NEW METHOD FOR 3D COORDINATES ASSIGNMENT

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Abstract: The paper addresses with the determination of 3D coordinates of an arbitrary chosen point from a scene using two grayscales images which are in general relation. These two images can be created for example by a stereo camera in practical applications. Calculation is based on the perspective geometry. In the paper, we have proposed the new fast method based on utilization of the relation between the location (in first image) of the selected point and migration of the nearby feature points (between first and second image). Search of the feature points in each of these images and establishing their correspondences are fundamental building steps to find spatial coordinates of the selected. An algorithm for fast elimination of false correspondences which could devastate the scene reconstruction was designed. The performed experiments confirmed usability of designed procedures.

Keywords: 3D reconstruction, feature points, image correspondence

1. INTRODUCTION

The reconstructed 3D models have widely application in many areas – especially in civil and building engineering, robotics, medicine, etc. Results of reconstruction are three spatial coordinates in a selected coordinate system. It is necessary to create a depth map of a 3D scene. This process is based on camera calibration and finding of the corresponding points. The interior and exterior orientation of camera must be obtained. The interior orientation represents the properties of camera *f*, u_o, v_o, s and its distortion. Interior parameters are expressed by calibration matrix *K* [1].

$$\mathbf{K} = \begin{bmatrix} f_u & s & u_0 \\ 0 & f_v & v_0 \\ 0 & 0 & 1 \end{bmatrix}. \qquad (1)$$

where f_u and f_v represent the focal lengths in pixel, (u_o, v_o) represent the coordinates of principal point, *s* represents the skew. Many methods were proposed for camera calibration [2], [3]. The exterior orientation represents the relation between camera positions given by rotation matrix *R* and translation vector ***T***. Relation (2) expresses calculation of 3D coordinate [1].

$$\begin{bmatrix} \mathbf{P}_3 \cdot x_i - \mathbf{P}_1 \\ \mathbf{P}_3 \cdot y_i - \mathbf{P}_2 \\ \mathbf{P'}_3 \cdot x'_i - \mathbf{P'}_1 \\ \mathbf{P'}_3 \cdot y'_i - \mathbf{P'}_2 \end{bmatrix} \cdot \mathbf{X} = 0, \qquad (2)$$

where $\boldsymbol{P}_1$, $\boldsymbol{P}_2$, $\boldsymbol{P}_3$ and $\boldsymbol{P}'_1$, $\boldsymbol{P}'_2$, $\boldsymbol{P}'_3$ are rows of the projection matrix ***P***, ***P'***. The projection matrix is obtained as ***P*** = [**I** | 0] and ***P*** = [***R*** | *T*]. Further x_i, y_i, x'_i and y'_i are image coordinates of corresponding points. Vector ***X*** contains the resulting spatial coordinates of points. The system of equations can be solves with a linear least squares solution [1].

The crucial step for determination of 3D spatial coordinates is achievement image correspondents. Finding the corresponding (identical) points in the left and right images is first the step to obtaining the correspondences. These points are pixels with salient properties which can be detected in both images. It is necessary to find the same pixel in each image. Therefore algorithms for this task are often examined and many compact studies of this problem exist [4]. Very important problem is an elimination of false correspondences. We propose fast elimination of false correspondences based on geometric constraints and extremities. Very difficult problem is spatial coordinate detection in both images for an arbitrary point lying in an area with regular textures or in “white region” without features and contrast. We have proposed and tested a method based on relation between arbitrary selected points (by user) and points in their neighborhood.

2. PROPOSED METHODS

The main aim of our work is to propose a fast method for obtaining spatial coordinates of an arbitrarily selected scene's point. Our approach is based on statistics and probability. A flowchart of the whole implemented system is shown in Fig. 1a. All algorithms used work with grayscale images. We can to divide system into several separate parts. At first, two images and the calibration matrix are loaded. The positions of images can be in general relation. This means that the sensing cameras can have different viewing angles, different distances from the scene and arbitrary displacement in horizontal and even vertical direction. A normal case of stereo sensing provides simplification. Subsequently, the significant points are detected and points correspondences are established. In the next step, we use the proposed algorithm for eliminating false correspondences. Then the 3D coordinates of feature points are calculated using a system of equations (2). In this moment we have all the required information to use the proposed method for reconstruction of spatial position of a selected point. Position of the point in the left image is selected. Subsequently, we can use the proposed algorithm to find its position in the right image. Through the knowledge of point positions in both images we can calculate its spatial position. In some steps open source algorithms have been used [5], [6]. In this section our suggested approaches are described.

2.1. FALSE CORRESPONDENCE ELIMINATION

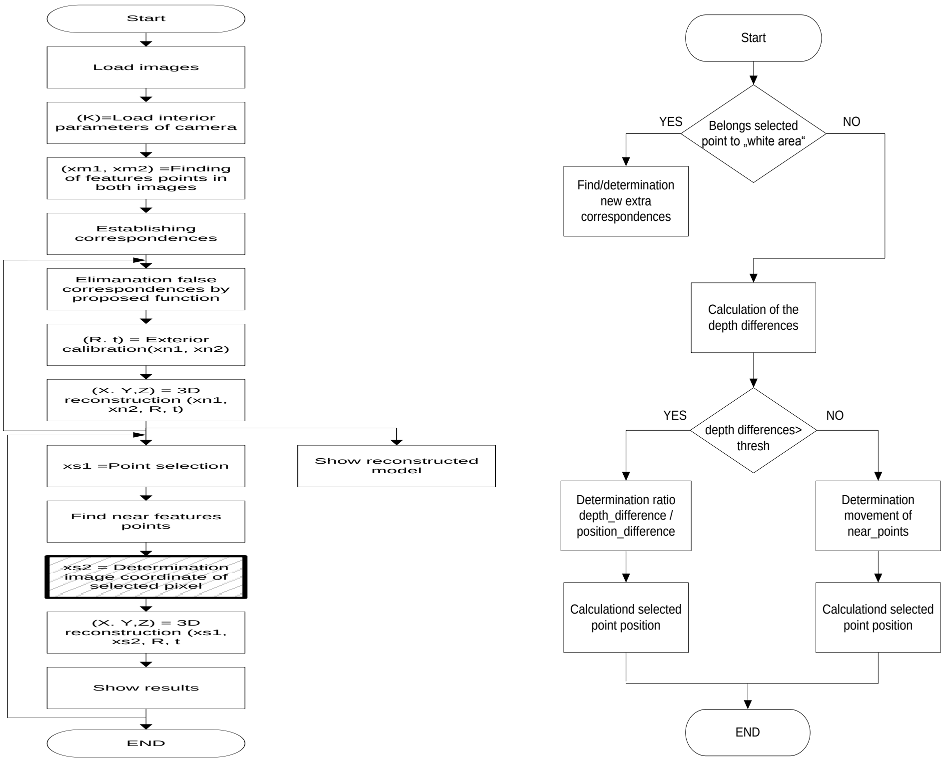
Our method draws on method published in [7]. We exploit rules which combine constraints for horizontal parallax, extremities in angle and similarity of neighborhoods. In first step, average slope of a straight line connecting the corresponding points in both images is calculated. Subsequently, correspondence is identified as false if its slope is greater than 1.5 the average slope. Correspondence is marked as false even if the horizontal movement between pixel positions is bigger than the determinate threshold (regularly half of image).

2.2. FINDING THE POSITION OF A POINT IN THE RIGHT IMAGE

The algorithm for 3D reconstruction needs image coordinates in both images as input. Coordinates in the left image are given by user click. The obtained coordinates of corresponding point in the second image is a difficult task which is commonly executed using different similarity measures (SAD Sum of Absolute Differences, SSD Sum of Squared Differences, RUI Ratio Image Uniformity, MI Mutual Information) and other [8]. In case that point belongs to texture or to coherent area without contrast, then the discovered correspondences have low reliability.

The proposed method is based on searching for the closest feature point (found in one of previous step, see Fig. 1a), for which reliable correspondence is known. Feature points are found by the SURF Speeded-Up Robust Features algorithm [5]. Base proposed procedure is performed in block "Determination of image coordinate of selected points"(1a), which is in detail described in flowchart on Fig. 1b.

In the first part of the procedure, we make a decision whether it is necessary to complete a set of points with extra points. Decision is made by a trained artificial neural network, its input are depths of near feature points and their distance from selected point. In the instance that point lays in dangerous area, adding extra information is necessary for obtaining accurate results. During the test, the information has been added using manual determination of auxiliary correspondence. Subsequently, differences between depths of individual near points and their distances from selected point are evaluated. In case that ratio of depths exceeds chosen threshold, then position of selected pixel point in right image is calculate only from two closest points. Influence of each point is given by ratio of their distance from selected point. Otherwise, the position of point is obtained by averaging displacements of five nearest points.



a) b)

Figure 1: a) The flowchart of the designed system for the reconstruction of 3D model. b) The flowchart of the proposed algorithm for determination image coordinates of selected point in the second image.

3. RESULTS

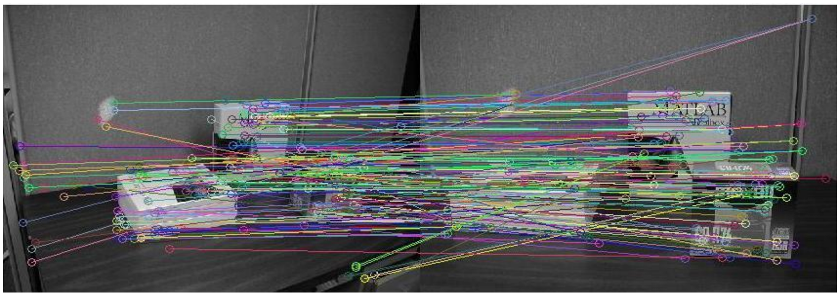
The system for fast reconstruction of spatial coordinates was designed in MATLAB and tested on a set of images. The set contains images with various properties:

- varying mutual position of the sensing cameras,
- varying content of the scene,
- various cameras.

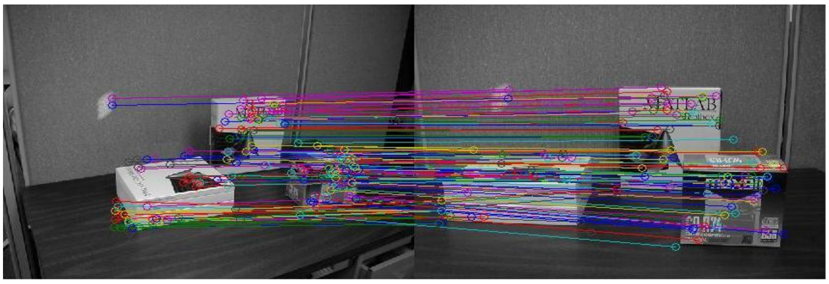
The calibration matrices have been obtain by MATLAB toolbox [6] inspired mainly by Zhengyou Zhang [3]. Features points were found by SURF algorithm [5]. Various methods were tested, however SURF achieved best results. In order to calculate spatial coordinates of feature points was used a familiar procedure [1]. We proposed a modification in elimination of false correspondence and a novel approach to gain 3D position of arbitrary points of image. Fig. 2 shows the initial correspondents. Obviously, some of correspondents are false. Fig. 2b shows correspondents after application of the proposed method for elimination false correspondents. The improvement is evident.

Fig. 3 shows the results of using proposed method for to find point position in right image. Figure represents a simple situation when closed feature points have similar depths. Obviously in this case, the position of the point is found correctly. As a consequence, reconstruction is executed correctly too. In other case, the selected point belongs to the dangerous area. This means that close feature points have significantly different depths withal they are distant from selected point. In this situation we obtained good results if we have found extra landmarks precisely.

Result of correspondence is shown in Fig. 4. Due to the limited article extent we present just a limited amount of figures with results. For clarity and lucidity, accurate manual correspondences were established which are used for modeling of objects in the scene (blue objects in Fig. 4). These correspondences have no function in the proposed algorithms and serve only for graphical representation of results.



a)



b)

Figure 2: Image correspondences a) before use algorithm for elimination false correspondences, b) after algorithm for elimination false correspondences.

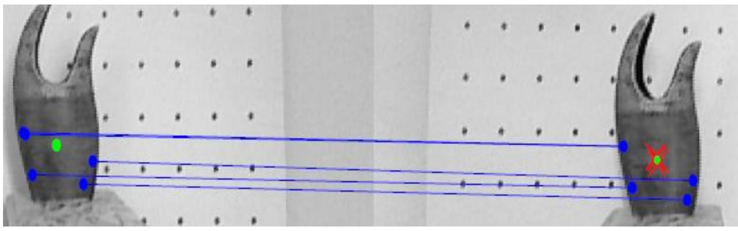


Figure 3: Finding the position of selected point in the second image by using the proposed method (simple situation). Blue marks represent the nearby salient points. Red marks represent possible positions of selected point in second image. Green marks represent positions of selected point in both images.

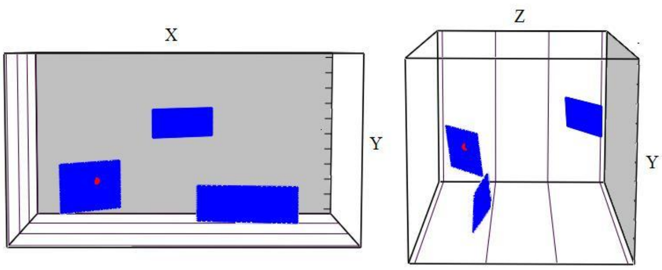


Figure 4: Resulting reconstruction position of selected points. Red marks represents location of selected point in space. Blue objects are pictured only for clarity.

4. CONCLUSION

The performed tests demonstrated usability of the proposed methods. The method contribution is particularly its speed, due to fact that we do not examine certain vicinity of image for each selected point. The obtained results confirm usefulness of adding a few extra landmarks to danger area (texture, constant intensity even color). There are different possibilities how gain these landmarks.

The first approach is supplementing an artificial contrast directly to captured scene by some targets. In the second way, positions of extra points in both images are addressed manually by operator. The last mode is based on automatic finding of correspondence using similarity measure. In the executed tests the best results are provided using mutual information.

Limitation false correspondences is important task too, therefore set of right correspondences allows finding correct exterior calibration and subsequently precise reconstruction. Our approach provides fast and reliable results.

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