Full Automatically Generated True Orthophotos, Sensational 3D Pointclouds and Dense Matching Techniques in Topographical Mapping

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Key words: True Orthophotos, Dense Matching Techniques, 3D pointclouds

Kadaster (Dutch land registration and National mapping agency)

SUMMARY

Kadaster has gained a lot off experience over the last two years with accurate Structure From Motion based photogrammetric processing techniques. To improve the efficiency and effectiveness of the surveying process in the Netherlands Kadaster started an experiment. Objective was to find out whether photogranmmetry techniques which refrains from terrestrial methods could simplify the surveying process. In a novel approach the verification process relies on recent and accurate aerial photographs of the topographic situation of the parcel(s) involved. The photographs show sufficient details and have a measurement precision of 3 centimeters or less, which is in fact a really sensational result. The still on-going experiments with data have proven it is possible to produce automatically orthophotos with a geometric accuracy of 3cm. This is very promising for cadastral usage, making Digital Terrainmodels. Further research also showed that if you decompose the photographs it is possible te create a 3D pointcloud based on the coordinates of the pixels of the photograph. This makes it possible to develop 3D models which can be compared with each other. In order to improve the thopographical processes using 3D pointclouds and 3D models, further research is necessary.

SAMENVATTING

Het Kadaster wil de dienstverlening naar klanten optimaliseren en de eigen processen zo effectief mogelijk organiseren tegen zo laag mogelijke kosten. Het Kadaster heeft zich in eerste plaats beziggehouden met experimenten naar de inzet van hoogwaardig luchtfotomateriaal binnen het landmeetkundig proces. Er werden orthofoto's bepaald, waarvan analyses leidden tot een geometrische nauwkeurigheid van circa 3 centimeter en zijn daarmee geschikt voor landmeetkundige metingen. Daarnaast konden opnamen opvallend eenvoudig ontleed worden tot 3D puntenwolken. Dit heeft geleid tot vervolgonderzoek naar toepassingen in het topografisch productieproces. Doel was het verhogen van de door klanten gewenste kwaliteitsverbetering van topografische basisbestanden en het efficienter inrichten van de inwinning. De conclusie is dat geschetste methodieken daartoe kunnen bijdragen en daarom dit verder onderzoek in de nabije toekomst rechtvaardigt.

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1. INTRODUCTION

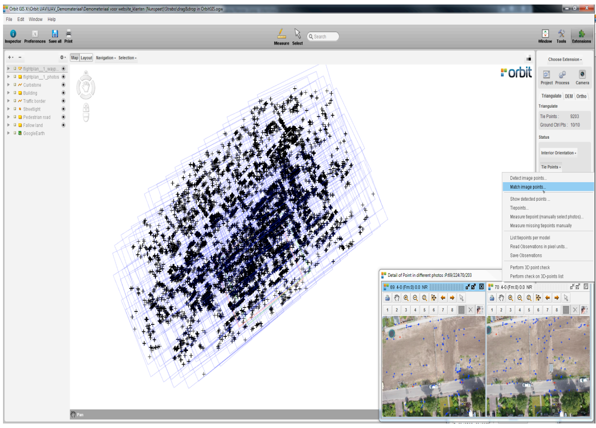
To improve efficiency and effectiveness of the surveying process in the Netherlands an experiment was set up by Kadaster in 2012 to use photogrammetry techniques which refrains from conventional terrestrial methods. In a novel approach the verification process relies on recent and accurate aerial photographs of the topographic situation of the parcel(s) involved. The photographs show sufficient details and have a measurement precision of 3 centimeters or less, which is in fact a really sensational result. The photographs can be used by owners of a parcel to determine the border but they can subsequently be used to measure the cadastral borders with high accuracy. During this research, some first experiments were done with the extraction of 3D pointclouds from aerial high resolution photographs. These experiments gave new insights in other applications of these high resolution aerial photographs. This led to further research questions in relation to other production processes of Kadaster.
The Product Innovation Department of “het Kadaster” started in 2013 new research with 3D pointclouds and high resolution photographs to involve in topographical mapping. Research question was “Are there applications possibilities for Kadaster’s high resolition aerial photographs in relation to 3D pointclouds in the topographical mapping process?”

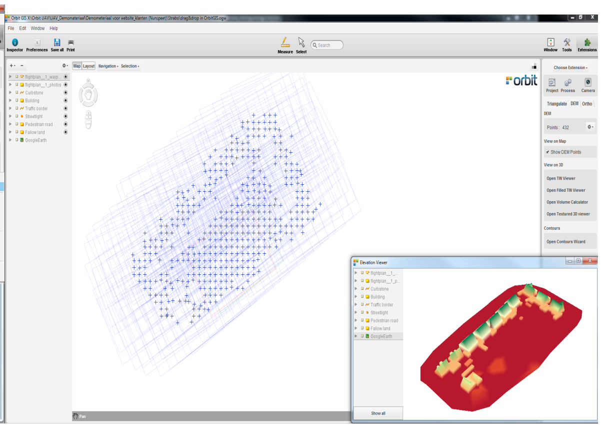
During an intensive research process by trial and error, different high resolution aerial photographs were extracted in huge datasets of 3D pointclouds. Main objective was to focuss on applications for the production of the TOP10NL 3D dataset and the 1:10.000 topographical basemap. Customers of these products want completeness and topicality against minimum prices.
This paper gives insight in spectular results of these experiments extracting aerial photographs to 3D datasets. First chapter gives insight in background and first approach to calculate orthophotos. Next chapter focusses at the application to topographical mapping processes. Also some insight will be given in the trial and error experiments with 3D pointclouds in relation to Kadaster's topographical datasets and the national aerial photograph-archive. Finally, some conclusions are defined and recommendations are made.

2. HIGH RESOLUTION PHOTOGRAPHS FOR CADASTRAL APPLICATIONS

2.1 Kadaster and Problems in Cadastral Surveying

Kadaster is the national land registration and mapping agency. Kadaster is responsible for maintaining an actual and complete registration of deeds of ownership and making cadastral maps and juridical borders of ownership of real estate. Kadaster has the responsibility to inform those who are part of the transactions about the current situation of ownership. When the ownership of a parcel or real estate property changes, verification of the cadastral situation is the first step to be made. For the verification process of ownership presence of both the owner and a cadastral employer is necessary. Appointments, initiated by the surveyor always take place during daytime when most people are at work. Usually more than one person is involved in transactions; at least two individuals have to make their attendance. Practically, this could be complex. Because the presence of the owner is necessary, the verification process stocks and a new appointment has to be made. In the mean time, the cadastral map is no longer actual. So, the verification process should become more efficient. All those who are stakeholders during these transactions need to be able to actually get "real a possible" insight in the new cadastral situation for a right verification. Because of this reasons a dataset of aerial photographs was needed with much better resolution than those made by conventional flights. Thatswhy Kadaster started experiments with making aerial photographs by Unmanned Aerial Systems (UAS).





Figures 1 and 2: Automatic Point Detection and Matching techniques at first experiments.

2.2 Generating Orthophotos

Research started to use high resolition photos in these surveying and verification processes. Herefor a high resolution aerial photograph dataset was made from the city of Nunspeet in the Netherlands. These experimental aerial photograph datasets -made by an UAS- were flown at an altitude of 50 meters and with overall photograph overlap of 80%. It resulted in high quality aerial datasets of around less than 1 centimeters pro pixel, which is relatively high qualitative.

During postprocessing and analyses Kadaster improved its competences working with accurate Structure From Motion based photogrammetric processing techniques. During this experiment experiences were build with Dense Matching Techniques, cameras used, usage of ground control markers and calibration of needed camera's. Furthermore experiences of the different used SFM software packages (Visual SFM/Bundler, PhotoScan, PhotoModeler and the Orbit software) were improved (figures 1 and 2).

Figure 3 and 4: Automatic DTM creation and zoomed-in orthophoto made by PIX4UAV with cadastral borders.

Postprocessing was started by importing the gathered data in Orbit software for making orthophotos to do surveying activities. Operators started with automatic step- and model creation, followed by auto-detection of points and matching images with the so called "Von Gruber" matching method. After Bundle Block Adjustment (BBA) the images were stitched geometrically and oriented correctly to each other. In the end, these orthophotos had a geometrical accurracy of 3 centimeters which was really a sensational result (figure 4). That means these ortophotos could be used for surveying activities.

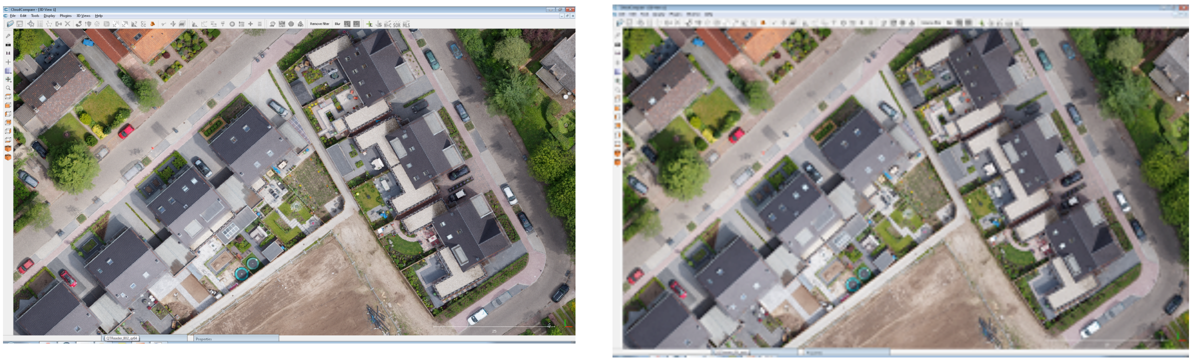


Figure 5 and 6: Automatic generated orthophoto with PIX4UAV and one from 3D pointclouds calculated by SURE software. The right one is improved, is a DSM and can be seen as True Ortho.

Next to orthophotos, some additional analysis were made. Georeferenced datasets were imported into Photoscan software. It did result in 3D pointclouds (figure 3). Of course these pointclouds are not real 3D Models, but it gave a first view of possibilities. Because of its visual success, it was decided to do more experiments focussed on other applications than surveying.

Main conclusion of this first part of research was UAS's are realistic and useful systems to take high resolution photographs for cadastral border verification and do measurements for the surveying process. This can be done with an an geometrical accuracy which is at least as good as conventional terrestrial surveying methods.

3 APPLICATIONS TO TOPOGRAPHICAL MAPPING

3.1 Problems in the Topographical Mapping Process

The experiments triggered to other interesting research questions. The experiments with high resolution photographs and ortophotos shows huge possibilities for the surveying process. But tests with 3D pointclouds focusses to possible applications for the topographical productionprocess as well.
Kadaster has invested a lot off effort the last few years to improve its topographical mapping products with lean and Just-in-Time methods. However, improvements are still necessary. Customers want topograpical maps which are more current, low priced and complete; they want a higher level of detail as well. The actual basemap made by Kadaster is TOP10NL 1:10.000. At this moment, this is an objectoriented product made from 10 centimeter resolution aerial photographs manually.

These aerial photographs have a topicality of one year, but as a result in the actual production process it all results in a map with an topicality around two years. In order to improve services and meet the customers expectations, Kadaster want to improve topicality. Could 3D pointclouds extracted from aerial photographs support these wishes? Could these 3D pointclouds also be used for changedetection to trigger topicality in the topographical mapping process? Could 3D pointclouds lead to more level of detail (LOD) in the 3D topographical map as well? An serious approach started to research the applications of high resolution photographs in relation to 3D pointclouds. Main objective is however to improve topicality of the national basemap TOP10NL.

The research was also facussed on the applications for the national reference 3D map TOPNL3D. This 3D map is generated comparing the national Lidar dataset ”Algemeen Hoogtebestand Nederland” (AHN-2) and the national topographical basemap TOP10NL automatically. Possible improvements of this products is to improve topicality and level of detail. At this moment, level of detail of this national 3D map is based on LOD01 (eg. no roofdetails). With 3D pointclouds it should be possible to improve detail from LOD1 to LOD2. Next, topicality of this national 3D map is based on TOP10NL with its two years topocality. By calculating 3D pointclouds from an aerial photographset mutations should be discovered sooner and involved in the mapping process as a trigger to get a better topicality of this 3D map too. An trail-and-error approach was started with different datasets and software to explore the above mentioned applications.

Figure 7: 3D pointclouds extracted from high resolution aerial (UAV) dataset.

3.2 Generating 3D pointclouds

Different 3D pointclouds datasets were extracted during Kadaster's experiments with the development of orthophotos. Softwarepackages used for creating orthophotos were Visual SFM and Photomodeller Scanner. It did result in orthophotos with 3 centimeter geometrical precision. Later, 3D datasets were calculated with Pix4UAV softwarepackage. Although there were some artefacts within this pointclouds the results were great from an overall visible view. Further experiments were done using better specialised softwarepackages. Best results were reached using the softwarepackage SURE. SURE has tools and skills to use it for density pointclouds and can calculate 3D pointclouds and DSM's full automatically. Although the procession time takes some hours, it gives a visual great result.

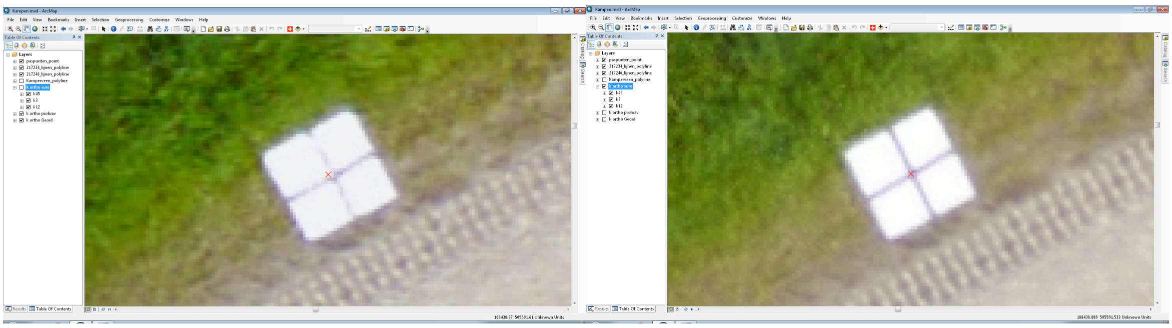


Figure 8 and 9: DSM made with PixUAV (left) and with SURE (right); SURE leads to an improved result(red dot better positioned in cross).

Results are for example high density pointclouds from the UAV dataset in Nunspeet (figure 7) which shows visualisations like it is a real 3D model. To proove its accuracy, these pointclouds were made flat to Digital Stereo Models with a z-coordinate 0 to get True Orthophotos. Different other experiments at other locations were generated. Important was to make sure the used photographs should be well positioned next to each other. For good results semi global matching methodologies were used. Herefore every common point at every photograph is matched in the photographs by the software. Analyses showed there was a match around 90% of common points in teh pointclouds. Further experiments showed minimal need of flightoverlap of photographs of more than 80%. In that case there is a match from more than 99,0% possible! With this level of overlap of used aerial photographs it is possible to derive Digital Stero Models with high accuracy. From a visual perspective the results are amazing (figure 9).

3.3 3D pointclouds from Kadaster's National Aerial Photograph-Archive

Kadaster manages a national public archive of 10 centimeter aerial photographs with an topicality of one year. Together with "Waterschapshuis" (the national representative of local waterboards) Kadaster is responsible for distributing and collecting public aerial photographs to all public agencies who are part of a signed agreement of use. Kadaster uses these aerial photographs dataset as source for mapping TOP1:10.000 topographical basemap.

Idea was to apply same techniques as be mentioned on this national aerial photograph-archive. For the experiment SURE software was used again for an area of aerial photographs around Zwolle (figure 11). For heights the related national part of the AHN-2 was taken. Because of less accuracy in relation to the UAV-high resolutionphotographs before in Nunspeet, a less quality result was expected. However, results were very optimistic from a visual perspective. Details are very well shown (woodpaths, roads, houses) and could be used as a trigger for inspection of mutations. Also, details are shown better than from original photographs which are in 2D. So, the 3D pointclouds could result in less terrain inspections by employees. From an overall perspective the models show a nice view of 3D pointclouds with less deviations and artefacts. Roofs are full complete and edges are clearly visible.

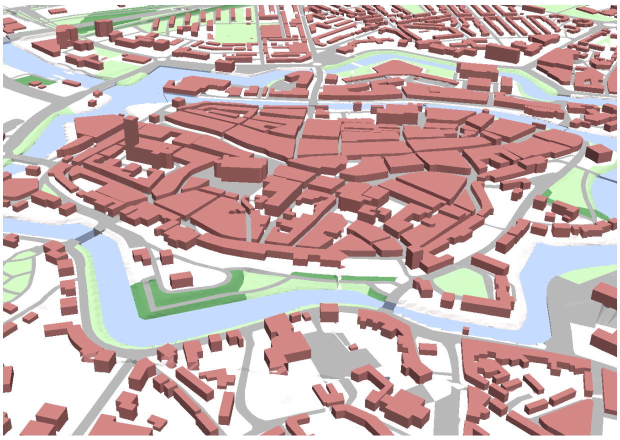


Figure 10: Referencemap 3D TOP10NL, city of Zwolle.

Also more ideas existed to use these techniques fo the new 3D product of Kadaster, the national referenceset 3D-TOPNL to increase its accuracy to LOD02 (eg. Roofs). At this moment, this dataset is meant as a national 3D referenceset with LOD01 (figure 10). Some first experiments to calculate LOD02 maps with TOP10NL and 3D pointclouds were made with experimental sofware. First results were very hopeful. This because a 3D map was full automatically calculated in LOD02. However, it's to early to report about it, more research has to be started in near future.

Trial and error experiments were also focussed to changedetections. Different photographs of the national aerial photograph library were used from the same area of the dutch Province Limburg. 3D pointclouds of different datasets (2012 and 2013) were extracted again by SURE software. Differences were mapped and visualised (figure 12). It clearly shows different recent changes in blue. From a critical point of view, it should be very interesting to conduct

Figure 11 and 12: At the left 3D pointcloud-model generated by comparing AHN-2 and national photograph archive with parts of the city Zwolle. At the right change detection method comparing two different 3D pointclouds from two different datasets (Limburg 2012 and 2013) at the same area. Differences are visualised in blue.

more research selecting sets of pixels on colour which are related to special atributes and themes, like houses, roads, waterways and so on. Recent results are very hopeful to use these kind of techniques as a trigger for increasing topicality of the national topographical basemap 1:10.000.

3.4 Some reflexions

This paper shows the results of calculated 3D pointclouds from aerial high resolition photographs from a qualitative perspective. It shows some fine results in visualisations as well. But more research is necessary, from a qualitative perspecitive, but also from a quantitive perspective as well. Although showed results are hopeful to use in change detection and at different other applications in the mapping process, minimal specifications have to be determined. Examples are more specific quantative knowledge about flightlines, using overlap percentages and proved accuracies to make this technique really structral usable in the mapping process and 3D TOP10NL.

4. CONCLUSIONS AND RECOMMENDATIONS

4.1 Conclusions

Overall conclusion is that 3D pointclouds extracted from high aerial resolution photographs are applicable in topographical mapping. This technique and its results could be useful for updating processes and increase level of detail. Next to the national basemap 1:10.000, it could also be useful for highering the level of detail of 3D TopNL reference map.

From this overall conclusion some subconclusions are defined:

- 3D pointclouds generated from the Kadaster/Waterschapshuis national photograph aerial archive give fine visual results and could be useful for customers for global visualisation and inspections;
- The methodoloy to extract 3D pointclouds automatically from aerial photographs could be useful to increase topicality and level of detail for the national basemap 1:10.000 (eg. edges, woodpaths) and 3D TOPNL (eg. roofs in relation to LOD02);
- 3D Pointclouds generated from high resolution aerial photographs could be used for changedetection in order to increase topicality of topographical products.

4.2 Recommendations

Based on the research conducted, the following recommendations are made:

- Define -from a quantative perspective- minimal specifications regarding flightlines, overlap percentages and pixelaccuracies of aerial photographs for structural use of 3D pointclouds methodoly in topographical process;
- Start more experiments also at other locations using 3D Pointclouds techniques for topographical applications. This should be focussed on the 3D TOPNL and changedetection as well;
- Arange Meetings with customers to gain more insight in value and usability of a national 3D pointcloud dataset generated from the national aerial photograph-archive combined with AHN-2.

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BIOGRAPHICAL NOTES

Martijn Rijsdijk (1975) has a professional career at Kadaster which is the Dutch land registration and mapping agency. He has a Master in Geodetical Engineering at Delft Technical University of Engineering (NL) and did a postmaster in Business Administration (MBA) at Keele University (UK). At this moment he works as a manager and is responsible for two innovation teams at Kadaster; respecively Geographical Information Systems Special Services and Product- and Processinnovation. Together with its employees he works on improving internal processes, innovating Kadaster's products and increase customer's intimicy.

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