ULTRAMAP - DETAILS AND RESULTS FROM THE DIGITAL PHOTOGRAMMETRIC WORKFLOW

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ABSTRACT:

UltraMap is a fully integrated and highly automated solution for supporting UltraCam images at their best in order to deliver value for the customers. Image processing after the flight mission, automated aerial triangulation (AAT), dense surface reconstruction and ortho image mosaicking are the major components of the software package. The fully automated dense matching module strives for high precision digital surface models (DSMs) which are calculated either on CPUs or on GPUs using a distributed processing framework. By applying constraint filtering algorithms, a digital terrain model can be generated which in turn can be used for fully automated traditional ortho texturing.

By exploiting the generated DSM information, a DSMOrtho is generated using balanced input images. Again, seamlines are detected automatically resulting in an automatically balanced ortho mosaic. Interactive block-based radiometric adjustments lead to a high quality ortho product based on UltraCam imagery. In this contribution we show results from larger projects areas which were processed by UltraCam users. The quality of the result as well as the performance of the software during processing and QA/QC is documented in this contribution.

1. INTRODUCTION

The UltraMap Software product has been introduced as the digital workflow for processing digital aerial images from the UltraCam sensor family. Beside the proprietary functionality to managing the basic functions of data download and initial image processing, the implementation of the all-digital photogrammetric workflow was our target. The first photogrammetric function implemented into the software package was the UltraMap Aerial Triangulation function (UltraMap AT), including the automated tie point matching and the least squares bundle adjustment based on the well-known BINGO software solution. Based on the tie point matching result a radiometric function could be implemented. This is the Project Based Colour Balancing (PBCB) which serves as the radiometric block adjustment module.

In early 2013 the new release UltraMap v3 is offered to the market and includes a fully automated processing pipeline which allows processing UltraCam imagery to a digital surface model (DSM) including a *DSMOrtho* (ortho mosaic based on an automatically generated DSM). In addition, we offer a traditional ortho mosaic, which we call a *DTMOrtho*. As a side product our pipeline generates a 3D point cloud, which convinces with high geometric accuracy and a very high point density.

The ortho mosaicking workflow takes into account all available inputs (i.e. a DSM and also an automatically generated DTM). Thus UltraMap v3 is able to generate seamlines at desired paths (i.e. avoid passing through houses). The remaining seamline editing for challenging regions are fixed by exploiting our DragonFly technology (Reitinger, Hoefler, Lengauer, Tomasi, Lamperter, Gruber, 2008). DragonFly has been developed for interactively managing large quantities of digital image information. It is our responsive visualization engine for quality control and interaction with user experience for working with large photogrammetric projects.

It is worthwhile to mention that UltraMap is a tailored system for all images taken by one of the UltraCam digital aerial camera models and thus enables the user to establish an efficient and seamless photogrammetric production workflow at the best level. This includes the use of full radiometric resolution at the 16 bit level as well as best practise geometry processing by the UltraMap aero-triangulation module.

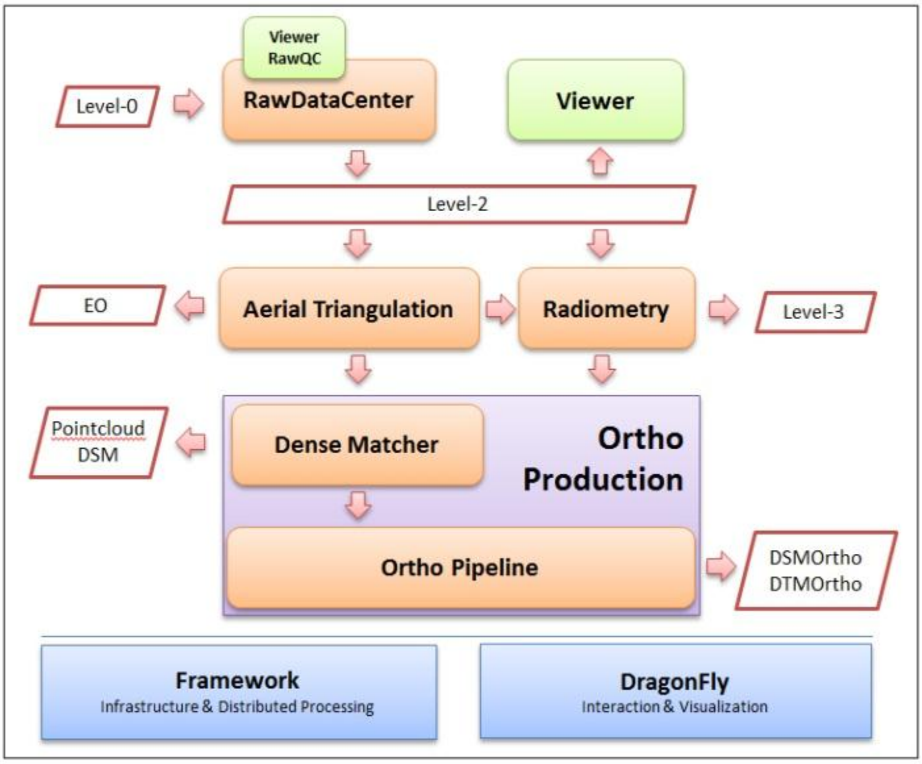

Figure 1: The UltraMap V3 processing pipeline.

Figure 1 shows an overview of our UltraMap v3 processing pipeline. The main components are the

RawDataCenter which is responsible for processing the UltraCam imagery into a so-called Level-2 data format. This data contains the digital negative of the camera (radiometrically and geometrically calibrated);

The *Aerial Triangulation* (AT) module offers the functionality for calculating image correspondences in order to generate a precise exterior orientation for a whole image block and the least squares bundle solution;

The *Radiometry* module offers interactive functions to manually improve the radiometric appeal of images and includes the Project Based Colour Balancing software – a fully automated radiometric mosaicking approach;

The *DSM Generation* module takes the Level-2 images including the precise exterior orientation information and generates per-pixel height values;

The final *Ortho Generation* module takes all available inputs (i.e. Level-2 imagery, AT result, radiometric settings, and the DSM/DTM) in order to generate the final ortho mosaic.

2. FULLY AUTOMATED ORTHO PIPELINE

2.1 Dense matching and fusion

The dense matching process searches for corresponding image positions in a pair of images in order to compute the 3D position of the specific match point by means of the stereoscopic approach (shape from stereo). As a prerequisite, the exterior orientation and the interior calibration of the camera must be known. In order to establish correspondences, image-based correlation methods are used (e.g. normalized cross correlation). The result of the stereoscopic pairwise dense matching approach is a range image which contains the intensity coded disparity values of a single image pair.
The following step performs a range image fusion which takes all generated range images and calculates on the one hand side a 3D representation (i.e. a point cloud), and finally a 2.5D height field known as the digital surface model. The range image fusion can be formulated as a global optimization step minimizing an objective function.

Figure 2: Point cloud generated from pairwise image matching and range image fusion.

As a side product we offer to filter the DSM (Digital Surface Model) in order to create the DTM (Digital Terrain Model). This processing step is managed by applying a constrained filter operation. A gradient-based approach allows us to filter out buildings and single trees while preserving other terrain structures. This dataset is then the basic information to generate a DTMOrtho in a fully automated way.

2.2 Ortho rectification

The ortho image rectification is the first step in the UltraMap ortho pipeline and performs the re-projection of the input images onto a defined map geometry. This process can be understood like mapping onto a virtual image plane which by means of parallel rays. Those rays are intersected with the scene and therefore generate a 2.5D surface. The process of generating an image from a new viewpoint is also known as image-based rendering. Due to the fact that one input image can only cover a certain area of the ortho projection, some regions are occluded (i.e. from buildings or other objects on the terrain). For these occluded regions we exploit the redundancy within the set of overlapping input image data take the radiometric (colour) information from neighbour images.

2.3 Seamline generation

After the ortho rectification process, the next step is to find seamlines between projected ortho patches. This step is also known as contribution mask generation, since the contribution mask is the dual structure to the seamlines (see Figure 3). Seams correspond to transitions from one input image to another one. This process can be defined as an objective function, where the minimization can be reformulated as a function of the sum of unary and binary costs. This function incorporates the viewing angle of the input image including the colour differences. The optimization for finding the best path is done by applying a graph-cut (Kolmogorov & Zabih, 2004) algorithm.

Figure 3: The colour coded contribution mask is a guide to the source images which are used for a specific region.

2.4 Ortho compositing

The final step of the ortho image generation after the geometric resampling is the so-called blending procedure. Although project-based colour balancing is applied to the input images, a final smooth blending is still necessary. For smooth blending of the tile patches, we use a method which was proposed by Uyttendaele et al. (Uyttendaele, Szeliski, & Steedly, 2011).

3. PROCESSING ENVIRONMENT

The UltraMap v3 processing pipeline is able to handle large quantities of digital image data and exploits the benefit of high level image processing technologies. Thus the computing environment needs to fit well. UltraMap offers support for different processing environments like scalable CPU clusters or dedicated GPU nodes. Especially the DSM/ortho pipeline includes parts were intensive computing is required. Thus it is beneficial if both options are available.

Nevertheless the GPU based approach speeds up these intensive parallel computing tasks because the dense matching is best suitable for a SIMD architecture such as graphics cards. Figure 4 shows a potential configuration of an UltraMap v3 system. The newly introduced “resource intensive” machines strive for high performance, since an entire machine can be used to work on one task at a time. In order to synchronise with the actual set up configuration, “resource intensive” machines can either be configured as CPU-only or as GPU-enabled nodes.

The front-end machine is used to interact with the data and is not designed for processing. A very import part of the processing environment is the network which is required to transfer the data most efficiently between processing nodes and disk storage.

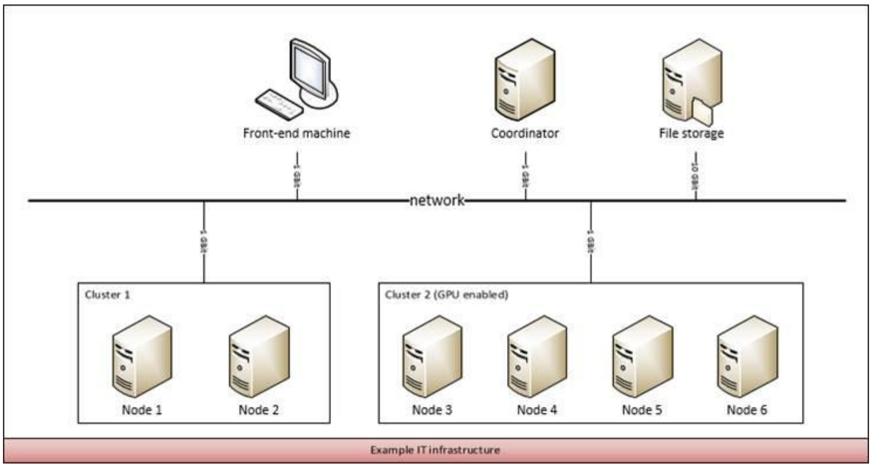

Figure 4: Example for the UltraMap V3 processing environment.

4. VISUALIZATION AND INTERACTION

4.1 DragonFly technology

Since the beginning of UltraMap, DragonFly is the technology which is used to interact with large amount of UltraCam image data (Reitinger, Hoefler, Lengauer, Tomasi, Lamperter, Gruber, 2008). DragonFly is based on a technology called Seadragon which is a Microsoft technology also built-in into other products (e.g. DeepZoom, Zoom-It, or Photosynth). For UltraMap v3, we introduce some more extensions and enhancements of the existing DragonFly technology. On the one hand side, we worked on optimization and improved user experience in order to have a smooth rendering of the processed ortho tiles. On the other hand side, we are able to exchange image content on the fly. This is required for any modification on the image data (i.e. modifying the DSM/DTM or the contribution mask).

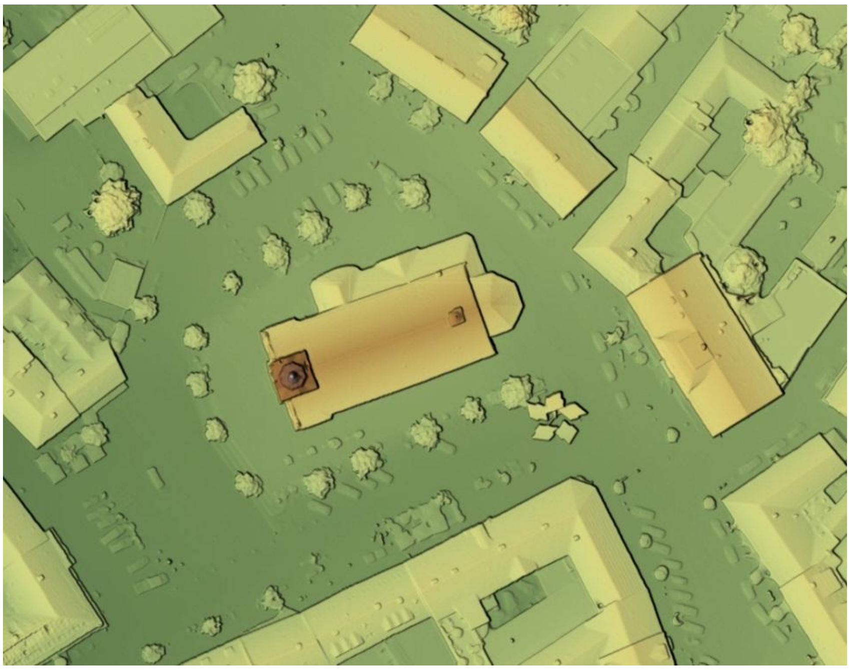

Figure 5: On-the-fly relief shading of a generated DSM which is one feature of the DragonFly technology.

The ortho application, which is the main user interface for working with ortho data, uses DragonFly for visualizing all data generated. By exploiting shader code on the graphics card, we are able to interactively blend between the DSMOrtho and the DSM. This allows for quick quality controls and data interpretation while evaluating the quality of the dense matching result. The shader is also used to control the final radiometric tone of the image block. Another feature of using shader code is to do relief shading based on DSM data (Figure 5).

5. RESULTS

The UltraMap v3 ortho processing algorithms already show up a long testing and production phase. In the last years, Microsoft produced a full US coverage and almost a complete European coverage of 30cm ortho imagery based on UltraCam technology.
Beside that kind of median scale imagery we have been able to deliver high quality results from large scale high resolution images.
Figure 6 shows an example of a DSM and DSMOrtho provided by City of Graz. The presented dense matching approach allows for reconstructing the heavy machines. They are shown with precise and sharp edges. The project was flown with a UC-Xp at 3cm GSD and with 60% forward and 60% sideward overlap.

Figure 6: DSM and DSMOrtho screenshot showing a gravel pit and heavy machines (data courtesy of City of Graz).

Figure 7 shows a different example of a DTMOrtho which was also generated in an automated way without any user interaction. The dataset was also flown with a UC-Xp at 3 cm ground resolution. The DTMOrtho was projected on an internally generated DTM using the presented constrained filter approach.

Figure 7: DTMOrtho showing the main terminal of the Airport Graz (left) and on the right the detail with the Airport Tower (data courtesy of City of Graz).

6. REFERENCES

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