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APPLYING CCD CAMERAS IN STEREO PANORAMA SYSTEMS FOR 3D ENVIRONMENT RECONSTRUCTION

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ABSTRACT:

Proper reconstruction of 3D environments is nowadays needed by many organizations and applications. In addition to conventional methods the use of stereo panoramas is an appropriate technique to use due to simplicity, low cost and the ability to view an environment the way it is in reality. This paper investigates the ability of applying stereo CCD cameras for 3D reconstruction and presentation of the environment and geometric measuring among that. For this purpose, a rotating stereo panorama was established using two CCDs with a base-length of 350mm and a DVR (digital video recorder) box. The stereo system was first calibrated using a 3D test-field and used to perform accurate measurements. The results of investigating the system in a real environment showed that although this kind of cameras produce noisy images and they do not have appropriate geometric stability, but they can be easily synchronized, well controlled and reasonable accuracy (about 40 mm in objects at 12 meters distance from the cameras) can be achieved.

1. INTRODUCTION

Producing three-dimensional models of the environment, displaying and measuring in these models is considered by many organizations. Three-dimensional models can be supplied in various fields such as completing the existing map, the urban model, control and robotics, providing three-dimensional virtual models, computer games, navigation and intelligent systems capable of understanding the environment [1]. In producing these three-dimensional models, the parameters of accuracy, speed and cost are important [2]. In a general classification, methods for producing 3D model are classified in two ways: geometric-based methods and image-based methods [1]. Image-based methods in the preparation of three-dimensional models due to its significant advantages such as low cost and provide a realistic view of the environment has received much attention [3, 4].

One way of modeling the environment, is applying stereo systems and provide full coverage and actual three-dimensional view of the environment. In between, the type of applied sensors is very important. Since different systems is presented to obtain stereo images of the environment. These systems generally are based on the use of the frame-based cameras [5, 6], linear array systems [7, 8], using fish-eye lenses [9, 10] cameras with hyperboloid mirrors [11, 12], omni-directional cameras [13, 14] or modular systems [15, 16]. In figure 1, examples of these systems can be seen.

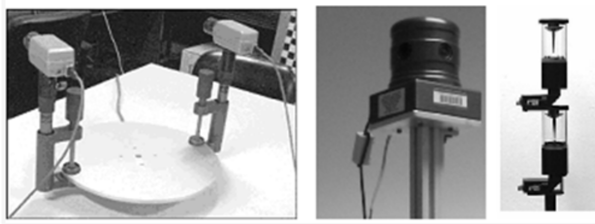

Figure 1. Examples of frame-based (left), modular (middle) and omni-directional (right) systems.

Generally in selection of appropriate sensors of stereo systems, high resolution in order to achieve the expected accuracy, low noise and good image quality, greater viewing angles up to cover the environment, good geometric stability, and camera controlling, synchronization, and low weight are important parameters.

CCD cameras are a bunch of computer vision cameras that are used more in monitoring and control applications. The main advantage of this type cameras are offering synchronized images and they can be controlled. These cameras are offered in various sizes and formats. Generally, the following features of these cameras make them different from each other:

- functioning in outside environment (Indoor/Outdoor)
- imaging in the day and night (equipped with IR)
- differentfocal length and viewing angle
- different resolution and quality
- ability the lens to mount on

Examples of these cameras are shown in figure 2.

Figure 2. Examples of CCD cameras

The purpose of this study is investigating the ability of using CCD cameras and their accuracy in creating three dimensional models of the environment and geometric measuring through.

For this purpose, in the research, a stereo vision system based on two CCD cameras, a digital image recorder (DVR) and a computer were implemented. Then the ability of the system was examined. The system, its calibration and tests in order to evaluate the accuray of the system are described as follows.

2. STEREO VISION SYSTEM AND CALIBRATION

As was mentioned, in this study, a stereo vision system based on two CCD cameras, a digital image recorder (DVR) and a computer were implemented. In this system, two CCD cameras were used with brand Cup. The camera nominal focal length is 3 mm, resulting in a relatively large angle at 80 degrees.

Imaging by this type of camera is in VGA format. To check the accuracy of the stereo camera system, a stereo system consists of two cameras, one bar with the ability of changing the base-length, and a four-channelDVR device for synchronization of two cameras and their images were used. In figure 3, the system used is shown.

Figure 3. Stereo Vision System used in the research

The stereo system calibration was performed by a test-field. In calibration process, eight pairs of images were obtained from the test field. In this process, four scale bars were used to determine the actual values of parameters.

According to the fixed position and orientation of the two cameras to each other, relative orientation parameters between two cameras can be used later in modeling and computation. Relative orientation parameters between two vision cameras were calculated. These values including rotation, transmission and the base-length between eight pairs of images taken by cameras, and the estimated standard error values are observed in table 1.

Parameters	Mean value	Standard error
$\Delta\Omega$ (degree)	-7.955	0.034
$\Delta\Phi$ (degree)	-5.079	0.070
ΔK (degree)	1.246	0.028
ΔX (mm)	325.971	1.028
ΔY (mm)	-34.720	0.556
ΔZ (mm)	-47.718	0.136
Base (mm)	331.320	1.025

Table 1. Transmission and rotation parameters between two cameras and their standard error values

It seems large standard errors especially for transmission parameters are due to the physical instability of cameras on stereo bar; consequently, they must be fixed on the bar.

Moreover, the geometric instability of cameras affected the error values, because these cameras generally cannot be adjusted manually and by changing the focus, the parameters are changed.

To investigate the efficiency and accuracy of the proposed system based on the CCD cameras, in this study; two investigations were carefully assessed in laboratory environment and in the real environment. In continue the procedure and results are expressed.

3. LABORATORY ENVIRONMENT INVESTIGATION

For laboratory examination of stereo system, an environment was considered with some target points in it and images captured from. To achieve the real accuracy, some definite length with real values was applied in the environment. Environmental assessment is shown in figure 4.

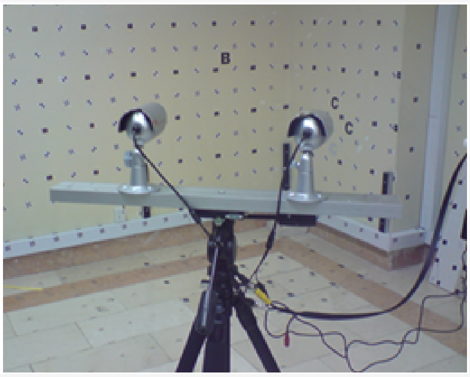

Figure 4. The laboratory environment used to evaluate stereo vision system

In this study, target points were measured manually. In the self-calibration process, the camera calibration parameters were estimated again to investigate variations of the calibration parameters of the cameras.

Moreover, relative orientation values between two cameras in vitro environment including, rotations and the base-length were also computed. Different values of these parameters with the results of test-field calibration are given in table 2.

Parameters	Values from laboratory investigation	Different values with the results of test-field calibration
ΔΩ (degree)	-7.6465	0.3093
ΔΦ (degree)	-4.4734	0.606
ΔΚ (degree)	1.5692	0.3229
Base (mm)	332.6480	1.3272

Table 2. Rotations and base-length values between two cameras in vitro environment investigation and their difference with values from test-field calibration

As is observed in table 2, the difference between the values of orientation and base-length of two cameras of stereo vision from the test-field calibration and values from self-calibration in the laboratory investigation is relatively significant amounts. As mentioned, reasons for this difference are geometric instability caused by impossibility of stabilizing the situation of the camera image acquisition condition. Consequently geometric parameters of two cameras are changed.

Standard error of the point coordinates from bundle adjustment for a stereo image pair in laboratory investigation is shown in Table 3.

Base-Line (mm)	Standard error of the point coordinates			
	δX(mm)	δY(mm)	δZ(mm)	Total(mm)
332	3.4584	4.0391	11.0033	12.2208

Table 3.Standard error of the point coordinates from bundle adjustment for a stereo image pair in laboratory environment investigation

Error values observed in Table (3), obtained from a stereo pair with base-length of 332 mm and with manually points measuring.

4. REAL ENVIRONMENT INVESTIGATION

To evaluate the accuracy of the system in real environment, a closed environment with dimensions of about 20 m at 28 m were studied. Imaging was performed an average distance of 12 meters from the side. Figure 5, shows the investigated environment.

Figure 5. The real environment used to evaluate stereo vision system

In this review, for matching, the actual features of the environment were used and the points and corners of the images were measured manually. Of course, to increase the accuracy, a number of target points were also used beside natural features. The target coordinates was estimated with a network of Geodesy and in Land Surveying method with an accuracy of 1 cm. Afterward, the coordinates and the distance between the targets were used as known values in the adjustment.

Standard error of the point coordinates from bundle adjustment for a stereo image pair in laboratory investigation is shown in Table4.

Base-Line (mm)	Standard error of the point coordinates			
	δX(mm)	δY(mm)	δZ(mm)	Total(mm)
332	12.4607	7.9400	35.7120	38.6479

Table 4.Standard error of the point coordinates from bundle adjustment for a stereo image pair in real environment investigation

Error values observed in Table (4), obtained from a stereo pair with base-length of 332 mm and with manually points measuring.

Important part of the error is due to the low resolution of the used cameras and their geometry instability. Moreover, one of the main reason for reduced accuracy is the small base-length between the two cameras, , particularly along the imaging axis (axis Z), specially with increasing distance, the error is greatly increases in this regard.

5. CONCLUSIONS

One of the methods of modeling the environment is using stereo systems for real three-dimensional viewing. In between, the type of sensor or the camera for stereo image acquisition is very important. The purpose of this study is investigating the ability of using CCD cameras and their accuracy in creating three dimensional models of the environment and geometric measuring through. For this purpose, in the research, a stereo vision system based on two CCD cameras, a digital image recorder (DVR) and a computer were implemented. Then the ability of the system was examined. The main results obtained in this research can be presented as follows.

The main advantage of the CCD camera can be named, offering image instantaneously, giving them a command and control, the ability to create synchonization between the cameras and their relatively low cost.

CCD camera used has been the lack of ability to stabilize adjustments, and with changing the focus, environmental conditions and time spending, their parameters are changed. Sharp change of camera calibration parameters indicates their geometric instability.

High noise and low resolution of the applied cameras for image acquisition has been reduced image quality. As a result, makes the matching process difficult. Besides, applying complete and appropriate corrections to the image space are essential.

According to the accuracy required in urban areas (about 200 mm) and maximum distance of mage acquisition to the objects in this area (about 25 meters), the precision obtained in laboratory studies and also in a real environment, almost supplies the required accuracy, and these cameras can be used in the modeling of environment. It should be noted that due to the low base-length of the stereo system, with increasing distance of stations to the objects, the accuracy decreases, especially along the imaging axis.

It can be concluded that with applying CCD cameras with low noise, high image quality at mega pixel (which of course increases the cost to them), using appropriate algorithms for image correction, and if geometric and physical stability of these cameras is provided, this type of cameras can be trusted to apply in stereo vision systems and modeling environment.

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