3D RECONSTRUCTION WITH INNOVATIVE APPROACHES

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Abstract: The article deals with 3D reconstruction of the analyzed scene. The inputs of the 3D reconstruction are two images of the analyzed scene. The outputs of this process are spatial coordinates. The created application serving for the 3D reconstruction is described in this article. The original proposed algorithm for finding corresponding points are implemented in the application. This algorithm is briefly described too.

Keywords: corresponding points, 3D reconstruction, software

1. INTRODUCTION

Obtaining of the spatial information about the scene is the actual task. Exact finding of the spatial coordinates of the selected point (cloud of points) of 3D scene is very important in many areas of human activity (e.g. architectural engineering, mechanical engineering). The spatial information can be obtained by using various approaches. This article deals with the approach based on the passive triangulation and projective geometry. This method for 3D reconstruction utilizes two or more images of analyzed scene. The process of the reconstruction was described in many publications (e.g. [1]). Main steps in the reconstruction are interior calibration, exterior calibration, finding corresponding points and triangulation. The fundamental idea of this method works equally as human eyes. Therefore, the spatial information is obtained by the assessment of the mutual positions (movement) of the corresponding points in both images. Corresponding points are image points which represent the same spatial point of the scene. Consequently the fundamental step in the 3D reconstruction is finding of the corresponding points in both images. The application allows execution of the whole process of the 3D reconstruction. Main attention was paid to the corresponding points. Some new approaches for finding corresponding points are proposed and implemented in the application.

2. USER INTERFACE AND APPLICATION FUNCTION

The user interface of the application is shown on the Figure 1. The workplace is divided to the five main work subareas. The majority of the operation is solved in main panel. The application provides export of the results from each step of the process. Exported data can be subsequently processed or load back to the application in another time. Options of the application can be follow up in flowchart on. Figure 2. Functions of the application are briefly described. The individual functions correspond with blocks in the flowchart. The user utilize successively blocks in the user interface from the left top corner to the right bottom corner. The work with the application is consistent with the fundamental procedure of the reconstruction of the spatial model. The estimation of the depth map is the only exception. There is not necessary to perform another operation.

The application offers various possibilities in the process of finding the corresponding points. For the correct determination of the spatial coordinates of the point from a scene, we have to find its representation in the left even right image. These points are called corresponding points. The pair of the corresponding points consists of the points which represent the same points of the scene. The finding of the corresponding points is usually divided to two steps. The finding of the significant points in the both images is first of them. The significant points are points which should be repeatedly found. Therefore, significant points are points which are distinguishable from other points in the image. The second step is a determination of the correspondences between significant points in both images. This means that we find match between significant points found in both images. The matching of the points is based on the comparing properties of the point and their neighborhoods. The application provides finding of the set of the corresponding points by various commonly used methods: Harris Detector [2], Scale-Invariant Feature Transform (SIFT) [3], Speeded up Features (SURF) [4]. The application allows finding of the corresponding points in various representation of the image: Monochromatic image, RGB image (model) with true colors, HSV image (model), RGB image (model) with pseudo colors.

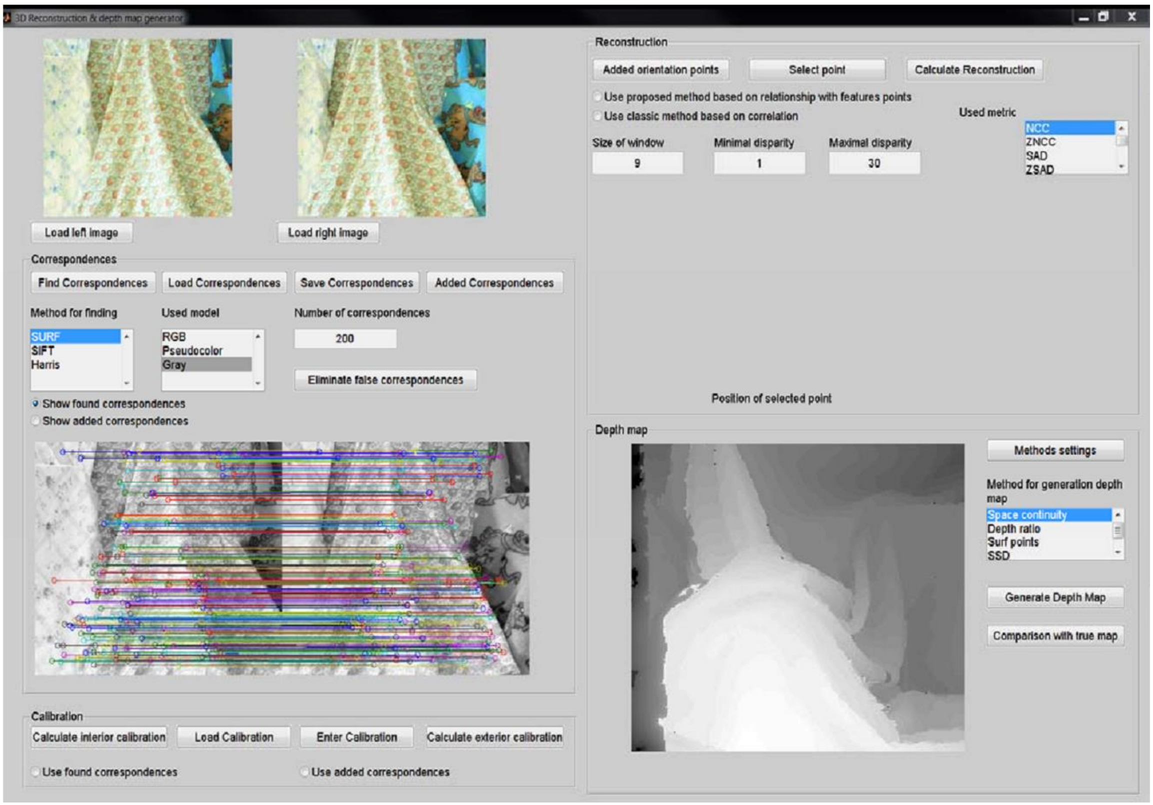

Fig. 1User interface of the application.

Especially the idea about finding in the pseudo colors is innovative and it is briefly described in section 3. The user can choose the desired number of correspondences. The user can save the found set of the corresponding points. Besides founding corresponding points, user can load saved correspondences. Moreover, the user can create a set of points manually by selecting points in both images. The sets obtained by various ways can be used concurrently. Therefore, the user can select which set want used. The application provides elimination of the false correspondences. The elimination of the false correspondences means finding of the wrong determined correspondences.

The calibration is important step in the 3D reconstruction. Commonly used and published methods are implemented in the application. The exterior calibration is performed by using eight-points algorithm [1]. The interior application is executed by using functions from free distributable toolbox for MATLAB Calib toolbox [5]. The toolbox uses calibration based on the calibration pattern published in [6]. The user can load calibration matrix from the memory or he can fulfill matrix manually. The exterior calibration can be executed with three various set of the corresponding point mentioned above (found, loaded, manually determined).

The application offers two possibilities what will be reconstructed. In both case, the reconstruction is executed by using linear triangulation. First possibility is calculation overall model of a scene. In this case, spatial coordinates of the set of the corresponding points are calculated. The spatial model is showed. Second possibility is a calculation of the spatial coordinates for one specific image point selected by user. In this case, user select (by click) point in the left image and its corresponding point in right image will be found. The resulted spatial positions of the select points are graphically expressed in model and in front view. Moreover, its numeric value is written. The corresponding point can be found by one of classic local method based on the measuring of the similarity. The proposed function described in section 3 can be also used for finding corresponding point.

The last section of the application window allows estimation of the depth map. Even in this part of created application, the user can to use few various methods to obtain results. In the application are implemented various procedures which can be mutually combined. The main method is estimation of the initial depth map by using method based on the measure of the similarity of the small neighborhoods of the points [7]. The initial depth map can be improved. The application contains simple proposed method for the improvement of the depth map.

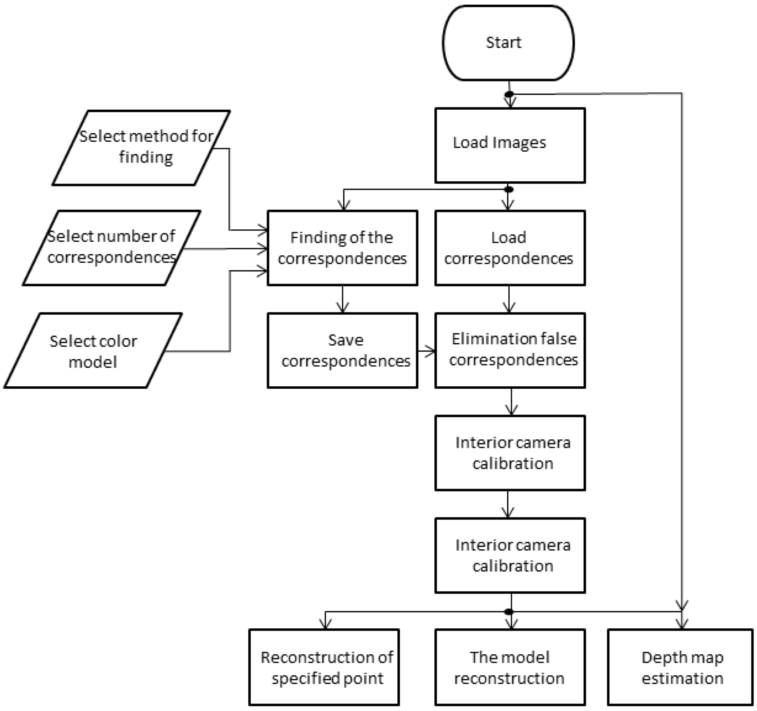

Fig. 2 The flowchart of the procedures in the application.

3. INNOVATION IN FINDING CORRESPONDING POINTS

The two proposed approaches for finding of the corresponding points are implemented to the application. The first of them is using of the pseudo colored image for finding of the corresponding points. Pseudo-coloring is a technique for converting gray scale images to false colors (pseudo colors), that does not correspond to the real colors of a scene. This method allows significant increase of resolution details in the scene. This paper deals with the possibility to use pseudo-coloring for finding corresponding points in areas without contrast. The drawback is in an increased computational complexity. In the application is used the method proposed in [8], which define converting using parametric equation of curve in RGB space.

The second one innovative implemented approach is finding of the corresponding point for image point specified by user. The proposed method is based on the relation with the close feature points. Obtaining coordinates of the corresponding point in the second image is a difficult task which is commonly executed by using methods based on the similarity measures. The discovered correspondences have low reliability if point belongs to repetitive texture or to coherent area without contrast.

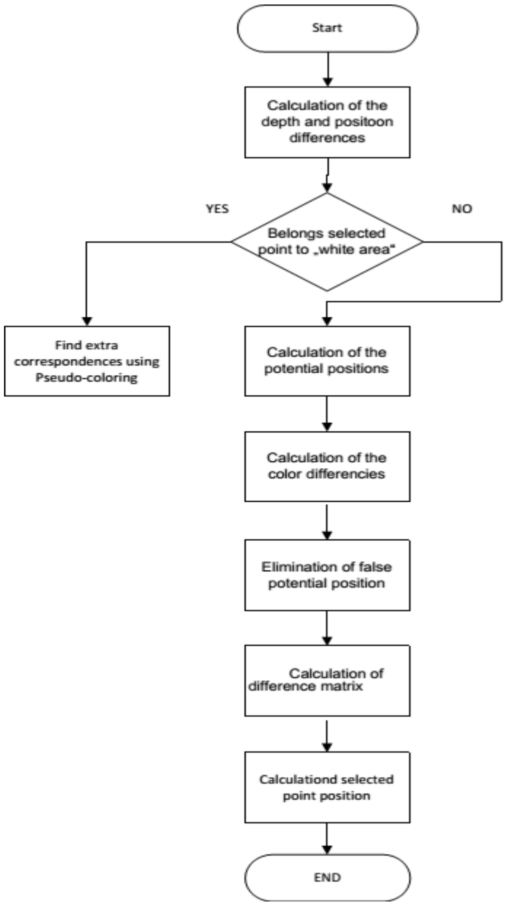

Fig. 3 The flowchart of the method proposed for finding corresponding point.

The proposed procedure is described by the flowchart shown in Fig. 3. The method is based on the determination positions of selected point in right image using knowledge about positions of significant points in both images. Therefore at first, we have to find a set of the significant points. Significant points are found by the algorithm SURF in the right (*SURF_pos_r*) and the left image (*SURF_pos_l)*.

In the next step we calculate the potential positions of selected points in right image, which forms the input to last step of the algorithm for determining the point corresponding to selected point, together with its position in the left input image. Potential position (*Pot_pos*) is calculated using following equation.

$$Pot\_pos = SURF\_pos\_l - SURF\_pos\_r\ . \tag{1}$$

Subsequently we calculate the difference in color of the selected point (in the left image) and of its potential position (in the right image).

$$coldiff = \sqrt{(R_{sel} - R_j)^2 + (G_{sel} - G_j)^2 + (B_{sel} - B_j)^2} \tag{2}$$

We eliminate the potential positions for which difference *coldiff* exceeds a treshold. In the next step we calculate differences between individual potential positions using the following equation.

$$dif(i, j) = \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2}\ . \tag{3}$$

Where *i*, *j* are serial numbers of the potential positions and *x*, *y* are image coordinates. Consequently we obtain the Difference Matrix containing differences.

$$\begin{vmatrix} dif(1,1) & dif(1,2) & .. & dif(1,j) \\ dif(2,1) & ... & ... & ... \\ ... & ... & ... & ... \\ dif(i,1) & ... & ... & dif(i,j) \end{vmatrix}. \qquad (6)$$

We calculate the final position of the selected point in the right image as weighted average from potential positions. The weight of each position is determined by the distances from the other point and *coldiff*.

4. CONCLUSION

The created application can be used for various purposes. The application can be used in education for showing and explanation of the whole process of the reconstruction. The application can be utilize even in industrial applications. However, some adjustments of the application should be executed for a specific industrial application. The extended possibilities of the finding of the corresponding points bring advantages in a practical application. We can examine influence of the each step of the 3D reconstruction to the precision. It is important for using application in research activity. The application is arranged and user friendly. The default settings make program usable even for laymen in 3D reconstruction. On the contrary, the variability of the settings allows significantly influent the process of the reconstruction and its results which is helpful for experts.

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REFERENCES

[1] Mikhail, E.M., Bethel, J.S., McGlone, J.CH. Introduction to Modern Photogrammetry. New York: John Wiley & Sons, 2001. 479 s. ISBN 0-471-30924-9.

[2] Harris, C., Stephens, M. A. Combined Corner and Edge Detector. Proc. 4the Alvey Vision Conference, p. 147-151, 1988.

[3] Lowe, D. Distinctive Image Features from Scale-Invariant Keypoints. International Journal of Computer Vision, vol. 60, no. 2, p. 91-110, 2004.

[4] Bay, H., Tuytelaars, T., Gool, L. V. SURF: Speeded up Robust Features. Proc. of the 9th European Conference Computer Vision, p. 404-417, 2006.

[5] Camera Calibration Toolbox for Matlab [open source software]: Jean-Yves BOUGUET, Last updated July 9th, 2010. URL: http://www.vision.caltech.edu/bouguetj/calib_doc/.

[6] Zhang, Z., Flexible Camera Calibration by Viewing a Plane from un- known Orientations. Computer Vision, 1999. The Proceedings of the Seventh IEEE International Conference, vol. 1, 1999, p. 666-673, doi: 10.1109/ ICCV.1999.791289,

[7] Lankton, S. 3D Vision with Stereo Disparity. In: [online]. [cit. 2013-02-26].

[8] Lehman, T., Kaser, A., Repges, R. A simple parametric equation for pseudocoloring grey scale images keeping their original brightness progression. Image and Vision Computing, 1997, vol. 15, no. 3, p. 251-257.