

LONG FOCAL LENGTH IMAGING FOR PHOTOGRAMMETRIC RECONSTRUCTION

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ABSTRACT:

The following paper describes a method to capture high quality image data for the use of photogrammetric reconstruction techniques. The main principle is to use long focal length to capture immense amount of spatial and radiometric detail. The method was tested at two mediaeval building sites, the Olavinlinna Castle in Savonlinna and the Church of the Holy Cross in Hattula.

Long focal length is typically not used in photogrammetry because it results in poor Field of View (FoV) which in turn leads to poor resections because of inadequate geometric quality. Therefore the use of panoramic imaging techniques is proposed to be used together with long focal length to capture both the high spatial and radiometric quality image with wide enough FoV to overcome the geometric problems.

The added value is that the photos can be taken from long distance without reducing the amount of detail. In the case of one of our test sites, this is essential because the castle is surrounded by waters. However, the method can also be used for shorter imaging distances if a high amount of detail is desired.

1. INTRODUCTION

The goal of the project was to develop a novel concept of 3-D model creation for the Finnish National Board of Antiquities which they could use independently to model various cultural heritage sites in Finland. The developed method exploits long focal length to capture immense amount of spatial and radiometric detail using a digital camera. This paper describes the preliminary results and test methods from the Olavinlinna castle which is the main test site for the long focal length panoramic imaging method. The method was first tested on smaller scale at Hattula Holy Cross Church but there we used a shorter focal length to capture the scene and as such it will not be described here in more detail.

Olavinlinna, the castle of St. Olav, is located on a small rocky inlet in Savonlinna, in the Province of Eastern Finland. The castle was founded in 1475 to protect the eastern border of the kingdom of Sweden in an area, where the interest of the Swedes, Novgorodians and Muscovites met. The mediaeval castle was built in three main phases and finished in the first decade of the 16th century. Over the years the structures of the castle have changed several times as a result of warfare and renovations. The last major renovation was conducted in 1961-1975 according to the principles of the 1964 Venice Charter. (Sinisalo 1985.) For the past decades the castle has been a tourist attraction and during the summer it has served as the venue of the Savonlinna Opera Festival. The constant use has worn down the buildings and new repairs are needed to ascertain security the structures.

The past renovations have produced a great amount of manual drawings, plans and photographs of the castle, but now it has been decided to use computer-based methods for the

documentation. The aim is also to create a dimensionally accurate digital model of the whole building complex which can be used for various purposes including planning and visualisation of the castle. The documentation of the outer wall has been started using panoramic photography (Fig. 1). The high resolution texture of the composite photographs is needed, because the aim is to avoid erecting scaffolding. The photographic distances vary between 50-400 meters and most of the photographs have to be taken across water.



Figure 1. Overview of the Olavinlinna castle and one of the metric panoramic images

2. METHODS

In most photogrammetric applications, the photos are taken with a wide angle lens to enhance the geometric accuracy by forcing a larger recession angle. However, if the sensor is kept the same, the resolution might be too low to capture the amount of detail needed for the application. Usually the solution is to get closer to the subject (Luhmann, 2006). In our case this would not be feasible because the subject is surrounded by water. Using a boat would be possible but as the river has strong currents, navigating to correct camera stations and keeping the boat stable would be very hard.

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Another problem is the size of the subject. The Olavinlinna castle is quite large, yet it has small details on the walls that need to be documented. If the photos were taken from a short distance, we would need to compromise between the amount of detail and good coverage. On the other hand we could have taken the photos in such a way that only a part of the castle would have been visible on a single frame. This approach could have easily led to confusion during the processing, because it would have been hard to distinguish the differences between images.

The proposed approach uses long focal length to capture the required amount of detail while the photos can be taken from a distance. This also enhances the stereoscopic disparity to be linearly dependent on the shooting distance rather than the distance squared if the focal length is increased respectively (Haggrén, 2004). However such a camera setup raises a concern about resection angle accuracy. Long focal length imaging results in a narrow FoV of as small as 4.2° in the case of a 300mm lens with a $4/3''$ sensor for example. This causes problems in orienting the photos and leads to poor reliability. Another problem is that it is hard to comprehend which part of the wall the single photo is from.

2.1 Panoramic Imaging

The solution is to use panoramic imaging techniques to merge the long focal length photos from each camera station into corresponding panoramic images. Before constructing the panoramic images, the subframes can be sorted by capture time and tagged with GPS location data to make it easier to figure out which images belong to a particular camera station. This makes it easier to later comprehend the scene because by using such high resolution panoramic images, we can reduce the amount of the camera stations needed.

The images are captured using a custom made panoramic head which allows the camera to rotate around the projection center. Usually this kind of solution would be used to make a spherical panorama, but here we want to construct a rectilinear projection because then the photos can be used in commercial close range photogrammetric software such as Photomodeler Scanner (Haggrén, 2004).



Figure 2. Panoramic head mounted on a standard geodetic tripod

The goal is to make the process as automated as possible. For panoramic stitching we use PTgui because it can automatically detect the feature points needed to construct the panoramic image. By using PTgui, it is also possible to detect poor feature points and eliminate them by just looking at the RMS-values from the point quality table. This proved feasible in practice as the points with poor RMS-values were in most cases detected from moving subjects such as trees. Another advantage in using PTgui is the ability to use open source Panoramic Toolbox when calculating the panoramic projection.

2.2 Camera calibration

Before the metric panoramic image can be made, the accuracy of the internal orientation of the camera must be considered. If the long focal length photos are merged into panoramic image without first calibrating the camera, the final image will include the error distributed unevenly. Thus calibrating the panoramic image, once it is exported from the PTgui, is unfeasible. This is solved by determining the calibration parameters of the camera from long focal length photos before, and during merging them into panoramic image. For this we use a special calibration wheel and built-in PTgui features.

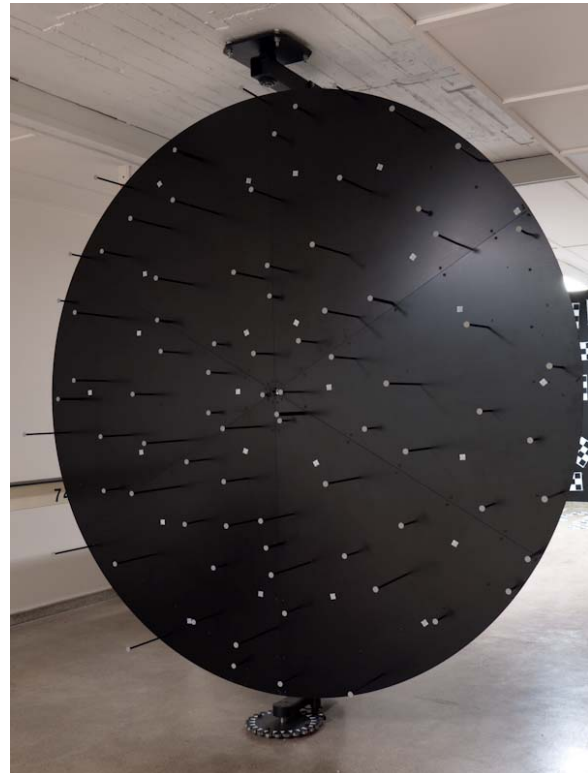


Figure 3. Calibration wheel

The wheel consists of 80 known targets which are mounted on an aluminium plate that can be rotated around two axis. The reflective targets are placed on top of columns of different heights. This is done to avoid correlation problems when finding out the orientation of the photos. Every time a photo is taken, the wheel is rotated 90° and on every fourth rotation, it is rotated 15° around the other axis. As the targets and the wheel are rigid, this approach effectively generates a hemisphere of camera stations as shown in the figure below. The wheel is located in the resection point of the imaging rays (Fig. 4).

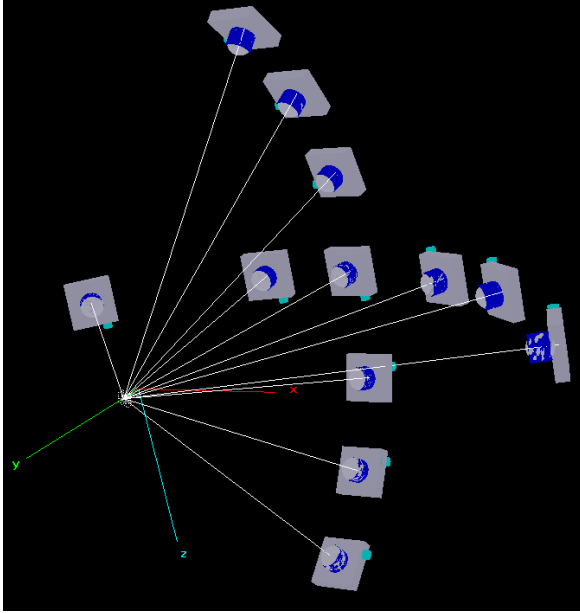


Figure 4. Calibration wheel camera station geometry

The above process is especially important for long focal length calibration. A good resection angle on the target is needed because it is impossible to have a large angle on the camera side as the FoV is so narrow. Another advantage is that we do not need to move the camera station, so it is possible to calibrate the camera from a long distance without moving. This allows the calibration to be carried out for example in a narrow hallway and still approximately maintain the shooting distance that will be used on the field. In this case we used a calibration distance of 65 meters. A similar approach could be used for calibrating aerial cameras. To keep the goal of automated processing in mind, the Callback feature in Australis software is applied to detect most of the points visible on the calibration wheel. Coded targets are currently not used so we have to manually measure a few points for each calibration image in order to use the Callback. We plan to automate the calibration process in the future.

3. RESULTS

3.1 Metric panoramic image measurements

We were able to capture the detail of the castle in centimeter precision from up to 400 meters distance (4 cm RMS) using imagery from low cost digital cameras (Fig. 5). In the case of St. Olav's castle, this is essential because the subject is surrounded by water. However, the method can also be used for shorter imaging distances when higher amount of detail is desired.

In practice the calibration was successful and we were able to measure the needed parameters. However we found out that the long focal length lenses typically have so low distortion characteristics that the bundle results in almost a zero for radial distortion parameters $K1$, $K2$ and $K3$. We ended up using only the principle point coordinates and camera constant from the calibration. The almost negligible distortion was corrected in PTgui by calculating the distortion parameter b from

homologous points used in the panoramic stitching. Using such an approach, a factor of 4 improvement (from 3 to 0,7 pixels) in RMS-values of the panoramic stitching was reached. It is important to note however that in panoramic stitching, the detected feature points are mainly in the border areas of the frame. So while a factor of 4 improvement might sound big, the error would be much less pronounced if the points were distributed evenly across the frame.

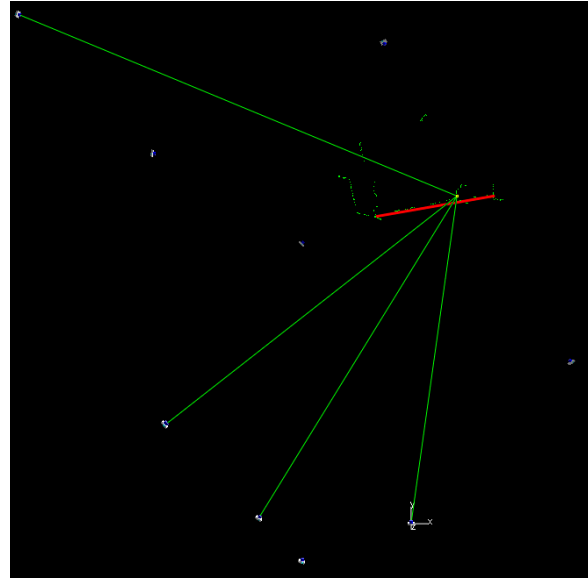


Figure 5. An example of the long range resection. The distance of the upmost resection ray to the target (castle) is more than 400 meters (4 cm RMS)

Once the panoramic photos are correctly stitched using only good quality points, corrected using calibration parameters and exported, they can be used directly in various commercial close range photogrammetry softwares. In this study we use Photomodeler Scanner, which allows automatic Dense Surface Modeling. Essentially this means that once we find out the relative orientation of the panoramic images, we can automatically measure a point cloud of the subject. This is where the superior amount of detail present in long focal length panoramic images help in automatic detection of homologous points. Of course it is also possible to manually measure the points from the panoramic images.

The resulting data is similar to a point cloud data measured by laser scanner but the radiometric quality is much better because all the measured XYZ-points also get a correct RGB-value without any registration (Figs 6-8).

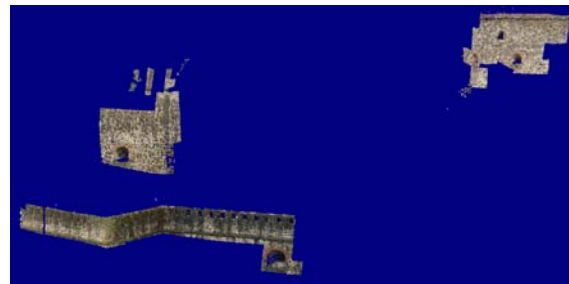


Figure 6. Overview of the point cloud data

This also greatly increases the amount and accuracy of texture detail because it can be projected from precisely the same viewpoint than where the 3-D data was captured from.



Figure 7. Close-up of a wall corner part

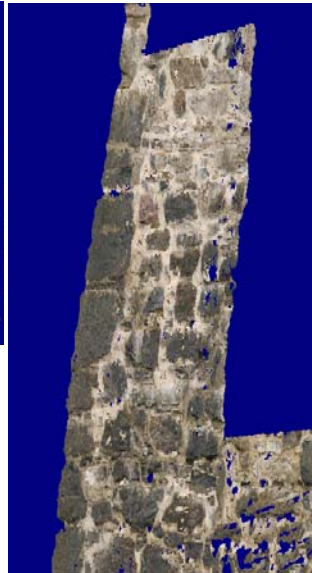


Figure 8. Breakline detail of the corner

3.2 Developed metric panoramic method for visualisation

The resulting data is ready-to-use in various visualisation products. For preservation purposes not even the 3-D model is needed, as the panoramic images alone can be used because they provide ample details of the target. In the figure 9 below, the area shown is only a small portion of a single panoramic image as shown in the thumbnail on the upper left hand side of the photo by a red rectangle.

It is also possible to generate orthophotos and line drawings from the panoramic images once the castle is modeled from the imagery. Based on the 3-D model of the castle, various

exhibitions and other virtual presentations can be made. It is even possible to use different development parameters for processing the panoramic images from raw files (Fig. 10) to give the model a totally new look by texturing it again based on the known 3-D data. The whole process from image acquisition to final textured 3-D model is summarized in figure 10.

In 3-D game industry one widely known method is to use relief information for the texture. To be able to do that a detailed 3-D model is needed from which the relief information will be calculated. The relief image is called normal mapping. It stores the relief information of the height model and offers a lightweight platform to enable real time applications. Because the small surface height detail is represented by the normal mapping, we can reduce the amount of polygons of the model while retaining the realistic look.

4. CONCLUSIONS & DISCUSSION

The principal conclusion is that by integrating the use of long focal length and panoramic imaging, the automatic measurement algorithms can be used to produce much higher quality 3-D data compared to conventional imaging approaches. The added value is that the photos can be taken from long distance without reducing the amount of detail.

We are confident that we can further improve the results when using all of the available data. Up to now we have only used a small portion of the captured data, as this is an ongoing project and the results are only preliminary.

We believe that by using long focal length panoramic imaging, it is possible to increase the amount of detail while keeping the imaging geometry feasible and robust. The approach solves the usual problem in close range photogrammetry that the user would have to get closer to the subject if more detail was needed. Using panoramic imaging it is possible to get good accuracy at least up to 400 meters away. The method can also be used for increasing the accuracy and amount of detail in more conventional close range projects.

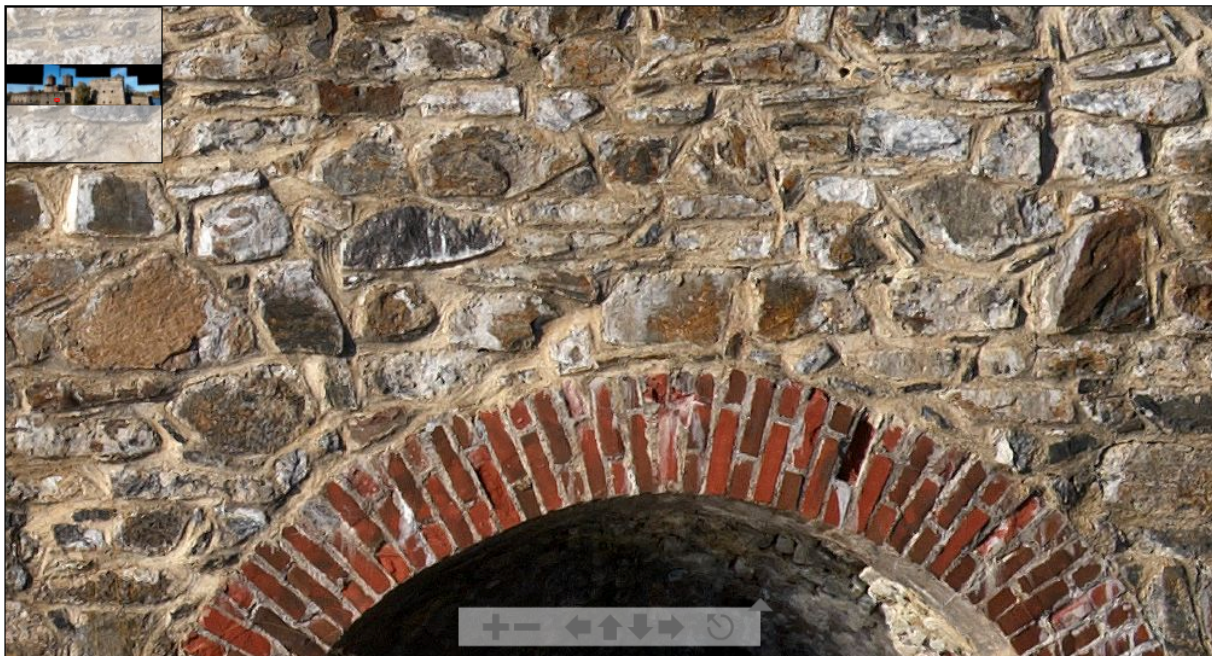


Figure 9. Panoramic image detail

In practice, highly accurate details are not enough, because lighting conditions effect the automatic feature search. Partially cloudy conditions are especially problematic because of the moving shadows present on the subject. For example the edge of the shadow might be detected and matched to the other shadow edge on the other frame. This would not be a problem if the photos would have been taken at the same time. However when using only single camera and walking through the camera stations, the shadows move between the image acquisitions causing problems in the feature match. On the other hand, while overcast weather might present suitable conditions to overcome this problem, it presents another challenge, the lack of light.

When using long focal length, it is important to keep the integration time short even when using a stable tripod. This can cause problems in dim lighting conditions. This can be solved using a large aperture which allows more light to reach the sensor. This approach however results in too narrow a depth of field which leads to poor resolution in the areas which are out of focus. Another option is to use higher ISO sensitivity for the sensor. This of course increases the noise on the images, reducing the resolution and making feature match less reliable.

Our solution for overcast weather is to use relatively high ISO of 800, 1/250sec. integration time and an aperture of F2.8. This does not give a sufficient depth of field so we use two focus distances, one on the closest wall and one further away. When choosing the borders of the panoramic image subframes, we can eliminate the out-of-focus areas almost entirely. For sunny conditions we use smaller aperture and only single focus distance.

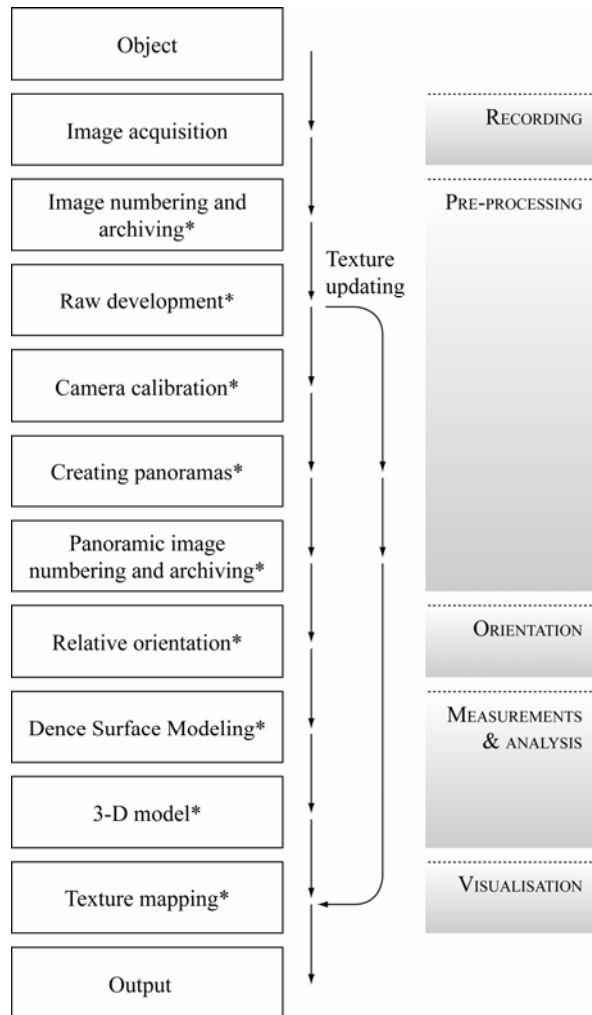


Figure 10. Metric panoramic imaging workflow

REFERENCES

- Luhmann, T., Robson, S., Kyle, S. & Harley, I., 2006. *Close Range Photogrammetry: Principles, Techniques and Applications*. Whittes Publishing, Caithness, pp. 9-13, 354-355.
- Sinisalo, A. 1986, *Olavinlinnan rakentamisen vaiheet suuresta Pohjan sodasta nykypäiviin*, Savonlinna, Pyhän Olavin kilta ry.
- Haggrén, H., Hyyppä, H., Jokinen, O., Kukko, A., Nuikka, M., Pitkänen, T., Pöntinen, P., and Rönnholm, P., 2004. Photogrammetric application of spherical imaging, *ISPRS Panoramic Photogrammetry Workshop*, Dresden, Germany, 19-22 February 2004.
- Haggrén, H. 2004. Stereoscopy application of spherical imaging. Videometrics VIII. In: *Beraldin, J.-Angelo; El-Hakim, S., Gruen, A., Walton, J. Proceedings of the SPIE*, Volume 5665, pp. 89-95