MANAGING LARGE BLOCKS OF AERIAL IMAGES

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ABSTRACT:

The size of photo-missions increased over the last decade and 10.000s of images in one and the same aerial image block are no longer unusual. Thus new requirements to maintain and control the photogrammetric processing chain raised and software needs to intelligently assist the operator analyzing the data set, to control quality and to document all steps of the automated workflow.

We show an intuitive and powerful solution, a versatile 3D graphical user interface is deeply integrated into the UltraMap AT workflow. This solution enables the operator to identify blunders and weak areas and to display in a color coded manner all relevant parameters of a project. Beside geometry parameters it is also helpful to visualize the time line of a photo mission. Thus sub-blocks and re-flights are well distinguishable from their color representation in the graphical user interface. We show examples of large blocks of about 30.000 shot positions which have been successfully processed and controlled via this graphical user interface.

Finally, we show how Microsoft's innovative 3D interface technology is applied to the Digital Surface Model editing tool (DSM Editor). The DSM Editor enables the operator to very efficiently interact with DSM data in a highly intuitive manner.

1. INTRODUCTION

UltraMap is the digital workflow product specifically designed and optimized for processing digital aerial images from the UltraCam sensor family. The first version of this software was designed to manage the basic functions of data download and initial image processing. Next came the all-digital photogrammetric workflow in 2008 with the introduction of UltraMap Aerial Triangulation (UltraMap AT). This UltaMap workflow module includes automated tie point matching and the least squares bundle adjustment (utilizing BINGO). Automated radiometric processing, known as the Project-Based Color Balancing (PBCB), provides very powerful radiometric block adjustment and was released shortly after the AT module.

Introduced 2013, UltraMap v3 includes a fully automated processing pipeline for the creation of Digital Surface Models (DSM), the *DSMOrtho* ("true" ortho mosaic based on an automatically generated DSM) as well as the traditional ortho mosaic, which we call a *DTMOrtho* from UltraCam imagery.

One important design goal of UltraMap is a fluent and intuitive user experience when working with large amounts of UlrtaCam aerial imagery. For that it was important to simplify the user interface of all workflow

tools so that they provide fast and effective user feedback which in turn allows for smooth efficient interaction with large aerial datasets. Utilizing Dragonfly, a Microsoft-proprietary technology provides the mechanisms to efficiently display and interact with large aerial blocks of images in a fluent and performant manner.
As aerial projects get larger and larger, the next version of UltraMap now allows for even larger blocks of images. The design goal was to comfortably process datasets containing up to 50.000 aerial images and to enable the operator to interact with such large data sets. It allows, for example to zoom and pan into the image data as well as to control and interact with the photogrammetric parameters as the exterior orientation, the quality of the parameters involved and the tools to visualize and to edit these data. In addition to these so-called visual analytics tools we also give a short overview on our DSM editing tool which may indeed add a very specific benefit to the workflow we offer via our UltraMap software package.

2. THE ULTRAMAP WORKFLOW AND PROCESSING CHAIN

The aerial triangulation solution available in the UltraMap software package is embedded into the end-to-end digital photogrammetric workflow. Figure 1 shows an overview of our UltraMap processing pipeline, its main components and the data products it is able to create. Highlighted are the AT module containing the new visual analytics tool as well as the Ortho module now containing the interactive 3D DSM editing tool. The main modules of the UltraMap workflow are:

RawDataCenter which is responsible for processing the raw UltraCam imagery into a so-called Level-2 data format which is then radiometrically and geometrically calibrated;

The *Aerial Triangulation* (AT) module consists of the image matching function in order to automatically produce image correspondence, the interactive tool to add manual measurements and the least squares adjustment software in order to generate a precise exterior orientation for a whole image block as well as the new option to interactively control the result exploiting the new visual analytics component;

The *Radiometry* module includes the Project Based Color Balancing software – a fully automated radiometric mosaicking approach;

The *Ortho Generation* module makes use of the Level-2 images and the exterior orientation information to compute per-pixel height values, the so-called digital surface model (DSM) and offers the new interactive 3D editing tool. As the final result the digital ortho mosaic is generated.

User research has shown that the amount of effort spent on QA/QC and trouble-shooting of increasing large blocks of aerial imagery can grow disproportionally and thereby cause additional costs and delays to a photogrammetry project. Thus it is obvious that Microsoft put extra effort in making these portions of the UltraMap workflow more efficient, even with very large blocks. This required the implementation of novel automation-guided manual operator tools into the workflow. As the most efficient way to improve the end-to-end digital workflow for large blocks of aerial images we have identified the QC of aerial triangulation and the geometry of the image based surface reconstruction procedure. At the same time new 3D visualization and user interaction models are introduced to make it easier for an operator to understand the complex spatial relation of all the components of an aerial project as well as to visualize in real-time the result of all user intervention.

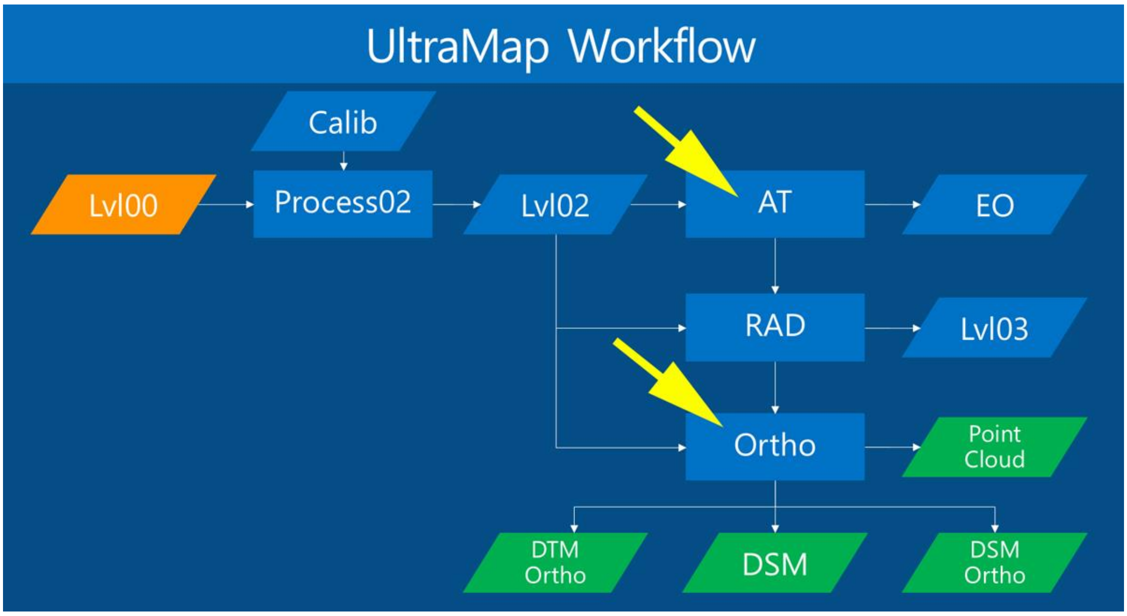

Figure 1: The UltraMap end-to-end workflow. The improved modules are flagged by yellow arrows.

3. VISUAL ANALYTICS AND HOW IT WORKS

3.1 Large blocks of images

Over the last decade the productivity of aerial operations and the demand for acquisition of large contiguous areas at increasingly higher image resolution has grown tremendously. To address those customer needs, Microsoft Vexcel has regularly developed increasingly more efficient aerial camera products. Today the UltraCam Eagle with a 260 MPixel frame format and a 20.010 Pixel cross track image dimension is at the top of the product line. The UltraCam Eagle was even exceeded by the UltraCam G sensor which was used for the largest photogrammetry project ever, the so-called Global Ortho project which was successfully completed in 2014. A complete ortho mosaic (30 cm GSD) covering the 48 states of the continental US and Western Europe was the outcome of that project. The Global Ortho Program, because of the large dimensions, has triggered a good number of innovations in hardware, software, logistics, processing and more. Many of these innovations and the experience derived during the execution of the project have influenced the development of new generations of UltraCam sensors, UltraMap software, and Microsoft photogrammetry tools in general. Processing large blocks of images thus had been developed and verified years ago by Microsoft and the Bing Imaging team and now it is introduced into the UltraMap software tools available to the commercial photogrammetry market.

3.2 Interacting with the help of 3D-visualization

Working with large photogrammetric blocks of images requires the operator to understand a huge number of parameters, unknowns and quality indicators. Even when the automated processing was successfully performed there is always need for QA and QC intervention. As soon as the size of such blocks increases and some ten-thousand images are involved any human interaction, quality assessment and blunder detection becomes time consuming. This may be even more difficult, when multiple flight missions, often flown on different days and/or using different cameras, are combined and need to be adjusted as a single large continuous block of images. From such complex project scenarios we deduced a set of requirements and basic functionality. We found that three dimensional visualization of large sets of data allows even novice users to quickly understand the various quality parameters and to intuitively identify problem areas or specific data problems. In addition the software design allows to fix issues in the same 3D environment and to visualize in real-time the impact of any user interaction.

Fully three dimensional visualization
Color coding of parameters:
Date of flight mission to visualize sub areas of the project
Camera type and flight equipment to visualize sub areas of the project
Position parameters and/or deviations from GPS/IMU (Camera position and pose)
GCP and deviations after adjustment
GPS/IMU residuals after least squares adjustment
Tie point positions and strength
Number of shared tie points
Time of day differences
Absolute time differences
Link diagram of images to images
Link diagram of images to points
Link diagram of points to images
Image Visualization

Table 1: Top level functionality of photogrammetric visual analytics

4. EXAMPLE PROJECT SCENARIOS

4.1 Large Project scenario of UltraCam Osprey

We illustrate several results on how visual analytics is presenting 3D project data. Figure 2 shows the layout of a 30.000 photo block and color coded mission dates. On the right the fully three dimensional view into the project geometry shows tie-points on the ground, photo stations and the set of rays from a distinct tie point to all images involved into the computation of the tie point coordinates.

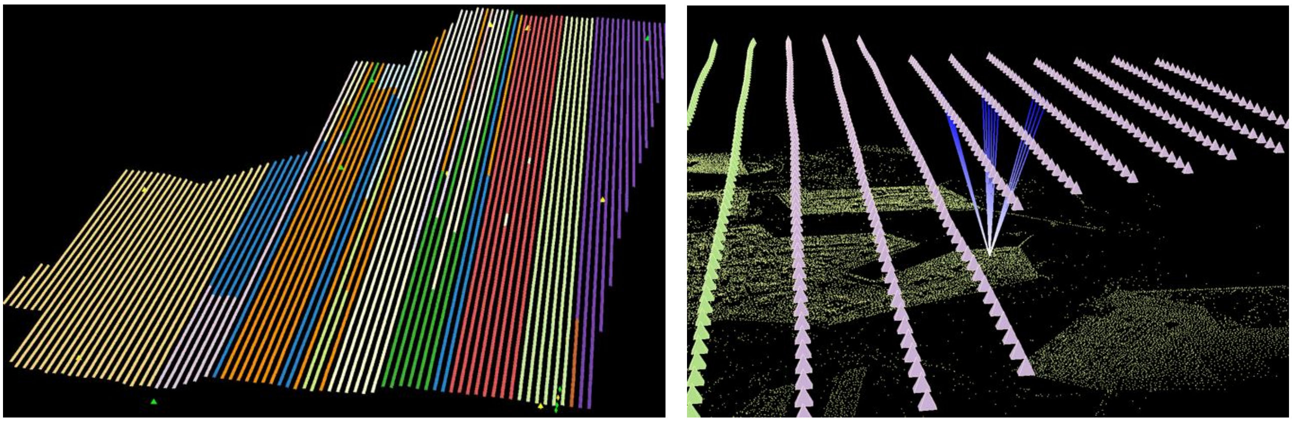

Figure 2: Project set up and layout (left) and detail with cameras, tie-points and ray (right).

Figure 3 shows on the left the link diagram which is color coded and alerts the operator when some regions of the project suffer from course tie point matching (e.g. caused from poor object structure like water bodies). Links are then no longer green but orange, red or missing. The right part of figure 3 illustrates the feedback on adjusted parameters and their residuals. Five images in a flight line are marked up in red to alert the operator. In this special example re-taking of the flight line segment with five images was the reason for deviations in image pose parameters after merging the two runs.

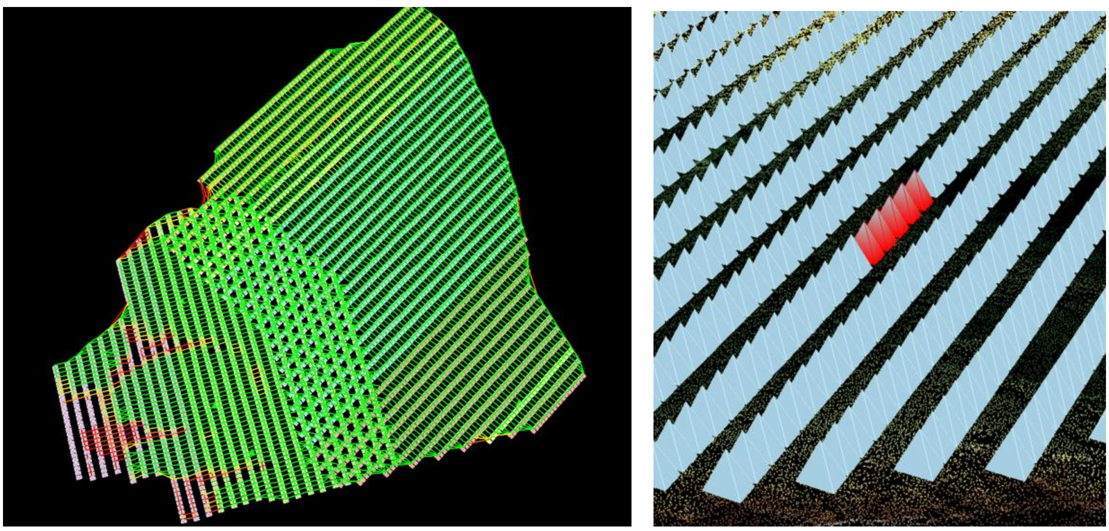

Figure 3: Link diagram (link between images) on the left and detail with camera parameters and color coded deviations of EO parameters (right).

5. REAL-TIME 3D DIGITAL SURFACE MODEL EDITING

The UltraMap DSM module uses image-based surface reconstruction algorithms. For many mapping and photogrammetry applications manual editing and refinement of raw DSM data is required. We are introducing the DSM Editor, a novel 3D interactive editing tool for digital surface models. Traditionally this was done using “drawing” tools (similar to image editing tools) to edit height-field (raster) data. For visualization different shading methods and image overlays or blending were used.

The DSM Editor is based on proprietary Microsoft 3D technology. With a circular 3D cursor, like with a magic wand, the user only provides hints to the software which then uses intelligent “3D brushes” to automatically and in real time fix the areas highlighted by the users. In case automation delivers imperfect results, the 3D cursor is used to provide additional guidance like highlighting an edge or break-line. In our example we show in figure 4 how the “flag pole” structure (marked up with the “A” on the left could be removed by guiding a 3D cursor over that area. On the right the starting point of the operation is marked up by “B” and the result is shown on the lower right (flagged by “C”). The interactive cursor is automatically guided in the vertical and interactively moved by the operator in x and y. The blue arrow on the lower right points to the circular cursor.

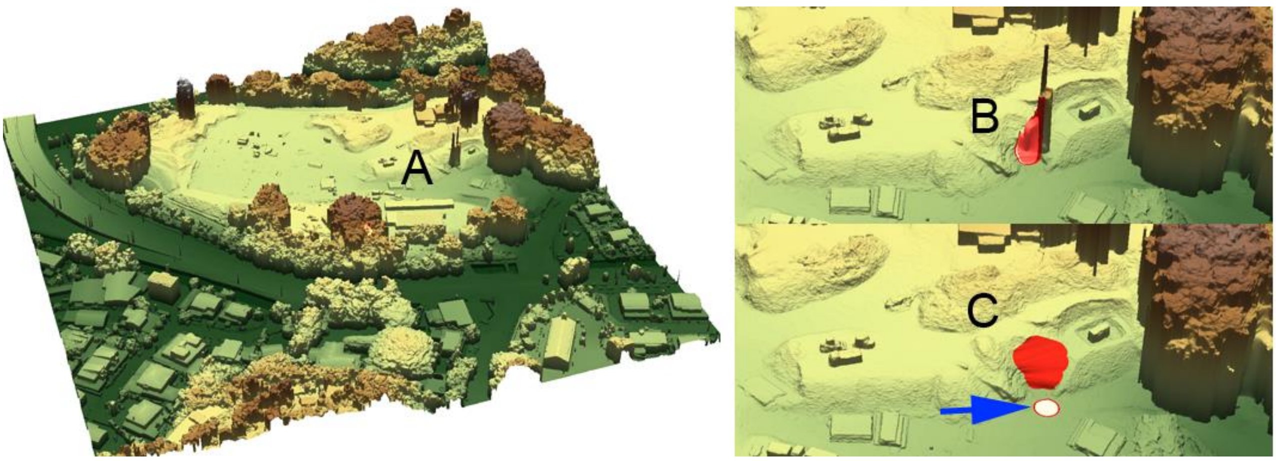

Figure 4: Example for the UltraMap Digital Surface Model. Pikes (region A on the left) are interactively eliminated (B and C on the right). The 3D cursor (flagged by blue arrow) is moving on the interpolated ground level.

6. CONCLUSION

The new innovative tools to the UltraMap photogrammetric processing chain open a new door towards efficient production and interactive quality assessment and quality control for large photogrammetric projects. Based on an intuitive user interface interactive investigations are well supported and the user is enabled to focus on his control task even if a huge number of up to 50.000 images and their parameters have to be inspected. In the same way, based on a three dimensional user experience we have designed the DSM editing tool. It significantly increases operator efficiency when creating high quality three dimensional description of the object surface.

7. REFERENCES

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