Quality analysis of digital photogrammetric models obtained in low light conditions

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Abstract. The paper presents the results of the study of the photogrammetric models quality depending on the photogrammetric survey. The presented data have been obtained by the Xiaomi Mi Home Security Camera 360. We examined the texture of the captured object and the general geometric parameters of the created photographing basis as the experimental variable. As a result, the paper contains general recommendations for the cameras optimal location for photogrammetric surveying in low light and space limits. The main author’s idea of the improvement of the photogrammetric models quality is projecting a temporary artificial texture on the subject of surveying.

1. Introduction

A modern developing enterprise is impossible without the introduction of autonomous robotic systems for management, control and production. Regardless of its purpose, any such system must include devices for collecting information about the surrounding space within its sphere of competence [1]. For mobile robotic systems, such tools should provide the ability to solve navigation tasks to determine their position and directly capture the surrounding situation.

The most technologically provided and promising way to solve this problem is the SLAM (simultaneous localization and mapping) algorithm [2]. One of the most common versions of its implementation is the application of two-dimensional and three-dimensional lidars, which form a digital model of surrounding space [3]. The practice of this approach has proved its reliability, but the necessity of using special lidars significantly increases the cost of such systems.

The approach based on processing photogrammetric three-dimensional models obtained from the stereo effect between a pair of photographs is the alternative to lidar SLAM algorithms [4, 5]. Even though the theoretical foundations of photogrammetry were formulated more than a century ago, their interpretation of modern computer algorithms for digital processing of photos is an urgent task [6]. The modern approach to photogrammetry allows significantly expanding the scope of implementation of this technology and in the future, make robotic systems more anthropomorphic not only in their form but in their essence.

2. Materials and methods

The main idea of the experiment is to study the degree of influence of geometric parameters of the photo base and shooting conditions on the quality of the resulting digital model.
We formed a test stand shown in figure 1 to get the initial data.

![Test Stand Diagram](image)

**Figure 1.** 1 - subject; 2 - camera; 3 - levelling rod 3 m; 4 - levelling rod 2 m; 5 - projector; 6 - screen

The object of the survey is the green metal console 1. Camera 2 was mounted on the levelling rod 4 in order to quickly determine the basis of the survey, which is the distance between the camera’s standing points. Levelling rod 3 is required for measuring the distance from the subject to the base.

Figure 2 shows the position of the captured images set.

![Image Set Diagram](image)

**Figure 2.** Camera’s standing positions

The Xiaomi Mi Home Security Camera 360 was used for an experiment due to its technical characteristics. In particular, the camera supports infrared shooting mode and the ability to record video
in 1080p resolution. The selection of a camera of such low resolution and quality was made to extrapolate the experiment results to systems using remote computing technologies based on the flow transmission of video and photo information.

The first part of the experiment is performed in three stages: with natural light, with artificial light and in the absence of light. During each of the phases, we obtained a set of photos taken from the same vantage points. Figure 3 shows an example of the received photos.

![Figure 3.1 – natural light; 2 – artificial light; 3 – in the absence of light](image)

The second and third stages of the experiment are performed in the absence of natural light. At the same time, in the second series of measurements, we used a projector as a lighting source, creating an artificial texture of a tuning television table on the subject. While photographing the third series of images, the infrared illumination created by the camera itself in night mode was used as a light source. Processing of the obtained images and three-dimensional building models performed in the Agisoft.

3. Results and Discussion
During the processing of stereo pairs, three-dimensional digital models of the subject were constructed. Figures 4-6 show the most representative of the obtained models.

![Figure 4. An example of input (left) and derived model in natural lighting (right)](image)
Figure 5. An example of input (left) and derived model in the absence of light (right)

Figure 6. An example of input (left) and derived model in artificial lightning (right)

The complexity of the texture of the captured objects significantly affects the quality of the resulting model. For example, in the case of natural and infrared lighting (figures 4 and 5), monochrome objects did not generate enough information to build the model correctly. In the case shown in figure 6, where an additional complex texture has been applied to the subject due to artificial lighting, the quality of the model increased.

It should be noticed that the purpose of the experiment was not to obtain a model of high metrological accuracy but to determine the main patterns of its formation, in particular, to solve the problem of the internal orientation of images. The program finds common points on a pair of images under consideration at the internal orientation step. The coordinate snapping of these common points in the field of the image allows solving the problem of determining the position of cameras relative to each other. After completing the internal orientation step, the closeness of the resulting point cloud becomes possible because of interpolating between shared pairs.

The presented results demonstrate that it is hard to expect positive results if the internal orientation of images is incorrect. The problem of the internal orientation of images can be represented as inverse geodetic intersection, which quality depends on the number and accuracy of identified common pairs of points on the images. Both of these factors depend on the complexity and chaotic state of the object's texture [7] (Fig. 7).
Figure 7. Automatic selection of common points on stereo pairs: 1 - with a simple texture; 2 - with a complex texture.

In addition to the obvious difference in the number of common points detected in pairs of photos, figure 7 demonstrates the limitations of existing automatic internal orientation algorithms. In the left part of figure 7, where the texture of an object consists of a regularly repeated square grid, a person could easily solve the problem of finding matches using abstract thinking and interpolation, but a program could not. On the other hand, in a complex, chaotic and noisy texture, a person is not able to determine common points for images, but the program finds them easily.

The second factor that affects the quality of matching is their relative position. After analyzing the number of matches found on the stereo pairs, a histogram was constructed (Fig. 8).

Figure 8. The number of common points on the stereo pairs depending on the position of the cameras.

The histogram shown in figure 8 quantifies the accuracy of the internal orientation of images only for the Xiaomi camera and subject under consideration, which allows formulating general conclusions about the regularity of this process. At the distance of 1 meter from the subject, only a limited area of the scene lies within the frame, which directly affects the number of common points. On the other hand, when the camera is more than 2.5 meters away from the object, the number of common points decreases.
due to the low resolution of the camera [8]. Figure 8 also shows that the program finds the largest number of common points when the cameras are slightly distanced from each other, ranging from 0.6 to 1.0 meters.

4. Conclusions

Based on the data obtained from the experiment, we formulated the following conclusions:

- increasing the quality of digital photogrammetric models is possible because of projecting artificial structures onto them;
- it is possible to create the independent models of the subject by projecting different textures onto them from stationary photography positions, thereby increasing the accuracy and control of the result;
- the higher the contrast and complexity of the projected texture is, the better the digital photogrammetry algorithms determine the correspondence between images in stereo pairs;
- while photographing, the frame should be filled with useful information as much as possible, and the step of photographing should correspond to the interval between 0.5 and 1 meter.

The results obtained from the experiment can be used in the operation of robotic systems in limited space and low light conditions. If the robotic system is stationary, projecting a complex artificial texture can significantly improve the quality of visual odometry [9]. Rotation of several pre-known textures allows controlling the quality of determining the position of the system.

While formulating guidelines, it should be emphasized that the formation of a three-dimensional model is possible both when surveying is carried out with two cameras at the same time, and when sequential processing of images is obtained when moving one camera in space [10]. In this case, the geometric parameters of shooting should be selected individually based on the technical characteristics of the camera.

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