STRUCTURED LIGHT BASED STEREO VISION FOR COORDINATION OF MULTIPLE ROBOTS

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Abstract: This paper reports a method of coordinating multiple robots for 3D-object handling using structured light based stereo vision. The system structure of using two robots (puma and staubli) for playing chess has been proposed. The key techniques for surface reconstruction and rejection of 'spike' are discussed. The feature of the active vision system for 3D object acquisition and their application for robotics and automation are introduced. Following experimental studies, conclusion and further work have been derived.

1 INTRODUCTION

We want multiple robots to operate in unknown, unstructured environments. To achieve this goal, the robots must be able to perceive its environment sufficiently to allow it operate with that environment safely. Most robots that successfully navigate in unconstrained environments use sonar transducers or laser range sensors as their primary spatial sensor (Lim and Leonard 2000, Guivant etc 2000). Although many indoor surfaces are indeed specular, rough surface reflections can be important in many environments. Incorporation of echolocation constraints from rough surfaces is more difficult because diffracted sonar returns provide weaker geometric constraints than specular sonar returns. Sonar barrier test may cause problems in situations when there are unmodeled objects present or when there are objects in the model, which are no longer in the same positions in the environment. Ultrasonic sensors have been widely used in indoor applications, but they are not adequate for most outdoor applications due to range limitations and bearing uncertainties.

Stereovision has been the object of research in many important research laboratories around the world. Recently, stereoscopic omni directional systems were used in indoor localisation applications (Drocout 1999). This type of sensor is based on conical mirror and a camera that returns a panoramic image of the environment surrounding the vehicle. Although a promising technology, the complexity and its poor dynamic range made this technique still not very reliable for unstructured environments, particularly handling mechanical components where texture are not rich presented. Because stereo vision mapping is very sensitive to errors, as the process of collapsing the data from 3D to 2D encourages errors in the form of 'spikes' to be propagated into the map.

Our recent work on 3D Reconstruction of a Region of Interest Using Structured Light and Stereo Panoramic Images has good results (Gledhill etc 2004), where 360^0C degrees of scene and 3D of region of interest can be easily captured and visualised. This paper focuses on the structure of robot sensing systems and the techniques for measuring and pre-processing 3-D data. To get the information required for controlling a given robot function, the sensing of 3-D objects is divided into four basic steps: transduction of relevant object properties (primarily geometric and photometric) into a signal; pre-processing the signal to improve it; extracting 3-D object features; and interpreting them. Each of these steps usually may be executed by several alternative techniques (tools). Tools for the transduction of 3-D data and data pre-processing are surveyed. The performance of each tool depends on the specific vision task and its environmental conditions, both of which are variable. Such a system includes so-called tool-boxes, one box for each sensing step, and a supervisor, which controls iterative sensing

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feedback loops and consists of a rule-based program generator and a program execution controller. The rest of the paper is organised as follows. Section 2 introduces the system design of vision based multiple robot applications; Section 3 discusses the 'spike' noise and its solution by using structured light based vision system; Section 4 reports experimental studies and conclusion is derived in session 5.

2 SYSTEM DESIGN

The aims of the projects are to build a multiple robot networks, where all the robot locations and the locations of targets can be monitored by their individual active vision system on each robot in the systems. A system design of the distributed system is illustrated in Fig. 1. The robots used are a Staubli robot and a Puma robot in our lab. For large scale of robot networks, a low cost vision system will be developed. Therefore, we design and develop a structured light based vision system, where two webcams are used for each robot.

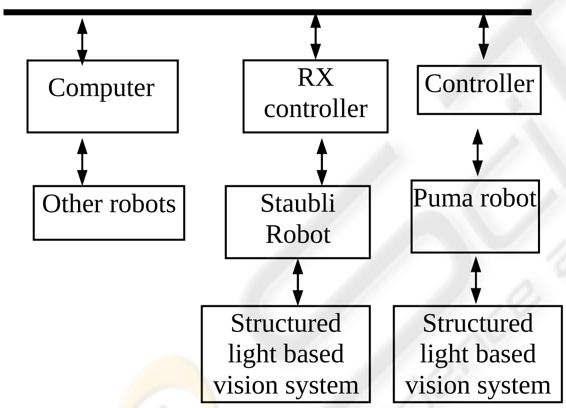

Figure 1: the system design of using structured light based vision system for multiple robot control

3 STRUCTURED LIGHT BASED STEREO VISION

Stereo vision normally uses correspondence methods for 3D-reconstruction (Nitzan 1988). Correspondence methods are less accurate in areas of low texture (Murray and Jennings 1997, Xiao etc 2004, Tian etc 2003). For example in an outdoor environment where texture is in abundance correspondence is very accurate, but an indoor environment usually has walls, and indoor walls usually have low texture, e.g. white paint. To overcome this lack of texture, it is proposed that a light pattern is projected onto the low texture areas to aid the correspondence search. Once a texture has been applied the correspondence algorithms achieve higher accuracy results. For this system a Gaussian noise pattern is produced. The image is filtered to ensure that no two dark pixels are next to each other, so that no ‘blocks’ of black are produced. Large areas of black result in inaccurate removal of the noise later. The structured light pattern has to be dense enough to create a useable texture for the correspondence algorithm, but with small enough dots to be able to remove them for visualisation. The result is then projected into the environment. Fig. 2 shows an example of 'spike' noise of 3D reconstructed object for a typical mechanical part illustrated in Fig. 5. To overcome the 'spike' noise, a structured light based stereo vision system is developed as illustrated in Fig. 3. The structured light can be laser light or any other visible light, which will depend on the targets to be handled or monitored as shown in Fig. 4.

The disparity results are validated in two ways. First, there is a ‘sufficient texture’ test. This test checks that there is sufficient variation in the image patch that is to be correlated by examining the local sum of the Laplacian of Gaussian of the image. Low texture areas score low in this sum. If there is insufficient variation the results will not be reliable, thus the pixel is rejected because there will be too much ambiguity in the matches. If there is not a sufficient texture, a structured light is exploited. Secondly, there is a ‘quality of match’ test, using structured light in particular. Rather than regular pattern structured light, a random Gaussian noise pattern is used, which can be easily filter out by using median filters from the captured images. Fig. 5. shows the flowchart of the image reconstruction and understanding. In this test, the value of the score is normalised by the sum of all scores for this pixel. If the result is not below a threshold, the match is consider to be insufficiently unique and therefore a likely mismatch. This kind of failure generally occurs in occluded regions where the pixel cannot be properly matched.

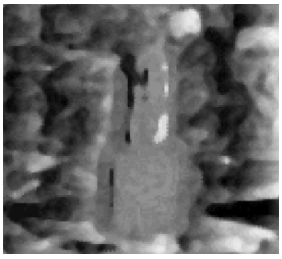

Figure 2: 'Spike' noise

Figure 3: Structured light based stereo vision system

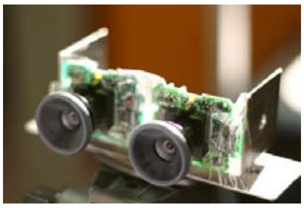

Figure 4: Alternative system with visible light instead of laser light

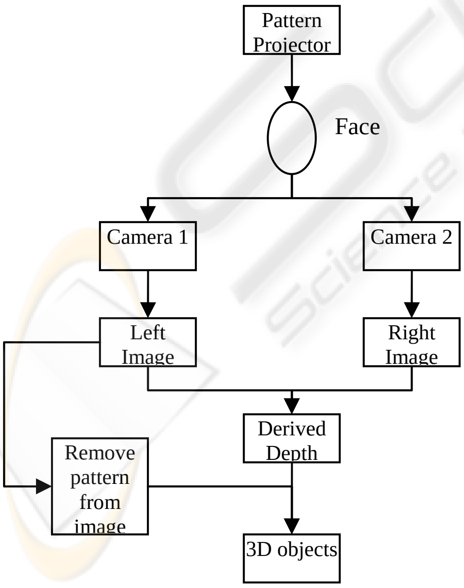

Figure 5: A real-time stereo vision system

4 EXPERIMENTAL STUDIES

In the experimental studies, two images were captured by two webcams displayed in Fig. 6. The structured light was used due to lack of the texture in the mechanical parts. The reconstructed 3D image in Fig. 7 has much better quality than the reconstructed 3D image without using structured light in Fig. 2, where 'spike' noise existed. Through the 3D-model acquisition systems, 3D objects as illustrated in Fig. 8 can be perceived by robots. The four images in Fig. 8 illustrate the different 3D views from different viewpoints.

The active vision system with adaptable structured light is uncalibrated 3D reconstruction. Uncalibrated reconstruction of a scene is desired in many practical applications of computer vision (Li and Lu 2004). We present a method for true Euclidean 3-D reconstruction using an active vision system consisting of a pattern projector and two low-cost cameras. When the intrinsic and extrinsic parameters of the camera are changed during the reconstruction, they can be self-calibrated and the real 3-D model of the scene can then be reconstructed. The parameters of the projector are precalibrated and are kept constant during the reconstruction process. This allows the configuration of the vision system to be varied during a reconstruction task, which increases its self-adaptability to the environment or scene structure in which it is to work.

The robot controllers will process the 3D images and extract information about the target pose and location, which are important for the plan of actions e.g. gripper control for the robot network. Further data fusion and communication control about the system will be published in a different paper.

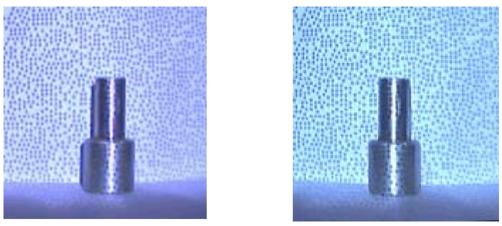

Figure 6: The left and right images from the capture system

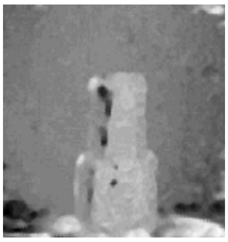

Figure 7: The depth map from the stereo system

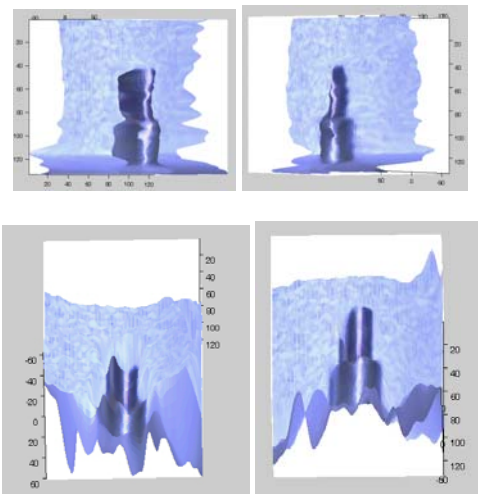

Figure 8: 3D images perceived by robots

5 CONCLUSION AND FURTHER WORK

Stereoscopic systems for robot navigation and robot networks are currently possible using structured light and low-resolution real-time devices. Although these devices don't have the same performances as the human depth perception system, they seem efficient for simple applications such as obstacle avoidance and co-ordination control for multiple robots. The system is low cost and easily implemented for autonomous systems. The active vision system can adapt different lighting environment and camera intrinsic and extrinsic parameters by using our normalisation algorithms (Finlayson and Tian 1999) and data fusion from the redundancy data of the structured light based stereo vision.

Until recently certain distributed systems aspects of multi-robot teams were not given much attention. A sensing approach has been proposed for cooperative robotics. In the future, the system will be integrated with panoramic stereo vision systems for wide range of position monitoring (Bunschoten and Kröse 2002). Further data fusion for robot networks or sensor networks will be investigated (Büker etc 2001).

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