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Creation of a Depth Map from Stereo Images of Faces for 3D Model Reconstruction

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Abstract

Today the 3D reconstruction of faces is an actual task. It is being used in various fields, for example, in scientific research, in recognition, in video games and in the movie industry. One of the existing methods of reconstructing 3D models of faces uses stereo cameras. The reconstruction process usually consists of several steps: calibration of cameras, acquiring the depth map (disparity map) and the creation of the 3D model. In this paper a method of acquiring a depth map is proposed that can later be used for the reconstruction of a 3D model of a face. The proposed method was tested in a virtual environment - a 3D editor "Autodesk 3Ds Max" was used to create a virtual scene containing stereo cameras and a human head. The proposed method was also tested using two “VISAR” cameras, and an “Arduino Micro” microcontroller. "Arduino" software allows to ensure synchronization of cameras, when using the “Arduino Micro” microcontroller. The images are captured from the cameras by using the “FlyCap” program. Since the initial images contain distortions, the first step of the algorithm is the calibrations of cameras. For calibration, similar points are found on both stereo images. These points are later used to calculate the degree of distortion, and the images are rectified accordingly. The rectified images are used to calculate the depth map. The depth map is created from the front half-tone images of faces.

Keywords: Depth map, face 3D reconstruction, stereo camera

1. Introduction

Reconstruction of a 3D model of a geometrically complex object, for example a face, today is one of the most

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difficult and actual tasks in computer vision[1]. Reconstruction is especially actual in tasks of face recognition, where the possibility of recognizing a face depends on the precision of the 3D model. In general, to reconstruct an object it is required to have at least two images, on these images it is necessary to find corresponding points and construct a depth map. Many factors can affect the quality of the acquired images: lighting, the texture of the object, camera angle and the focal length of the cameras.

Several methods are described in this paper: methods of acquiring stereo images, reconstruction of a 3D object in a virtual and real environment with camera calibration. The main objective of this study was to check how accurately the 3D models can be reconstructed, when using low resolution cameras. The following sections show the results of the developed algorithm.

2. The proposed algorithm of reconstructing models from two stereo images

This paper describes a method of reconstructing a 3D model of a head from two-dimensional coordinates that were acquired from two images. The reconstruction of a 3D model consists of the following steps:

- Camera calibration (determining the internal and external camera parameters)
- Locating the corresponding points on two images that were acquired from different cameras
- Constructing the three-dimensional model of an object

All these steps of reconstructing an object are now going to be described in detail.

2.1. Camera calibration

Camera calibration is one of the steps of 3D model reconstruction where it is necessary to determine the internal and external parameters that affect the error in determining the location of an object. Calibration is important, since it allows to link the camera parameters with the object parameters in a real 3D world. Also, the relationship between the camera measurements (pixels) and real world values (meters) are very significant when restoring the structure of a three-dimensional scene.

The relationship between a point in a world coordinate system (see Fig. 1.) $Q=(X,Y,Z)^T$ and its projection on an image $q=(u,v)^T$, in homogeneous coordinates ($\tilde{q} = (u, v, 1)^T, \tilde{Q} = (X, Y, Z, 1)^T$) is described by the expression:

$$\tilde{q} = A \cdot [R \quad t] \cdot \tilde{Q}\,, \tag{1}$$

where A – contains the internal parameters of the optical system of the camera:

$$A = \begin{pmatrix} f_x & \gamma & u_0 \\ 0 & f_y & v_0 \\ 0 & 0 & 1 \end{pmatrix} \tag{2}$$

where:

f_x, f_y – focal length of a lens,

u_0, v_0 – the coordinates of the main point in the camera's system of coordinates.

There are two types of camera calibration: internal and external. Internal calibration is performed once. This is done because the internal geometric parameters, the optical characteristics of the camera lens and display device settings do not change while shooting. The internal calibrated parameters of the camera are: the focal length, the central points on the images, distortion coefficients.