Direct 3D Information Determination in an Uncalibrated Stereovision System by Using Evolutionary Algorithms

Alain Koch, Université de Bourgogne, France
Albert Dipanda, Université de Bourgogne, France
Claire Bourgeois-République, Université de Bourgogne, France

ABSTRACT

This paper proposes a 3D panoramic shape reconstruction method based on an uncalibrated stereovision system (USS) composed of five cameras circularly located around the object to be analysed. First, some interesting points are detected from markers placed on the object such that they are visible by two successive cameras of the USS. These points are then matched on both images acquired by a couple of successive cameras. This process is repeated for all the couples of cameras. Second, by using an evolutionary algorithm, the depth values of the different interesting points are calculated. A comparison with a traditional method based on calibrated cameras validates the accuracy of 3D information provided by the proposed method. Finally, by combining all the interesting points, a panoramic view of the object is obtained.

Keywords: 3D Reconstruction, Depth Values, Evolutionary Algorithm, Image Processing, Uncalibrated System

INTRODUCTION

The recovery of 3D information (depth) using stereo vision analysis is one of the major areas in computer vision and has given rise to a great deal of literature in the recent past. 3D information is a real need in various domains such as medicine (Zhang, 2008), security (Yang, 2006), virtual reality or robotics (Ayache, 1989).

This paper deals with the passive stereo vision approaches that use two cameras. Two broad classes of systems can be defined to obtain a 3D reconstruction: the calibrated and the uncalibrated systems. The calibrated systems are characterised by an initialisation step called system calibration (Faugeras & Toscani, 1987). The calibration provides the corresponding matrix between the real coordinates and the images coordinates. After the calibration process, the camera locations cannot be changed before the image acquisition. Concerning the uncalibrated
methods, no preliminary step is required before acquiring the images. However, it can be necessary to know the value of some particular features in order to find the corresponding matrix between the real coordinates and the image coordinates (Zhengzhou, 2000). The reconstruction is made on the fly. Whatever system is used, obtaining 3-D information involves the identification of the corresponding 2-D points between left and right images. Most existing methods tackle this matching task from singular points, i.e. finding points of interest (POIs) in both image planes with more or less the same neighbourhood characteristics. One key problem to solve is that in the first instance it is unable to know a priori whether a point in the first image has a correspondence or not due to surface occlusion or simply because it has been projected out of the scope of the second camera. This makes the matching process very difficult and imposes a need of an a-posteriori stage to remove false matching. In this paper, we introduce an original uncalibrated 3D reconstruction method based on Evolutionary Algorithms (EAs) (Goldberg, 1989). In order to facilitate the detection of POIs, some markers are placed on the object. Since the system is uncalibrated, some (or all the) parameters that allow the calculation of the 3D transform between the couple of images are missed, which leads to a very hard non-linear issue that cannot be solved with a classical optimisation method. We have expressed this problem as a minimization of a global function that we offer to achieve by using EAs (Brunetti, 2000; Chang, 2001; Dipanda, 2003; Dipanda & Woo, 2004).

This paper is organized as follows: First, we briefly introduce background notes on epipolar geometry. Next, we detail the different steps of the proposed 3D reconstruction method. Experimental results are presented and the conclusion, along with some of the further works to improve the proposed method, is mentioned.

**BACKGROUND ON THE EPIPOLAR GEOMETRY**

Usually the 3D reconstruction process requires a stereovision system composed of two or more cameras (Figure 1). The 3D coordinates are calculated by triangulation. The triangulation process is the cameras in the scene and the coordinates of point in each image. Usually, the pinhole camera model is used to calibrate cameras. In this purpose, the intrinsic and the extrinsic parameters must be calculated. The extrinsic parameters allow obtaining the transformation between a real point in the world system and its corresponding point in the camera system, while the transformation between the image plane and the camera system is provided by the intrinsic parameters. The intrinsic and extrinsic parameters must be calculated for each camera.

For a given camera the intrinsic parameter matrix $I_c$ is obtained as follows:

$$
\begin{bmatrix}
\alpha_u & 0 & u_0 & 0 \\
0 & \alpha_v & v_0 & 0 \\
0 & 0 & 1 & 0
\end{bmatrix}
$$

Where $(u, v)$ are the coordinates of the 2D point $p$ in the image plane, $(x, y, z)$ are the coordinates of the 3D point $P$ on the object in the camera system, $s$ is a scale factor (generally, equal to one) and $(u_0, v_0)$ are the coordinates of the optical centre in the image plane.

The values of the parameters $\alpha_u$ and $\alpha_v$ are calculated by:

$$
\alpha_u = k_v f
$$

$$
\alpha_v = -k_u f
$$

Where $k_u$ (resp. $k_v$) is a vertical (resp. horizontal) scale factor of the camera and $f$ is the distance named the focal length.