PHOTOGRAMMETRIC SOLUTIONS OF NON-STANDARD PHOTOGRAMMETRIC BLOCKS

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ABSTRACT

The use of small and medium format sensors for traditional photogrammetry presents a number of prominent challenges. The relatively small footprint usually leads to a larger number of images which need to be processed. Traditionally this fact has limited the use of small and medium format sensors to simple projects of small and unchallenging areas. Additionally users are forced to rely on the accuracy of the external orientation data measured at capture.

This paper will describe the use of the Icaros photogrammetric suite (IPS 2.1) with an extreme example of a difficult project captured with a small format sensor.

The object of this paper is to demonstrate how the Icaros software enables the use of small and medium format sensors in large and difficult photogrammetric projects with high accuracy requirements.

KEYWORDS: Aerial Triangulation, Automatic tie points, Photogrammetric automation, systematic error, Non-standard photogrammetric project

INTRODUCTION

As mentioned above, the use of small and medium format sensors can present many challenges and limitations. As a direct result of the problematic base to height ratio of small format sensors it is usually necessary to collect data at a higher resolution than needed in order to achieve the desired accuracies. This leads to a very large quantity of images per area unit. Not only does this raise the cost of data acquisition, but it also increases the cost and time of the photogrammetric process. Processing such a project in the traditional photogrammetric workflow requires a large team of skilled operators, powerful hardware and high quality project management. This fact has encouraged most companies using small and medium format sensors to avoid the traditional photogrammetric workflow and apply direct geo-referencing techniques. This requires the use of high precision IMU and GPS systems to generate telemetric measurements of the external orientation data at the time of capture. These systems are extremely expensive and have very limited export licenses. Presuming a company was able to acquire the necessary licenses to purchase these expensive systems, they are still susceptible to systematic and random errors such as drift and satellite blockage. Low quality orientation data can be corrected in the aerial triangulation stage usually with manual editing. As a result difficult flight conditions or inherent system errors will result in low accuracy of the end product or time consuming manual editing in the AT stage. In this case the images might not be useful and the flight will be repeated, this can cause costs to exceed the project budget.

The accuracy of the aerial triangulation process and the accuracy of the final product are highly dependent on the quality and coverage of the extracted tie-points. Late advances in the field of computer vision have lead to new extraction and matching schemes that are less dependent on accurate mutual orientation reducing the need for high accuracy GPS and IMU systems.

Early this year (2011), Icaros was approached by an Israeli surveying firm that already photographed a project in Botswana Africa using a medium format sensor. The firm approached Icaros after two years of failed attempts to process the project themselves. The photogrammetric block would not converge with the using their traditional tools making it impossible to extract a DEM and create an Ortho-photo.

Icaros succeeded in converging the block and producing a high quality Ortho-photo within two working days.

This paper will summarize the unique Icaros technology which made it possible to complete this challenging project and focus on the AT process in the Icaros IPS2.1 software suite mainly the automatic tie-point extraction and bundle-block adjustment modules, MatchMeTM and Solution ManagerTM.

TECHNICAL DATA

<u>Sensor:</u> 39 Mp with a 35mm focal lens.
<u>Stabilization:</u> 3-axis automatic stabilization.
<u>IMU:</u> The payload contained a high accuracy IMU however due to a serious technical malfunction the measurement was highly unreliable.

Project Details

Number of images in the project: 1500.
Resolution: 10cm.
Number of ground control points: 200.

Control Point Distribution

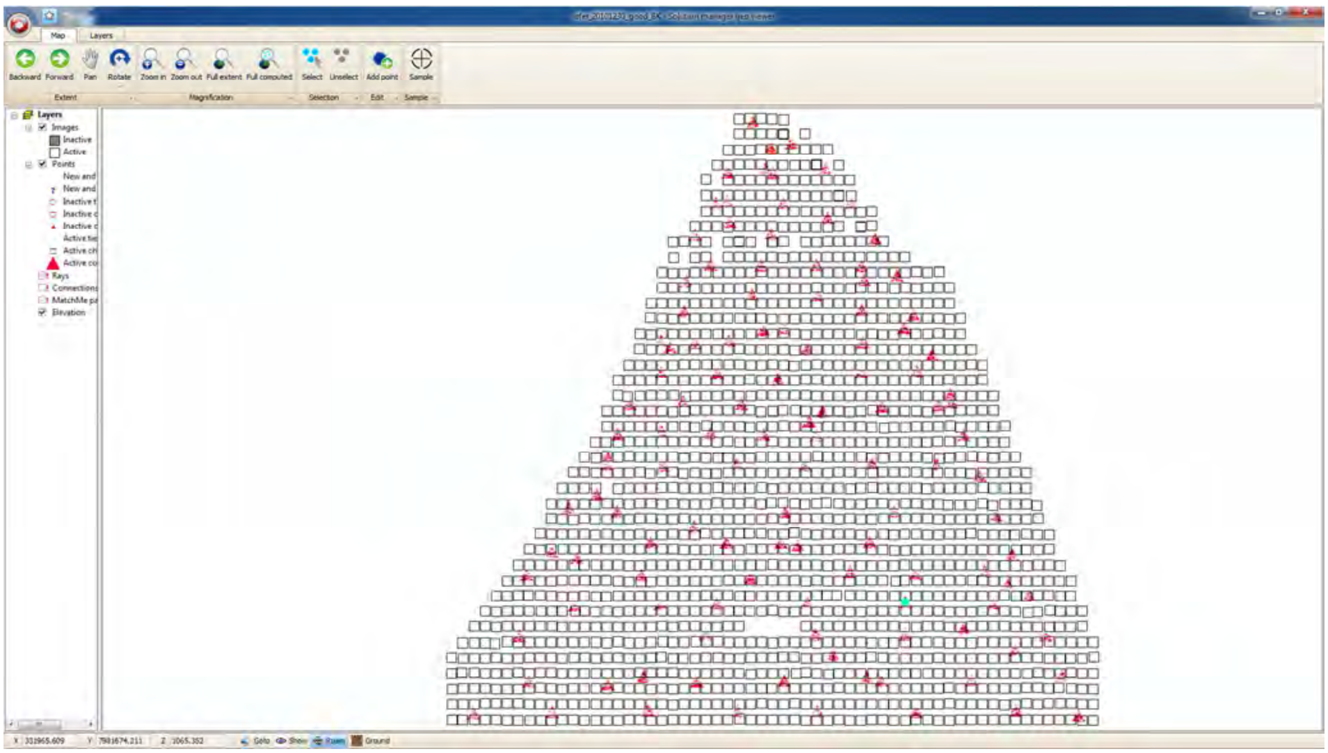

Figure 1. Control Point Distribution.

Aero-triangulation

Aero-triangulation was performed with the Icaros MatchMe™ and Solution Manager™ proprietary software modules. MatchMe™ offers a unique tie-point extraction approach based on innovative vector representation of image points. The MatchMe™ Module implements several algorithms including interesting point extraction, fast interesting point matching, and several steps of geometric filtering that ensure 100% capture of correct tie points.

To increase efficiency and streamline the process the extraction phase is performed in the original image scale without any need to downscale the image dimension. MatchMe™ uses a unique descriptor found to be more efficient in the case of aerial images. This framework is especially efficient for matching large groups of images.

Applying these algorithms effectively yields thousands of tie-points without any outliers. The tie-points with the highest contribution to the geometric stability of the block are selected by a projective driven mechanism. The selected points are then imported into the Icaros bundle block adjustment software (Solution Manager™).

The bundle block adjustment process applies a state-of-the-art numerical approach. The adjustment includes another outlier detection algorithm (as a "triple-check") in order to filter-out slightly inaccurate tie-points.

Major Features of the MatchMe™ Module:

- **No human intervention required (negligible errors!):** Icaros' tie-point correlation process has no major errors. As a result, the solution process is streamlined, and productivity increases **dramatically**.
- **No extra data is needed (e.g. rotation, scale, orientation,):** The Icaros correlation component requires no orientation information about the aerially captured image. Although all images are adequately stabilized and measured by the Icaros stabilizer, the MatchMe™ module guarantees that image capture is not unusable in the event of a malfunction of the aerial equipment, or challenging weather conditions.
- **Thousands of tie-points per image-pair:** Contrary to other triangulation methods that use a small number of points, Icaros' triangulation process identifies thousands of good points and selects the points that passed fine geometric filters.
- **Intelligent filtering based on robust geometric statistics:** The tie-point acquisition process contributes to total system automation by filtering out inaccurate points before they enter the bundle block adjustment process.
- **Indifferent to misleading regions (e.g. clouds, lakes…):** Icaros' tie-point correlation process is not affected by homogenous areas, such as clouds. In such cases, the correlation process bypasses the white area and correlates only the interesting areas.
- **Fast (~10 sec per image):** multi-core & GPU technology used.

Major Challenges in this Project

1. Problems in the heading measurement caused some of the images to rotate up to 180 degrees. The rotation was not constant and occurred randomly; in one line we found a spectrum of kappa angular inaccuracies from less than one degree to 180 degrees.
2. Large visual (radiometric) differences between images that were captured at different dates and different illumination conditions; the differences were so large that in some parts of the project even a skilled operator could not detect mutual features in two overlapping images.
3. Due to hard weather conditions some of the images omega and phi angles, where large (±18° from nadir) resulting in poor overlap in some areas and weakening the geometric strength of the block.
4. Some of the image GPS centers had inaccuracies of more than **200** meters (the largest image inaccuracy was 250 meter).

The conclusion of all these problems was that the mutual orientation of this block was totally inacceptable; however there was no way they could repeat the flight, so this block needed to be converged and solved, extract DTM and finally Ortho-rectified and mosaiced.

Tie-Points Extraction

Tie points where extracted with MatchMe™; in this project MatchMe™ unique approach was very significant due to the poor mutual orientation that was measured during the flight and the differences between the images due to different flight dates.

MatchMe™ tie points correlation does not need external orientation in order find **correct** tie points. MatchMe™ uses the X, Y coordinates to determine neighboring images; this is done mostly in order to save time. Finding tie points between images is a time consuming process therefore there is no reason to correlate images that definitely will not have any connections.

Tie-Point Extraction Results

Each line represents the connection between two images made by shared tie-points. A thicker line means more shared tie-points between the image pair.

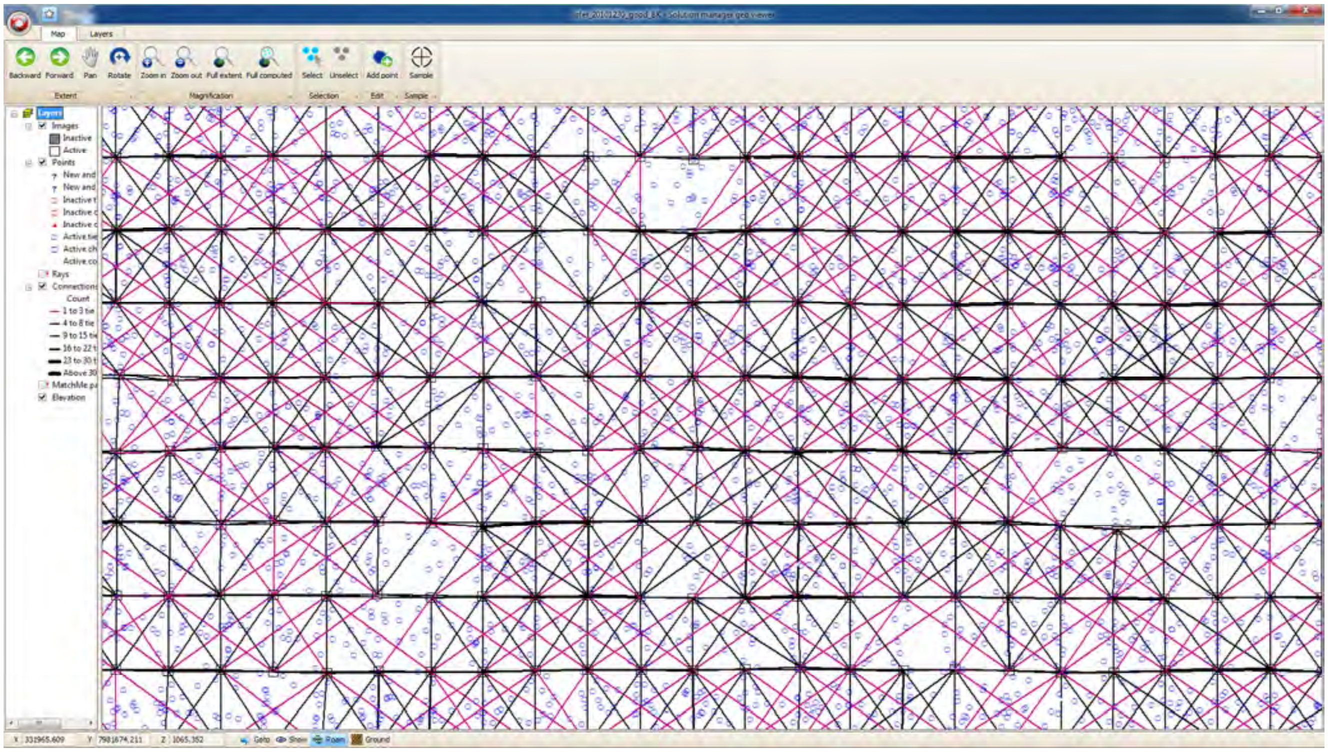

Figure 2. The Strength of the Block Automatic Tie-Point Done by MatchMe™.

Bundle Adjustment Process

After connecting all images with sufficient amount of tie points Icaros started the solution process; here, another challenge appeared; images that had kappa inaccuracies of up to 180^0.

While MatchMe™ can extract **correct** tie points without external orientation, Solution Manager™ (Icaros solution engine and interactive point measurement) cannot converge and compensate these huge gaps and Icaros needed to detect these images and rotate them back to their approximate correct kappa.

Identifying the rotated images can be done manually, however this might take a long time since the images inaccuracies where random and the photogrammetrist have obscurity of which image to rotate and where these images are (reviewing over 1500 images is a long process).

Icaros used, for this mission (rotation of the inaccurate kappa value images), the special characteristics of MatchMe™ and Solution Manager™. After the first iterations of the solution process, some tie points had high residual pixels, yet we know that MatchMe™ have negligible amount of outliers. After thorough examination all of the high residual tie points appear on the images with inaccurate kappa values.

After understanding that rotated images exist we needed to determine what image to rotate; Solution Manager™ has many fields that are collected during the solution, one of the data sets collected is the kappa difference between the airborne measurement and the solution adjustment to the angle. In the inaccurate images the photogrammetrist could see the kappa trend of the image; after rotating it to the right kappa angle the images where converged adequately and the final pixel RMS was 0.764; Icaros discovered 46 images out of the 1500 that were completely (~180°) rotated.

Solution Manager™ uses an adaptive weighting function that enables the user to converge very difficult blocks, or in the typical cases gain better accuracies.

An adaptive weighting function strengthens the weight of the low residual tie points and weakens the weight of the high residual tie points. In this particular project the high residual tie points were located mainly in the areas of the inaccurate kappa value images; the fact that the photogrammetrist rule out the option of many outlier tie points due to the way MatchMe™ works, led him immediately to understand that one of the external orientation parameters (in our case the kappa angle) is radically incorrect and attend the problem.

RESULTS

The whole solution process took 2 working days and included sampling control points and running an automated DEM extraction. Final pixel RMS was 0.764 and vertical accuracies met the client's requirements that were vertical accuracy of 50 centimeters and positional accuracy of 35 centimeters.

In a thorough quality assurance stage, we found adequate geometric stability with maximum height differentiation between neighboring stereo pairs of 40 centimeters, what led to an adequate creation of DEM and Ortho-photo.

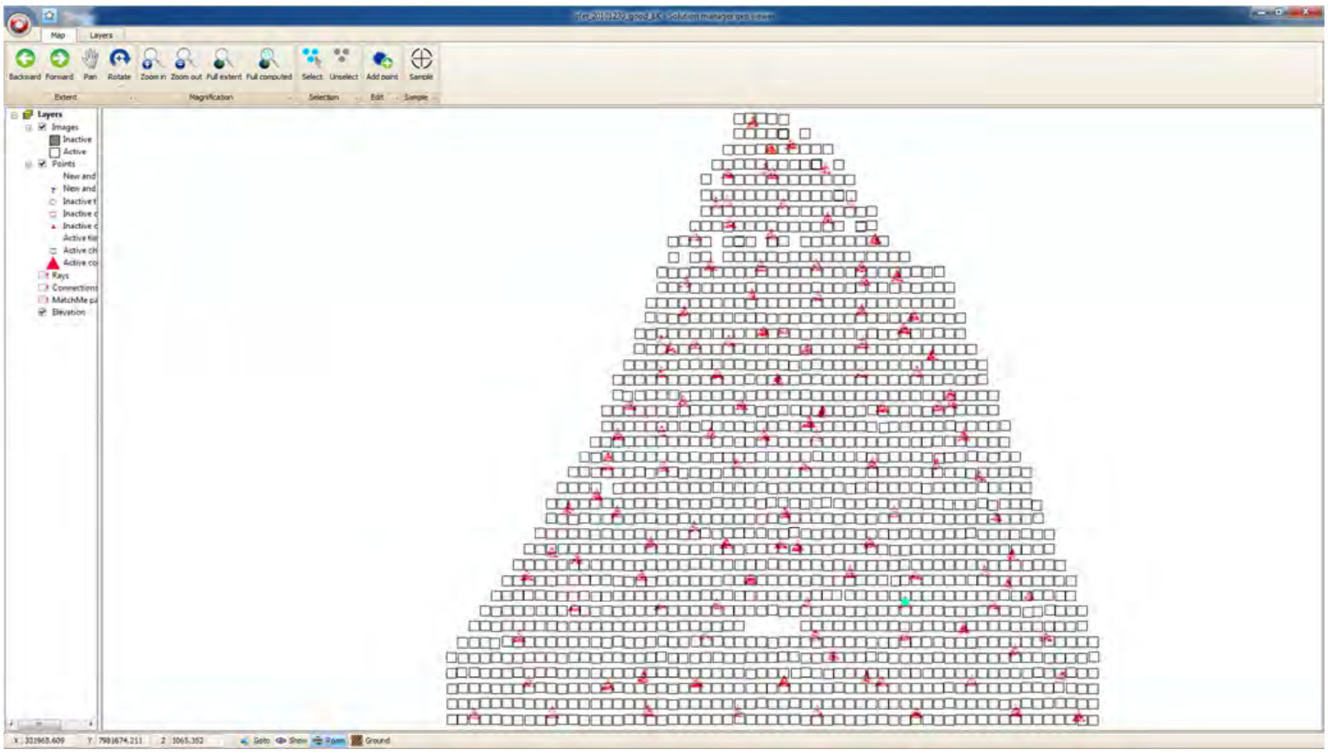

Figure 3. Spatial Distribution of the Control Points.

SUMMARY

This photogrammetric project was challenging due to inaccuracies in the external orientation measured during capture, the quality of the images and the visual differences; yet Icaros succeeded in converging and solving this project within a short time making this project cost-effective despite the inferior starting point.

The ability to firmly know that the automatic tie point's correlation has negligible errors despite the fact that mutual orientation quality is poor and adaptive weighting function that enable the block to converge from a challenging starting point, made this project a success both from the time it took to solve the project and the results that met the accuracy standards required by client.

One might argue that a typical flight with adequate inertial navigation system data would make these abilities unnecessary and that classic automatic tie point's correlation based heavily on mutual orientation will work with the same level of automation; however the harsh reality of airborne systems create all kinds of malfunctions especially in large projects where thousands of images have been photographed.

Another important capability of the Icaros IPS2.1 is its ability to manage and solve thousands of images in a single block avoiding multi-block solution. The ability to firmly know that the automatic tie point's correlation has negligible errors regardless of the type of area that the software is trying to correlate, enable the photogrammetrist to solve efficiently thousands of images in on block. Reducing the amount of photogrammetric blocks shortens the time it takes to produce the project, reduce the amount of ground control points and gain better accuracies.

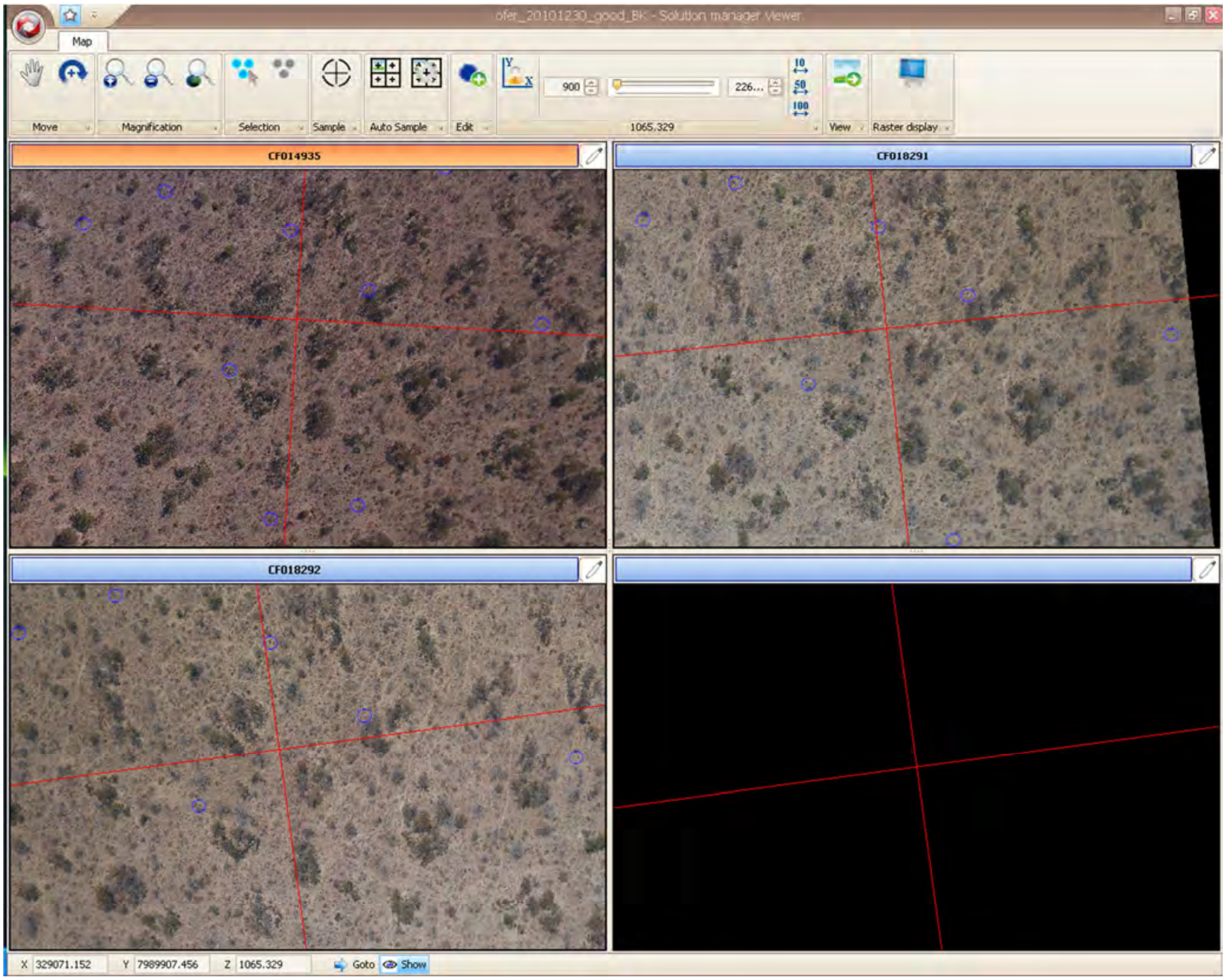

Figure 4. Mutual Tie-Points Extracted Automatically Shown in Solution Manager™ After Block Adjustment.