New developments in photogrammetry

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Abstract: *In the first part of this paper is presented an algorithm for the geometric modeling in multimedia photogrammetry, which can be implemented as a module into spatial resections, intersections or bundle solutions. The solution is limited to the standard case of multimedia photogrammetry, where the object is situated in a liquid, the sensor is positioned in air, and a plane-parallel glass plate divides these two media. The second part presents the hardware components as standard video cameras for to measure deformations of the horn hoof capsule under different load condition with a suitable accuracy.*

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1. Introduction

Multimedia photogrammetry represents applications of photogrammetry, where the beam from an object to the sensor passes several optical media with different refractive indices. For the geometric modeling in this case, there are many-sided algorithms, which can be implemented as a module into spatial resections, intersections or bundle solutions. In the standard case of multimedia photogrammetry the object is situated in a liquid, the sensor is positioned in air, and a plane-parallel glass plate divides these two media.
The refractive indices of the liquid and the glass plate can be integrated into a bundle adjustment program with self calibration and introduced as an unknown and determined simultaneously.
The problems of multimedia photogrammetry have been studied by a number of authors in the past. Rinner (1948) studied the relative orientation underwater imagery on stereo plotters and introduced the term "two-media-photogrammetry". Höhle (1971) and Okamoto (1972) showed an analytic solution and performed the step from two-media to multimedia photogrammetry by replacing the straight lines of the central perspective model by polygons. An overview on theory and technique of multimedia photogrammetry has been given by Wrobel. Kotowski (1988) developed an algorithm for ray tracing through an arbitrary number of parametrized interfaces, which was implemented into a bundle program [Maas, H., G., 2004].

2. Multimedia module

The multimedia module computes a radial shift of each object point relative to the nadir point of the respective camera (figure 1), which can be used as a correction term in the collinearity equation. If the X-Y plane of the coordinate system is chosen parallel with the plane interface glass/liquid (or with the air/glass interface), a relatively simple model becomes possible. If the point $P(X,Y,Z)$ in object space is shifted to $\bar{P}(\bar{X},\bar{Y},Z)$, the collinearity condition can be applied for P using the object coordinates of the shifted point $\bar{P}$. Only a radial shift by ΔR parallel to the X-Y plane has to be computed for each point relative to the nadir point of each camera. Thus, rays from different cameras C_j to an object point P are calculated with straight beams from different virtual objects points $\bar{P}_j$ with the broken beams still intersecting in P.

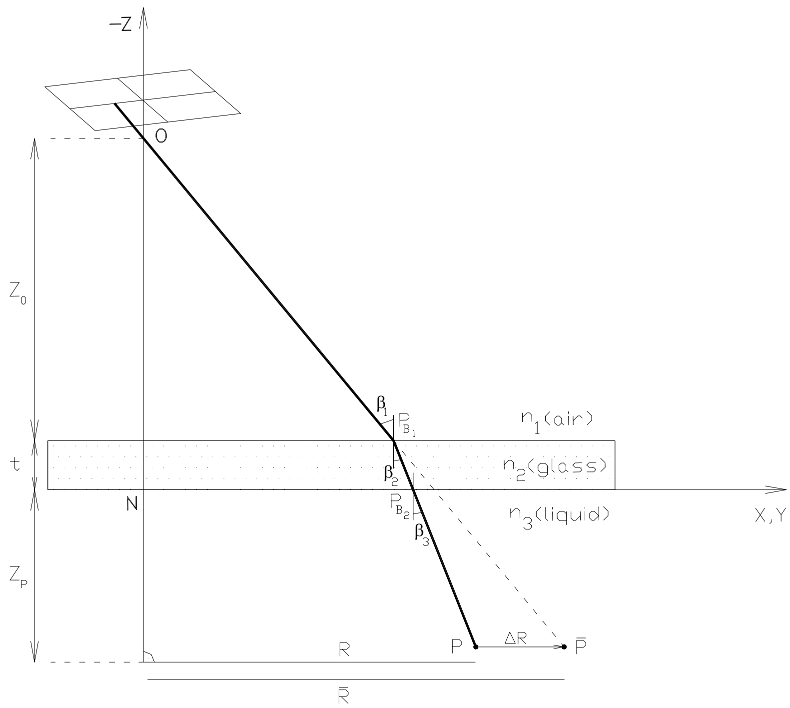

Fig1. Radial shift for compensation of multimedia geometry [Maas, H., G., 2004]

$O\ (X_0, Y_0, Z_0)$: camera projection center
$N\ (X_0, Y_0, 0)$: camera nadir point
$P\ (X_i, Y_i, Z_i)$: object point
$\bar{P}\ (\bar{X}_i, \bar{Y}_i, Z_i)$: radially shifted object point
$P_B\ (X_B, Y_B, Z_B)$: break point
R : radius in X/Y - plane
n_1, n_2, n_3 : refractive indices
$\beta_1, \beta_2, \beta_3$: angles in Snell’s Law

As an additional option, the multimedia bundle allows for the introduction of the refractive index of the liquid as an unknown to be determined simultaneously. This can become necessary when coordinates of an object in a liquid with unknown refractive index have to be determined. The option can also be used as a tool for the analysis of a liquid itself. The refractive index of water, for instance, depends significantly on temperature and salinity, so that the multimedia bundle can be used for indirectly estimating these parameters.

There are some problems caused by multimedia environment, which are not contained in the mathematical model but do have a non-negligible influence on the accuracy of results:

- inhomogenities of the refractive index (due to local temperature differences, salinity etc.) cause deviations from the strict mathematical model, which can often not be modeled;
- deviations from the planeness of the glass walls falsify the incidence angles. This point will be the major source of error in many applications;

- the network geometry is deteriorated by the smaller intersection angle of rays due to the fact that rays are broken towards the optically denser medium. This causes larger errors in the depth coordinates;
- diffusion and absorption in liquid cause an extinction of light and reduce the image contrast;
- the dispersion e.g. in water is much larger than in air. The variance of the refractive index in water over the visible spectrum of light is 1.4% in contrast to 0.008% in air (Hoehle, 1971). This leads to colour seams at the edges of imaged objects which will appear as blur in black-and-white images. Moreover, special care has to be taken when using lightsources with different spectral characteristics in one application;
- the optical system (liquid-glass-air) passed by each ray is not corrected for aberrations if lenses are corrected for the use in air. This leads to a degradation of image quality, especially as the cameras are arranged convergently.

3. Photogrammetric measurement of deformations of horse hoof horn capsules

The Department of Veterinary Surgery at the University of Zürich in cooperation with the Institute of Geodesy and Photogrammetry at ETH Zürich, discovered a system for the measurement of three-dimensional deformations of horse hooves under different load conditions. The systems consist of a force sensor panel and three cameras mounted on a trolley which can be moved on a circular rail around the hoof. To achieve a reliable photogrammetric network and to ensure the full coverage of the hoof, triplets of images are acquired at three different positions of the trolley. The nine images are processed separately for each single experiment to determine discrete marked points mounted on the horn capsule of the hoof. Prior to the experiment, the horse was sedated to reduce its movement to a minimum. The force sensor panel is used to assure a more or less constant load condition of the hoof during the image acquisition. To increase the accuracy of the object point determination, a calibration of the three cameras is performed before the experiment. For the definition of the reference system, 84 points were milled into the anodized surface of an aluminium plate [Jordan, P., Willneff, J., 2007]. The aluminium plate has a size of 0.5x0.5 meters and in its center a notch for the force sensor panel upon which the hoof is placed. For a good visibility of the reference points a diameter of 8 mm was chosen and to improve the contrast on the images the milled position was covered with retro-reflective sheeting. Using nine images distributed regularly around the hoof, each marked object point is visible and can be measured on three images. The reference points on the aluminium plate might even appear on more images and provide for a well-defined photogrammetric network. To analyze the deformation of the deformation of the horn capsule, another set of nine images is acquired after changing the load conditions by remaining the horseshoe or placing a wedge pad under the hoof. After image acquisition the data is processed with the commercial software to determine the 3D coordinates of the marked points on the hoof. The estimated precision of the 3D point positions is in the order of 0.1 – 0.2 mm, which is sufficient for this application. The two resulting 3D point clouds can then be used for a deformation analysis.

4. Conclusions

In this paper are presented only some exemplas from multitude of application possibilities of theories and practices of the modern photogrammetry.

The application of the so-called softcopy photogrammetry in the field of veterinary surgery proves the flexibility and potential of this optical 3D measurement technique.

5. References

1. *Kotowski, I., - Phototriangulation in Multi-Media-Photogrammetry. International Arvhives of Photogrammetry and Remote Sensing, Vol. XXVII, 1988;*
2. *Maas, H., G. – New developments in Multimedia Photogrammetry, 2004;*
3. *Jordan, P., Willneff, J. - Photogrammetric measurement of deformations of horse hoof horn capsules, Proceedings of SPIE, San Jose, California, 2007.*