THE POWER OF MULTI-RAY PHOTOGRAMMETRY - ULTRAMAP 3.0

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ABSTRACT

Starting 2007 a dense matching algorithm and an automated ortho/true-ortho workflow has been developed by Vexcel Imaging GmbH that has exclusively been used for the automated 3D city model production of Microsoft’s Virtual Earth project and is now also in use for the production of the current BING maps platform. This famous automated workflow has now been disclosed and has been implemented into UltraMap 3.0. This makes the workflow now commercially available for all UltraCam users world-wide. The dense-matching algorithm generates very dense surface models from overlapping aerial images by multi-ray photogrammetry, superior to airborne Lidar collection. Based on the results of the dense matcher, an automated workflow generates ortho images and true-ortho images automatically within UltraMap 3.0. The paper shows the new UltraMap 3.0 workflow, the results of the automated dense matching such as point clouds and DSM and the results of the automated ortho and true-ortho workflow.

ULTRAMAP

In 2010 UltraMap Version 1.0 has been announced as the new software for the image processing for the UltraCam camera series. It supports all UltraCam cameras and extends the workflow into a full photogrammetric workflow by a seamless integration of aero triangulation and bundle adjustment functionality into the existing image processing workflow.

UltraMap is designed to handle all kind of projects ranging from projects with a few hundred images up to projects with ten thousands of images and it is optimized for UltraCam images. For this, it implements a new, revolutionary technology and concept of image handling, a direct spin off from the latest available Microsoft technology. Outstanding features such as automated distributed processing, automated tie point matching, monolithic stitching and project based color balancing have been implemented since its release. The figure below shows the basic modules and the basic workflow of the current UltraMap software.

![UltraMap Modules](image)

**Figure 1.** UltraMap concept and modules.
With the upcoming version of UltraMap 3.0 two new modules will be added. These two modules provide revolutionary new features, namely the automated generation of point clouds, DSM, DTM, DSMOrtho and DTM Ortho from a set of overlapping UltraCam images. Results from the basic image processing and the aero triangulation are used by the new modules to generate a point cloud, then a DSM, then a DTM and then two different ortho images, the so called DSMOrtho (images rectified by a DSM) and DTMOrtho (images rectified by the DTM).

The processing is being kicked-off automatically after the aero triangulation and fully supports the automated distributed processing and the full 16-bit workflow. The new modules support processing on GPU(s) if available in the system. Visual output and QC are smoothly integrated into the existing viewer.

**DENSE MATCHING and 3D POINT CLOUD**

A significant change in photogrammetry has been achieved by Multi-Ray Photogrammetry which became possible with the advent of the digital camera such as UltraCam and a fully digital workflow by software systems such as UltraMap. This allowed for significantly increased forward overlap as well as the ability to collect more images but virtually, and without increasing acquisition costs. However, Multi-Ray Photogrammetry in a first step is not a new technology; it is a specific flight pattern with a very high forward overlap (80%, even 90%) and an increased sidelap (up to 60%). The result is a highly redundant dataset that allows automated “dense matching” to generate high resolution, highly accurate point clouds from the imagery by matching the pixels of the overlapping images automatically.

The 3D point cloud generated by the dense matcher of UltraMap has a point density of several hundred points per square meter and thus is much denser than any airborne Lidar scanning point cloud.
Figure 3 shows the point cloud generated by UltraMap based on a set of overlapping UltraCam images. The point density is around 300 points per square meter. For better visualization only a quarter of all points are shown.

The achievable height accuracy of the point cloud is better than the GSD, thus a 10cm imagery leads to <10cm height accuracy of the resulting digital surface model. The quality of the automated dense matching process depends significantly on the camera and the structure of the terrain. Geometric stability and radiometric dynamic of the camera have a direct impact on the matching results.

**DSM AND DTM**

Once the DSM has been processed out of the images, the DSM and the original image can be combined in a true-ortho projection which results on a so called true-ortho image. This is an image with no perspective view as each pixel of the image has been (true-) ortho rectified by a surface model and not by a terrain model like the standard ortho image. True-ortho images have a significant benefit in some applications as they do not have any leaning objects.

Figure 4 shows the shaded relief of a DSM which has been generated from the point cloud. Remarkable is the high level of detail and also the very sharp building edges. The white spot at the lower left corner is the church tower shown in detail in figure 3.
The next step after the DSM generation is the processing of a DTM. The DTM will be processed out of the DSM using a “Winston-Salem” algorithm developed by Microsoft which utilizes computer vision based classification for the terrain filtering. Figure 5 shows the DSM (left) and the filtered DTM (right).

Figure 4. DSM generated from the point cloud by the UltraMap dense matcher module

Figure 5. High-resolution DSM (left) and DTM (right) processed using automated dense matching with UltraCam images and UltraMap processing software.
DSMORTHO AND DTMORTHO

An additional new UltraMap 3.0 module then combines the image data and the DSM or DTM and generates automatically either a DSMOrtho or a DTMOrtho image including automated seamline generation. Figure 6 shows a DSMOrtho image, figure 7 a DTMOrtho image.

Figure 6. High resolution DSMOrtho, generated automatically by UltraMap.

Remarkable are the very sharp edges of the buildings and the high level of details of the roof structures with literally no artifacts of the DSMOrtho. The reason is the outstanding quality of the underlying DSM thanks to the high point density of the point cloud.

Figure 7. High resolution DTMOrtho, generated automatically by UltraMap.
The DTMOrtho is the traditional ortho image, processed by rectifying the images with a terrain model. The seam lines have been generated automatically by using information from the image content and also from the height field.

**CHANGE IN THE INDUSTRY**

We expect a significant change in the industry with the release of UltraMap 3.0. The software enables UltraCam users to generate 3D data in addition to the images by a highly automated workflow. This makes additional airborne Lidar scanning obsolete for many applications. Further strong are the significantly higher collection efficiency of the UltraCam compared to any airborne Lidar scanner and the much higher point density. The strip width of the UltraCam is around three times bigger compared to a Lidar system and the point density is around 30 times higher. As the 3D data is generated from the images, the data sets are consistent which is not the case if a Lidar system is flown in addition to a photo flight. Dense matching is especially strong for DSM related applications and provides superior efficiency and quality here. Vegetation penetration is not possible, high resolution terrain models in forests for example would still require a Lidar flight.

Today’s application landscape could be visualized like shown in figure 8:

![Figure 8](image_url)

**Figure 8.** Today’s application landscape, differentiated between airborne Lidar and photogrammetry.

With the release of UltraMap 3.0 we expect that many applications will be served better by photogrammetry. That will lead to a change as shown in figure 9:
Applications such as Urban Mapping, Mining, National Mapping are much better served by photogrammetry in the future. Forest applications might still require the use of both technologies; the terrain model could be flown every several years by an airborne Lidar sensor system whilst the annual flights to map the canopy for the change detection are server better by photogrammetry.

REFERENCES