GUI FOR THE RECONSTRUCTION OF 3D COORDINATES

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Abstract

The article deals with design of user interface for reconstruction of 3D coordinates. The interface allows automatic creation model of the scene for inexpert user. On the other hand, program provides possibilities set of many attributes during process of reconstruction for expert user. Besides calculate of 3D coordinates interface can serve for creation of depth map. The application user familiar math equations as well as some proposed modification. The interface allows using different method in each steps of the reconstruction, therefore it can serve as education program.

1 Introduction: Reconstruction of 3D coordinates

The reconstruction of a 3D model of a scene is actual and perspective topic in computer vision. The reconstructed model can be used in many applications in various areas– especially in robotics, civil and building engineering, medicine, etc. The output of the reconstruction are three spatial coordinates in a selected coordinate system. Related problem is the creation of a depth map of a scene which results in a grayscale image. Intensity of each pixel is equivalent to the relative depth.

In order to build the model, there are several main procedures which need to be executed successively. Appropriate flowchart is shown in Fig. 1. 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[13]

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

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. In literature, we can find many methods for camera calibration [1], [2], [3]. The **exterior orientation** represents the relation between camera positions given by rotation matrix **R** and translation vector **T**. Then the relation (2) expresses calculation of 3D coordinate [14].

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

where $\mathbf{P}_1$, $\mathbf{P}_2$, $\mathbf{P}_3$ and $\mathbf{P'}_1$, $\mathbf{P'}_2$, $\mathbf{P'}_3$ 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 [14].

The fundamental task is achievement image correspondents. The image correspondents are used in each subsequent step of the reconstruction. The location the significant points in the left and right images is first the step to get the correspondences. The significant points are pixels with salient properties which can be detected in both images. We need to find the same pixel in each image. Algorithms for this objective are often solved and many papers of this problem exist [4], [5]. Moreover, elimination of false correspondents is important, too. We propose fast elimination of false correspondences based on geometric constraints and extremities.

The above described approaches can be used only for reconstruction of spatial coordinates of points, these, which we are able to find in both images. This task it is a very difficult for a point, which belongs to an area with regular textures or without contrast. We proposed and tested a method based on relation between arbitrary selected points (by user) and feature points in nearby. The main idea uses hypothesis, that small areas in image lies in same depth.

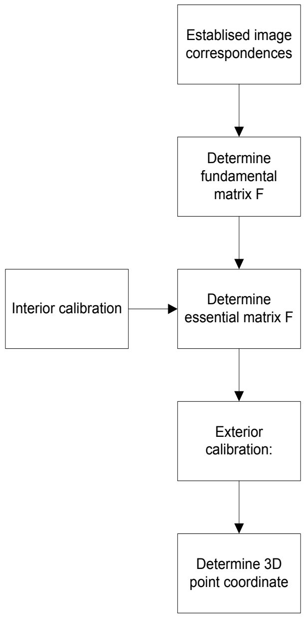

Figure 1: The general flowchart of designed system for reconstruction 3D model.

2 Proposed interface

Proposed interface will serve as tools in laboratory lessons. The interface is shown Figure 2. The application allows perform all steps necessary for reconstruction of 3D coordinates describe in section 1 (see figure 1). The application uses concurrently known mathematical relations, open source MATLAB algorithms or toolbox (for example for calculate interior calibration) and own proposed procedures publicated in [10]. The inputs are two picture of the same scene taken from different positions. In first phase we need find correspondences between pictures. The user can load correspondences, automatically find new correspondences various methods

- Speeded up robust features SURF [7],
- Scale-Invariant Keypoints SIFT [8],
- Harris corner detector [16].

Subsequently, user can select various types of image representation used for finding of correspondences

- Grayscale,
- RGB model with true colors,
- RGB model with false colors.

Image in false colors is obtained using process pseudo coloring from grayscale image. In false colors, image has more contrast. This fact can be useful. This possibility will examined and described in detail in our future publication. In designed interface was implemented algorithm for pseudo coloring proposed in [12]. One image in false colors is shown in Figure 2. Next possibility is determination correspondences manually. Last selectable parameter of the correspondences finding is number of correspondences. Subsequently, the user can save founded correspondences.

Figure 1: Image in false color, obtained by algorithm implemented in interface (picture is taken from [15]).

The application allows elimination of false correspondences by method proposed in [10]. Next step is determination of the interior calibration of the camera. The user can calibration matrix load from disc, enter manually or calculate using MATLAB Toolbox Calib [11]. In subsequent step, the user need calculate exterior calibration of the camera.

Now user has all data required for calculation of the model of the scene or for calculation depth map. The results are display on the second half of the interface. The interface allows various representations of the result. First of them is graphic representation by ground plan. Second one is graphic representation as 3D model. Next possibility is numeric representation of the spatial position of the concrete corresponding pixel. Important part of the application is reconstruction of image point selected by user. The user select point in first image and finding of corresponding in second image can be problem if point belongs to area without contrast. In this issue regular used methods can fail. We proposed approach which can solve this problem. The algorithm is publicated in [10] and implemented in this interface.

In the process of creating depth map, user can select, whether want use some of local based method (for example Sum of Absolute Differences SAD, Sum of Squared Differences SSD, Ratio Image Uniformity RUI, Mutual Information MI) or method based on founded correspondences and image segmentation.

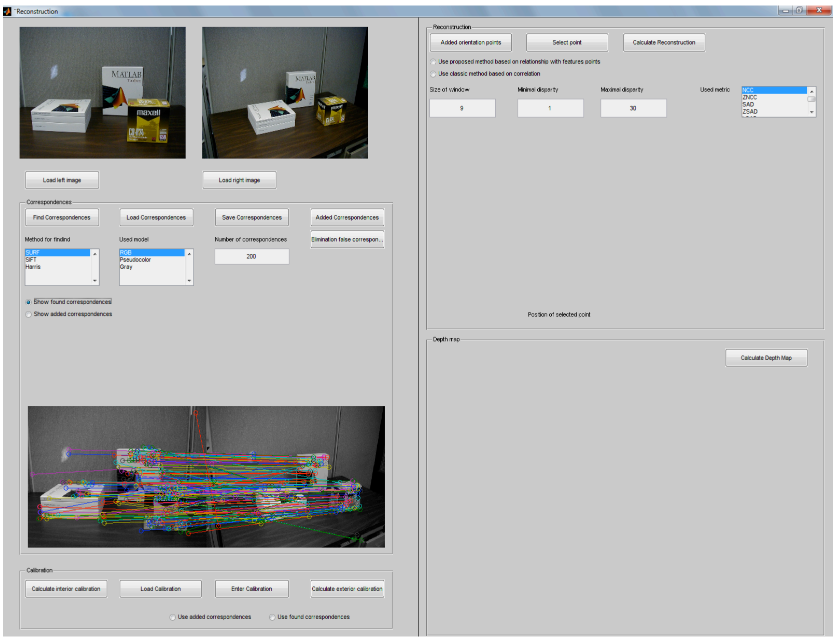

Figure 3: Interface for reconstruction of 3D coordinates.

3 Results

In this section, we are going to present results obtained by using proposed application. Figure 4 shows results of the elimination of the false correspondences. In the figure 5 are presented some 3D model of the scene. In the first column is picture of the scene and in second column are theirs model. Figure 6 show some depth map obtained by algorithm implemented in interface.

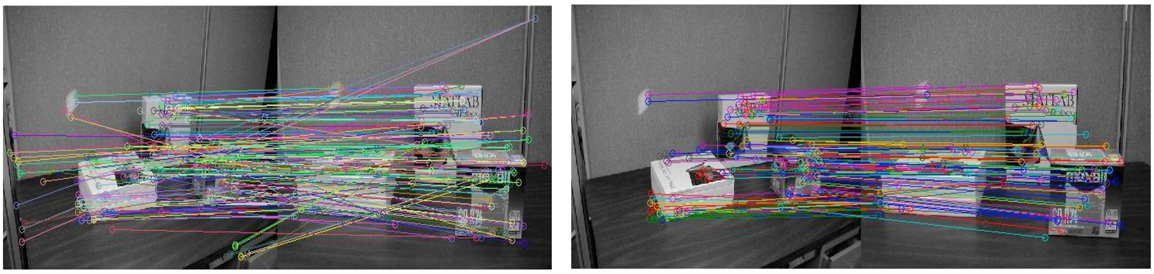

Figure 4: Image correspondences before and after use algorithm for elimination false correspondences (picture is taken from [15]).

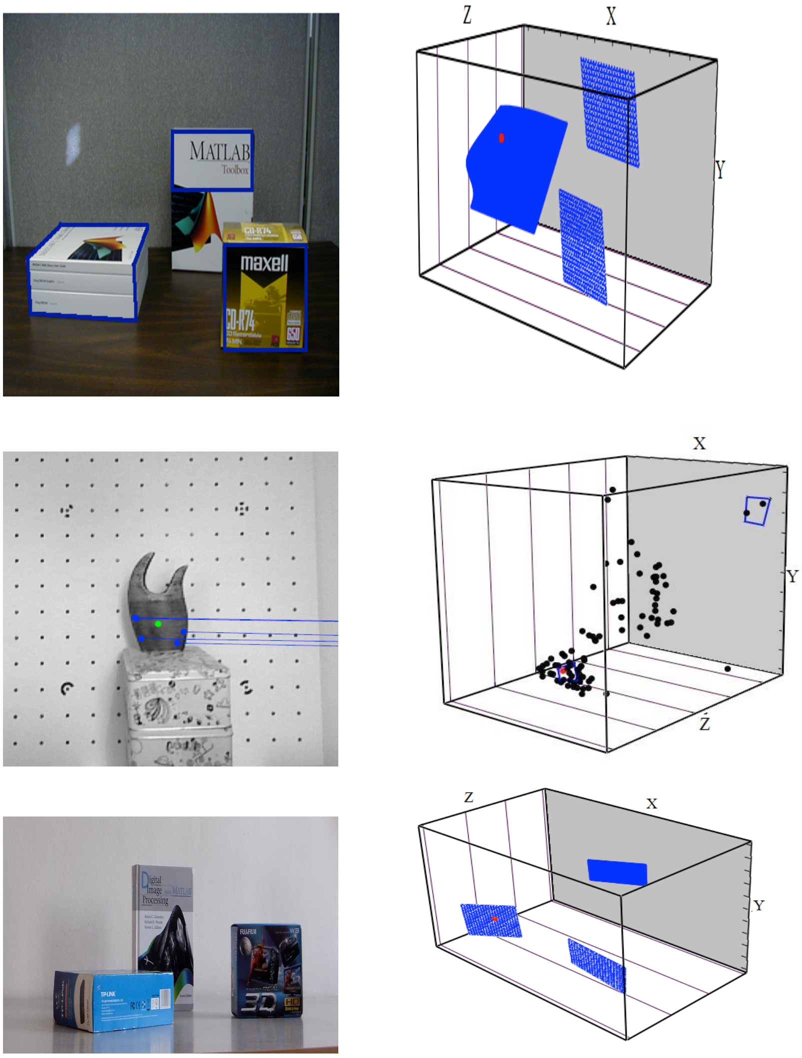

Figure 5: In first column are images of the scene. In second column are resulting reconstruction. Red marks represent location of selected point in space.

The application utilizes possibility of design simple GUI in MATLAB. Next advantage is opportunity to use functions integrated in MATLAB, which makes work simpler. The application combines our own algorithm with open source algorithm. The interface should serve for students and their introduction with topic of the reconstruction of spatial coordinates. On the second hand interface can use even for simple execution some tests of proposed algorithms.

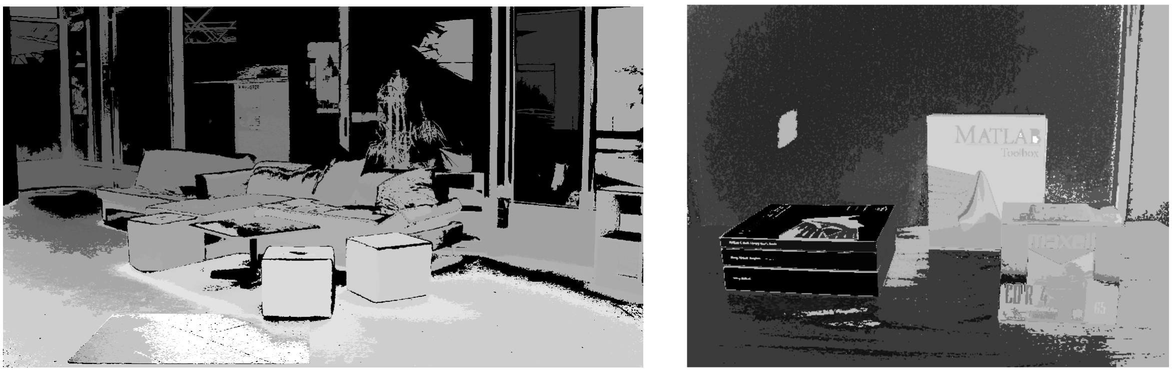

Figure 6: Depth map obtained by algorithm implemented to interface.

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