammetry in production environments. Big chances and changes were predicted, like fast automatic generation of digital elevation models (DEM's), semi-automatic mapping procedures and automatic triangulation. The disadvantages perceived were the urge for the availability of mass computer power and huge data storage capabilities, but the photogrammetric world expected to get over these difficulties in the near future.
In that time, the Survey Department (MD) of Rijkswaterstaat followed the main stream of belief in the opportunities of digital photogrammetry, and started different kind of projects (Han, 1992).
The main questions were how to use digital photogrammetry to fasten up our production lines, or to get a maximum gain of the benefits of new products to be generated with digital photogrammetry. Thereby, it is the MD's objective to be one of the front liners in the Netherlands in using new techniques, to enlarge the product assortment, and to improve the quality of its final products.
The last years we have carried out projects and pilot studies in the field of digital photogrammetry, to make a well-based start with this technique. Now we are on a starting point for using digital photogrammetry in our production environment.
This paper describes firstly our product range, and secondly the potentials of digital photogrammetry to improve our products, to accelerate the production, or to extend our product range. Thirdly and finally the organising aspects will be described.

2. ORGANIZATION AND PRODUCT RANGE

2.1 Organization Rijkswaterstaat

Rijkswaterstaat (Public Works Department) is the largest division of the Dutch Ministry of Transport and Public Works. It is responsible for the protection of The Netherlands against the sea and rivers, and for ensuring that all parts of the country are accessible and habitable. Therefore it develops and maintains a large infrastructure (roads, waterways, et cetera). Rijkswaterstaat is also responsible for the proper maintenance of dikes and dunes and for controlling the distribution and water quality of the Dutch lakes, rivers and estuaries.
For the performance of these tasks a vast amount of geographical data is required, which is supplied by the MD. The MD also ensures that Rijkswaterstaat's various divisions are able to use modern acquisition, analysing and presentation techniques to meet its geographical information needs. In addition, it provides advice and policy support in the field of geographical information supply.
The main customers of the MD are the various Rijkswaterstaat users. Only in exceptional cases, we enlarge our clientele to other users of geographical data.
The MD photogrammetric production unit counts about sixty persons and twelve analytical photogrammetric instruments.

2.2 Photogrammetric product range

The MD generates a variety of geographical products. Some of the main current MD-products for which (analytical) photogrammetric techniques are used, are listed below. Most of these products form a base or a layer for geographical information systems (GIS).

<u>High way databases</u>
The high way databases are digital vector databases of the high ways of the Netherlands. The total length of the Dutch high ways is about 3000 km. This product contains geographical information of the position of significant objects on and in the near surroundings of the high ways, for example road boundaries, road markings, lampposts et cetera.
Because the customers for this product are mainly interested in XY positions, quality insurance is focused on these co-ordinates instead of the Z co-ordinates.
This information is derived from 1:4000 colour photographs, using analytical photogrammetric instruments.

River databases
The river databases are digital vector databases of the river areas of the Netherlands. These databases contain XYZ co-ordinates of the most relevant features, like buildings, dikes (upper and lower break line) and water lines.
The XY position of the vector data is basis information for the databases, but it is also used for an easier interpretation. Opposed to the high way databases, the height information is very important for the river databases; each hectare contains at least 4 height points, and a large number of breaklines is present.
The data is gathered from 1:4000 colour photographs using analytical photogrammetric instruments.

DEM's for high way construction
For the construction of proposed high ways, DEM's are generated. These DEM's consist of several zigzagging strings, making a reliable coverage of the terrain. Next to these strings, break lines are measured, giving an indication of the most relevant height changes in the terrain. A high accuracy of Z co-ordinates is characteristic for this product.
The DEM's are generated with analytical instruments, using colour 1:3000 photographs.

Coastal base maps
The coastal base maps scale 1:2000 contain mainly contour lines and vectors of features of the Dutch coastal area along the North Sea shore. This area is roughly limited from the sea water line to the fore dunes.
The map contents is gathered from aerial photographs 1:4000 and 1:5000. Although digital techniques are used for the collection of information, the final product is a hardcopy at present.

Beach profiles databases
For monitoring the movements of sand masses along the Dutch sea shore, each 200 m a height profile is measured perpendicular to and from the sea water line to the fore dunes.
These profiles are measured using analytical instruments with photographs 1:5000.

Vegetation maps
Vegetation maps present the various vegetation types in river and coastal areas. Aerial false colour photographs are visually interpreted with the help of a mirror stereoscope. The vegetation boundaries are manually delineated on a transparency. In a second stage the transparency's are scanned to digital images, vectorised by skelettonizing, and visually corrected.

Road network database
Besides the above mentioned 'high way database', Rijkswaterstaat (AVV) maintains a database with XY co-ordinates of all the road axes in the Netherlands, even the narrow streets in the cities, accompanied with thematic information. The database is primarily used for accident monitoring
This database is assembled and updated by combining all kinds of geographical information; photogrammetry is not being used. Although this is not a MD product, the MD is to a certain extend involved in its development.

2.3 Customers needs

We carry out a continuos research to the customer's wishes in terms of completeness, accuracy and actuality of our products.
The current Rijkswaterstaat development from isolated management for only a few tasks to integral management, results in a tendency to a need for integral products suitable for these tasks, for example databases of river areas with height data, directly linked to databases giving information on vegetation types and land use.
Thereby the need for highly accurate data decreases, and the need for actual data increases.
As stated above, the geographical databases are most efficiently used in a GIS-environment.
Finally, the power of new computers gives us the opportunity to make visually attractive products, for example bird's-eye-views.

3. DIGITAL PHOTOGRAMMETRY

3.1 The use of digital photogrammetry

For us, digital photogrammetry is defined as a technique for collecting XYZ co-ordinates of objects using digital images.

The advantages of digital over analytical photogrammetry are the possibilities to:
1. automatically generate DEM's and display data sets in both perspective and plan view;
2. produce digital orthophotos, mosaics and bird's-eye-views;
3. implement digital image processing functions (contrast enhancement, vector on raster overlay, change detection);
4. interface with GIS software for overlay analysis and modelling applications.

The major drawbacks are data volume, processing speed, costs and the lower quality of stereo display (Trinder and Donnelly, 1996), (Welch, 1992).

In addition to 'regular' digital photogrammetry with scanned aerial photographs, we use video images digitised with a framegrabber as well. These video images are cheaper in use, but less accurate. The manner of handling these images for data collection is principally equal to the use of scanned photographs.

Another fast, cheap and fairly new technique for DEM generation is airborne laserscanning. Using this technique delivers DEM's with a height accuracy and point density comparative to DEM's generated with digital photogrammetry. Laserscanning is cheaper and the DEM's are available in an earlier stage after the flights. On the other hand, digital photogrammetry opens the possibility to gather thematic information like land use, edges of houses, and to generate orthophotos.

3.2 Digital Photogrammetric Equipment

Digital photogrammetric workstations can be subdivided into three types (Welch, 1992) (Dowman, 1993):
a. high-performance workstations providing a complete range of photogrammetric tools, like aerotriangulation, DEM-generation and editing, orthophoto generation mapping, et cetera. Up to now only a few of these workstations are available, among these DPW of Leica, Imagestation of Intergraph and Phodis of Zeiss;

b. systems designed for specific applications, optimised for performance but with limited functionality.
   Examples of these instruments are the Leica DCCS for semi-automatic aerotriangulation and Autometric Pegasus for DEM generation and editing.
   Stripped versions of the complete workstations (a) are covered under this category too;
c. pc-systems designed for specific applications. These are characterised by somewhat lower accuracy and slightly less speed, but these realise a greatly reduced cost.
   Examples are the R-Wel DMS and Leica DVP for mapping.

4. OUR USE OF DIGITAL PHOTOGRAMMETRY IN THE PAST, PRESENT AND FUTURE

This chapter describes various projects in the field of digital photogrammetry carried out the last decade.
Making a subdivision into past, present and future activities is difficult since the projects are not so well divided in time. Nevertheless the next set up is made.

4.1 Experiences in the past

Five to ten years ago digital photogrammetry was expected to be developing into a valid tool for generating cheap and high dense DEM's and orthophotos. Next to this, the processes of aerotriangulation could be accelerated by using (semi-)automatic techniques, and mapping could possibly be automated by using knowledge based systems.

4.1.1 Semi-automatic aerotriangulation The first tests in the early nineties were focused on semi-automatic aerotriangulation. The tests on the DCCS of Leica were promising (Han, 1992), resulting in the purchase of the system in 1991. This first step into digital photogrammetry was only a small step: the data capture followed after the triangulation was still carried out on analytical plotters.
Up to now, we make use of the DCCS. The speed of carrying out the aerotriangulation is not as promising as we expected, but comparable to the performance on an analytical instrument. Moreover, the performance on difficult areas like bare beaches was poor: matching results were unsatisfactory or wrong too often. This made us decide to use analytical instruments instead in these areas.

4.1.2 Orthophotos Orthophotos were expected to be a supplementary product next to the standard geographical databases for high ways, rivers and coasts. These orthophotos could be delivered as digital images, acting as an underground layer for GIS'ses.
The RWS-users were rather positive about this product, and they considered it as an useful addition. However, the extra costs were an insurmountable obstacle then.
Rectified images are used instead in a few cases. Maybe this use of rectified images is due to the absence of large height differences in the Dutch terrain: it is not worth much to spent extra costs for generating orthophotos instead of rectified images.

4.1.3 DEM generation In 1990, techniques for automatically generating DEM's from digital images were about to become operational in a commercial sense (Ackermann, 1991).
As described in chapter 2, the beach profile databases need height information of the Dutch shore. In stead of measuring profiles manually, digital photogrammetry provides tools for automatically generating DEM's. These DEM's could possibly substitute the profile databases in a later stage. In the meantime profiles could still be extracted from the DEM's by interpolation.
We carried out benchmark tests, where we compared the analytically measured profiles to the interpolated profiles out of the DEM's. Superficially, the results were encouraging, but after a closer examination, strange errors, sometimes more then 3 m, occurred: the DEM's presented non-existing hills, and some systematical errors on beaches and dunes as well. Most likely these errors are caused by the lack of texture on the bare sand beaches and dunes (Wicherson, 1994).
Our RWS-customers concluded the digital photogrammetric technique not being ready yet for delivering DEM's for their coastal monitoring.
For further research work with DEM and orthophoto generation, we purchased the OrthoMAX-module within 'Imagine', developed by Autometric. This module supports all digital photogrammetric activities, except mapping. We use this module especially for research work; its present performance and poor flexibility makes it unsuitable in a production environment.

4.1.4 Knowledge-based systems The generation of high way and river databases takes about fifty human-years annually. A slight improvement in efficiency results therefore in a high saving of money. Since the high way databases contain many objects with fixed size, colour and relative position, the mapping procedure could probably be supported by knowledge based systems.
An external research project, supported by Rijkswaterstaat, started which had it's subject in updating the high way databases with actual scanned photographs as basis, a high way database, and a knowledge based computer program. During the execution of the research work, concentration was put on recognising edges of high ways with use of the old database, and measuring and updating the database successively.
This method worked fine, and could easily be translated to other elongated objects with well-known appearance, like road-markings (De Gunst and Den Hartog, 1994). However, developing this method to a user-friendly software package, would cost too much time compared to the effort: saving of processing time for a human operator. Moreover, only some tens of kilometres were constructed in The Netherlands annually, and thus this method would not deliver the gain expected.
Another important aspect is that it is not efficient to use digital photogrammetric workstations for mapping at the moment.

4.2 Present experiences and developments

Our first experiences with digital photogrammetry were not very encouraging: except the test and purchase of the DCCS, the tests didn't work out successful so that digital photogrammetry wasn't implemented in our production environment yet.
Further research and development of new products is technique-driven: asking ourselves how the benefits of digital photogrammetry and other new techniques could be applied optimally.

Another drive comes from our customers: they wish complete databases, suitable for integral management.

4.2.1 New data sets for monitoring river areas In 1995 we restarted a project for developing new products for integral management for the river areas using digital photogrammetric techniques, in particular (semi-)automatic DEM, orthophoto and bird's-eye-view generation. The reason for this development push are among others the problems caused by the river floods in The Netherlands in 1993 and 1995. The need for hydrodynamic models became clear, and these models require up-to-date height and roughness information of the river areas, as these two aspects influence the stream velocity and water capacity most.
The river areas consist mainly of pastures, surrounded by dikes, river-banks and the river itself. Next to that other objects are buildings, roads et cetera. Height information is one of the most important parts of the river databases.
We expected a serviceable use of digital photogrammetry for this product for several reasons:

- the main area of interest for the river databases (pastures, overgrown dikes) is very suitable for automatic DEM matching techniques. Especially if the resulting raster DEM is completed with the most important break lines, the resulting DEM is highly densed and of high accuracy, made without much human effort;
- a significant part of the vectors to be gathered in the present river databases are mainly meant for easier interpreting the databases. Making an orthophoto delivers at least the same, but likely more information for interpretation purposes. Therefor, making an orthophoto would save time which is now used for gathering vectors meant for interpreting purposes (see figure 1 and 2);
- the addition of bird's-eye-views makes the final product more attractive. These products can be used for presentations of plans for citizens and other parties concerned.

Next to the above mentioned advantages, the digital photos can be used for accurate mapping, either on digital or analytical instruments. Moreover, the acquisition of thematic information, like a land use classification, can be executed directly.
This digital photogrammetric work will be carried out in a production environment using a DPW-770 of Leica, purchased at the beginning of 1996.

Probably airborne laseraltimetry in combination with video images provides us data which is accurate and complete enough for the purposes mentioned above. In a project currently carried out, we take a closer look at the potentials and we make comparisons between laseraltimetry, video, digital photogrammetry and satellite remote sensing in terms of efficiency.

4.2.2 New data sets for monitoring coastal areas Last year the MD launched a proposal for the introduction of new techniques for the acquisition of elevation data and thematic imagery of the coastal zone. The techniques consist of airborne

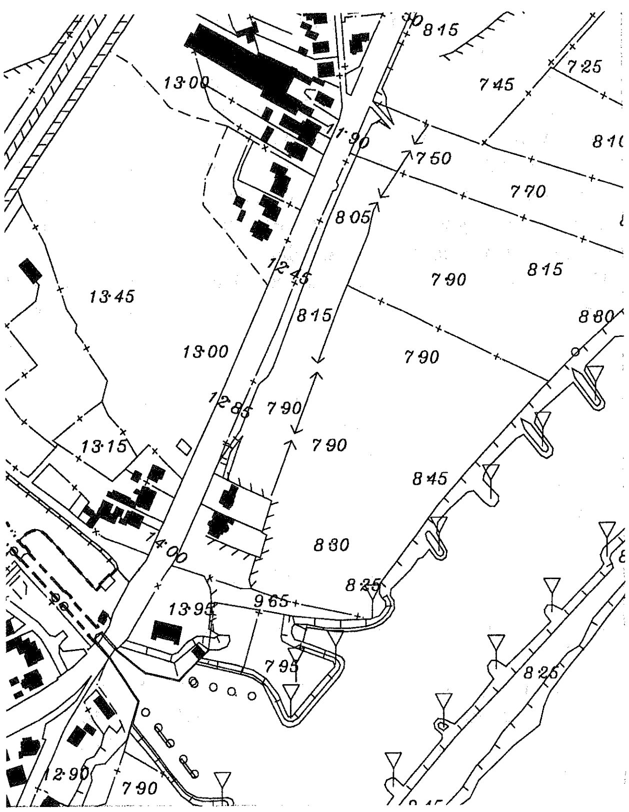

Figure 1: Part of the river database; the most relevant features are represented by vectors, and in addition single height points are measured.

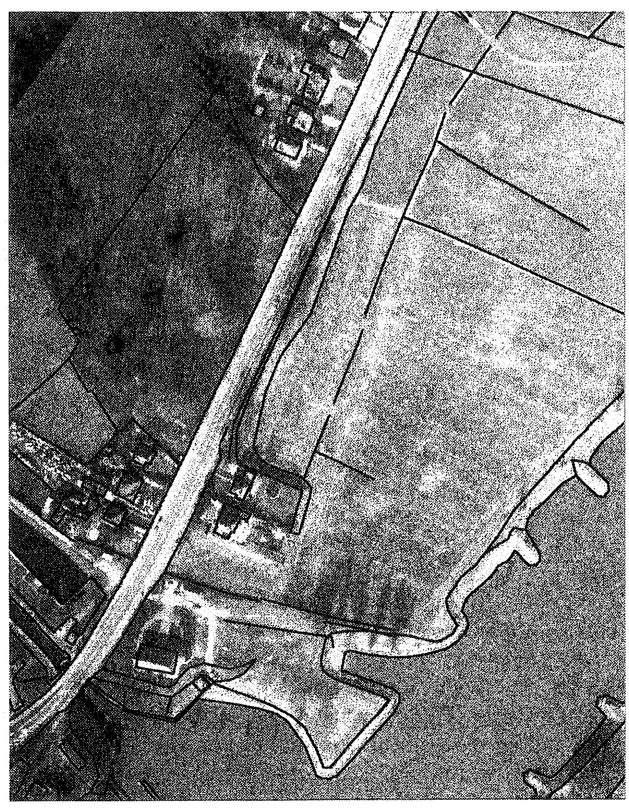

Figure 2: Part of the new river database: an orthophoto for as underground for interpreting reasons and the main vectors, additioned with a highly densed DEM

laser scanning for elevation measurement and airborne video for thematic data in time. The laser scanning is to replace the traditional photogrammetric approach to obtain profiles of the beach and foredunes (see figure 3 and 4). These techniques seem to be much more promising for these kind of areas then digital photogrammetry: the lack of texture doesn't influence the accuracy of laseraltimetry data badly, and the little objects to be gathered by vectors won't need high precision images like (scanned) photographs.
As of 1996, a DEM of the beach and foredunes of the Dutch coast will be provided annually, based on laser scanning data. Also, once every year the complete coastal zone (incorporating dunes) will be surveyed. Video data will provide information on e.g. vegetative cover, development and migration of blow-outs. In addition, by means of bird's-eye-views a good visual impression of the coastal area is obtained (Huising and Vaessen, 1996).

4.2.3 Road network database The appearance of the final product 'road network database' is mostly as desired by the users. A major problem is to keep this database up-to-date, i.e. all roads and existing streets are present in the database, and streets and roads which are changed in position, are moved in the database.
Photogrammetry could be a suitable technique for updating the database, in particular digital photogrammetry giving the opportunity to use low-cost pc-systems in stead of expensive analytical plotters or analogue stereoscopes.
During 1994 and 1995 we carried out a test using our pc-mapping system DVP of Leica, and scanned aerial photographs scale 1:18.000. This small scale basis product accompanied with a comparative low-accuracy mapping system, delivered a relatively cheap update process; the human power costs are about $ 0.6 million and the costs for the instruments used are about $ 0.05 million (Wicherson and Van der Kraan, 1995).

4.3 Future expectations

At this moment at least two other topics are in view for using digital photogrammetry efficiently in the future: automatic aerotriangulation, substituting semi-automatic aerotriangulation performed on the DCCS, and generating vegetation maps digitally.

4.3.1 Automatic aerotriangulation Many reports that have been published during the last years give an optimistic prospect of the operational use of automatic aerotriangulation, see for example (Tang and Heipke, 1996). The DPW-770 of Leica provides a module for automatic aerotriangulation. We tested this module extensively during our benchmark in 1995, and the earliest results were promising indeed. Subsequently we will carry out extended tests in 1996, and if these tests bear out our careful optimism, we can substitute the DCCS by a stripped version of the DPW-770, embodying only the most necessary modules for automatic aerotriangulation.

4.3.2 Digital vegetation maps As described in chapter 2, the vegetation maps are only available in digital format at the very end of the process. This mainly analogue process can be substituted by a digital-photogrammetrical process, probably with rather much profit.
The idea is to scan false colour photographs and to use a pc-based photogrammetric mapping system, like our DVP. Advantages of using digital images and techniques above our current process using analogue images and techniques, are the possibilities to use old vector maps for superimposing purposes and to fasten up the internal process by removing the stage of scanning, skelettonizing, vectorising and correcting the vector map. Moreover the possibility arises to quantify vegetation types by using (semi-)automatic multi-spectral classification as an extra product.
Despite these advantages, we still don't use digital photogrammetry because of some technical problems (huge storage capacities needed) and other organising aspects, like starting problems resulting in loss of production, and minor importance given to implement this technique in our production environment at the moment.

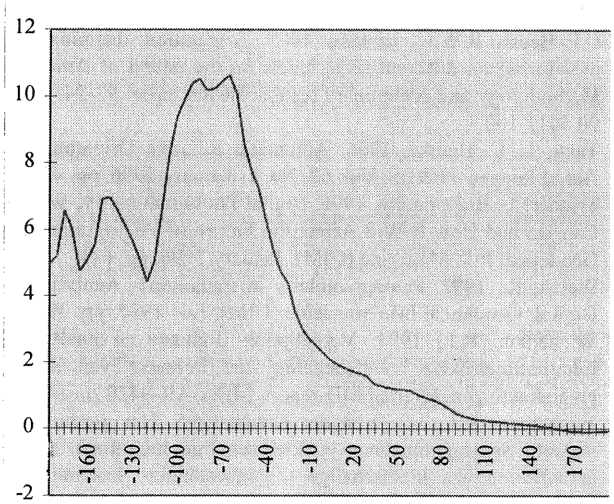

Figure 3: Beach profile, as currently produced

Figure 4: Laseraltimetry DEM of a part of Ameland, heights are represented in grey values.

5. ORGANISING ASPECTS

5.1 Hardware aspects

At present, one high-performance digital-photogrammetric workstation is available (DPW-770) and twelve analytical instruments. The analytical instruments are intensively used for mapping now, and not written of yet.
This year, our workstation will be used for development of new products mainly. In a successive stage, this instrument will be used for new products like orthophotos. Gradually digital workstations will substitute analytical instruments for mapping purposes too, assuming that problems dealing with data storage and processing speed are solved.

The DCCS-system is still used for semi-automatic aerotriangulation, although this system is written-off already.
If our tests of the module for automatic aerotriangulation are successful, a stripped version of the DPW-770 will possibly be used for aerotriangulation.

Mapping with lower accuracy can be carried out efficiently on relatively cheap pc-systems, like our DVP. A test on vegetation mapping with the DVP will be executed in the near future. Most likely, positive test results will lead to an operational use of pc-systems for (vegetation) mapping afterwards. Up to then, the existing process, using stereoscopes, will be continued.

5.2 Personal consequences

Essentially the use of digital photogrammetry doesn't decrease the annual demand for human-power in our production unit. The expected efficiency increase, for example with automatic aerotriangulation, will at least be compensated if not outweighed by extra human-power needed for making new products. Growth of human-power is expected to be about three human-power years annually.

A change in workflow must be taken into account. Besides an extra stage needed for scanning photographs, new operations like correcting automatically generated DEM's arise. These operations need a change in mind for the operators working with the new techniques.
Digital photogrammetry makes use of new hardware components, such as stereo screens, that may be more tiring for operators.

People working with analytical photogrammetry now, need additional training for using digital photogrammetry. A subdivision is made for three types of training:

1. a basic training on digital photogrammetry in general, containing subjects like contents and structures of digital images, matching, orthophoto generation et cetera.
   This training is meant for all operators working with digital photogrammetry;
2. a training for operators on specific digital-photogrammetric instruments;
3. an advanced training for a small group of users. These users are skilled to solve particular problems dealing with the use of digital photogrammetry, for example matching problems.

6. CONCLUSIONS AND OUTLOOK

In this paper our approach to digital photogrammetry is described, focused on our experiences in the past and present.
Up to now we use the DCCS for semi-automatic aerotriangulation. Furthermore, we have purchased a pc-system for mapping, and a workstation for research and product development and one for product development and production.

Digital photogrammetry delivers us the opportunity to speed up aerotriangulation, to do lower accurate mapping with cheap systems, and to generate new products (high dense DEM's, orthophotos and bird's-eye-views). The last mentioned gives us the chance to wide-out our spectrum of products. The new products are primarily used for integral databases for coast and river management.
Finally, the use of digital photogrammetry answers the MD's objective to be one of the front liners in the Netherlands in using new techniques.

For the next few years we expect digital photogrammetry to be developing into a technique giving us the advantages mentioned above. In a later stage, digital-photogrammetric workstations can most likely substitute analytical instruments for mapping.

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