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Stereo Vision based Object Tracking Control for a Movable Robot Head

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Abstract: In this paper, we have developed a visual tracking control system on a purposely built movable robot head mounted on a Baxter robot. The tracking control algorithm used a stereo vision system provided by a Bumblebee camera, facilitated by the MATLAB computer vision toolbox. The objective of this work is to enable a robot to move its head as in a similar manner as our humans beings to focus vision on a moving object. Identification of object and estimation of its coordinate are performed based on image processing techniques. A fuzzy logic technique is applied to control the moving head in order to bring human like motion into the robot. The method developed in this work can be extended to any other movable robot head platform. Extensive experimental studies have been performed to test the effectiveness and efficiency of the proposed method.

Keywords: Fuzzy logic, Stereo vision, Image processing

1. INTRODUCTION

Our human vision system is subject to a limited range of view, but the range can be extended by moving our head and eyes to cover larger surrounding areas. The head of human has 3 degree of freedom (DOF) which are yaw, pitch and roll. These movements allow us to see the surrounding area without moving our body (Song (1996)). Moreover, human have the ability to estimate the distance. Thanks to stereo based vision system, human eyes are able to estimate the depth of visualized objects. Aiming at bringing this ability to robots for capability enhancement, we develop a stereo vision based object tracking system on our purposely designed movable robot head. There is an obvious advantage of moving cameras/eyes that are integrated on a robot, i.e, where it allows the robot to discover the surrounding environment without adding additional movements to the robot body. The movement of the camera make the tracking of an object easier and keeps the object nearer to the center of the camera axis where its reduce the computation time be reducing the area of calculation S.Rougeaux et al. (1993). This function embraces the robot for being more flexible in different environments to adapt new tasks (Rodriguez and Yu (2011)) .

A conventional vision uses one camera to analyze the surrounding environment or the task. By using one camera we can get a flat image (2D information) about the environment such as identify different shapes or colors ect. The conventional vision cannot supply a 3D dimension (Adrian and Gary (2008)). On the other hand, stereo vision has the advantage over the conventional vision by providing a 3 dimensional space. Stereo Vision systems capable of creating a 3D cloud of point to restructure the environment in order to analyze the surrounding area with a measurement by using two cameras (Ramesh C. Jain and Schunck (1953)). The stereo vision can be used as an alternative to measuring sensors such as the laser sensor that is used in robots to measure distance. Where laser scanner are more expensive than using camera.

Computer vision has been wildely utilized in manipulating arms. The vision system is used as a feedback sensor that supplies the information about the object's position. Both stereo vision and conventional vision use the vision servoing (s.Hutchinson et al. (2002)). This kind of process is called visual servoing (VS) control. There is a great advantage of using visual servoing control, where machines have their on eyes to see. The conventional teaching and training on robots can be eliminated by this method. The manipulator arms can plan thier movements around the environment. Visual servoing control offer more accuracy with a less setup time (Low (2006)).

There are two different approaches to control the manipulator arms based on visual servoing, position based visual servo PBVS and image based visual servo IBVS (Corke (2013)). In PBVS the camera fixes on the top of the end-effect of the manipulator arm. Based on the calibration of the camera and the manipulator arm, the position of the target can be found according to the camera coordinate then the position transformed to the world coordinate. In IBVS the camera is fixed in a known coordinate according to the world coordinate in which the coordinate of the target transformed through the camera to the manipulator arm.

There are sevral research were done on both approaches, many of them were focusing on tracking objects. One of

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experiment was performed on stereo vision to detect the human motor reactivate(Šuligoj et al. (2014)). In this experiment, the camera was fixed in a specific position while track the moving object. another study was conducted on two amanipulator arms that complete each other where one of them is holding the camera as a guider in order for the other arm perform the assigned task. A study also was done on a fixed platform with two rotated cameras to produce a zero disparity by tracking the object and keep it in the center of the cameras (S.Rougeaux et al. (1993)). This experiment's result proves the difficulty of providing zero disparity, as a result of there system design.

However, humans have the ability to make the decision quickly with less information available; whereas the machine work on precise information hence it is difficult to make a decision as quick as human (Zadeh (1984)). Decision made by human are based on experience and skill gained during life (common-sense) thus, they do not need a precis fact during decision making while probability might be an important factor in the making decision (Guanrong and Trung (2000)). For example, humans do not need to measure the height of a person to say he is tall or short. The fact of a human being tall comes from our experience and classification of heights. Due to the elegance areas of fuzzy logic to find a solution in a complex system which is difficult to describe by the traditional logic (Bojadziev and Bojadziev (1996)).

Fuzzy logic has been widely used in many experiments. In (Farooq et al. (2013)), fuzzy logic has been used in autonomous car experiment to navigate in unknown locations. The experiment shows the stability and the fast response to any action. Experiments have been conducted on manipulator controllers, where the fuzzy logic is used to control the joints of the robot (Smith et al. (2015), McLauchlan et al. (1997), Lea et al. (1993) and Malki et al. (1997)).

In (Pal et al. (2012)), fuzzy logic (FL) has been used in two stages; at the binning FL was used to detect people during image processing, and in the second stage (FLPF) uzzy logic particle filter used to track people. The tracking system was used depth information to decided which person first detected. A research was done on active vision in autonomous navigation using FLC in (Kundur and Raviv (2000)). In the experiment they used FL control to process the incoming data. FLC allowed the control to be in real-time feedback process.

In this paper, a stereo vision with a two degree of freedom platform was developed to keep the robot tracking an object and send the feedback of the object position. The controller of the camera was designed based on fuzzy logic system. The fuzzy logic was implemented in this experiment since the aim of this work is to simulate the movement of human's head in robots, in the behavior of moving.

2. BACKGROUND AND PRELIMINARIES

In this paper, we employ a purposely designed movable robot head, which was designed to be fixed on the top of the head of the Baxter robot as illustrated in (Fig.1). This platform is equipped with two servo-motors (Dynamexil servo-motor AX-12) to move the camera in yaw and pitch. These type of motors give 50 RPM. The micro-controller used was Arduino UNO board. The communication between Baxter and the main computer was based on a UDP communication via wireless LAN.

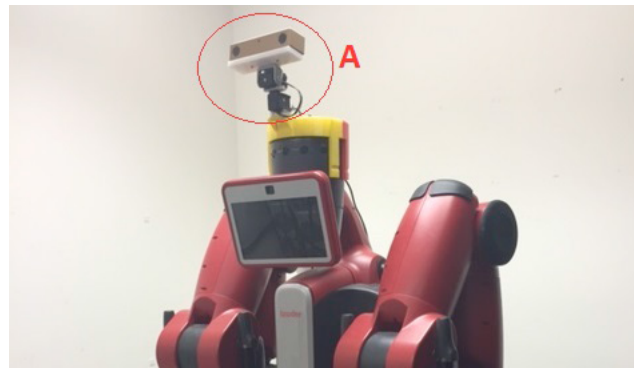

Fig. 1. Experiment setup consist of two DOFs and bumblebee camera(Stereo Head at A)

2.1 Stereo Vision

The ability of image processing using one camera to identify an object and to find its position(x,y) and orientation θ in 2 dimensions is a very useful process. Despite the fact that this process is providing a 2D coordinates of an object, it is still important to measure the depth of that object. This may require adding extra sensors that can measure the depth of the object. Stereo vision system can be alternative of using extra sensors such as laser sensors. The stereo vision uses two cameras. It applies algorithm to find the position of the object in 3 dimensions. The stereo vision algorithm goes through four processes to find the coordinate of the object (Adrian and Gary (2008)).

Calibration process is the first step, where the calibration is a process used to find and correct the parameters of the camera. Because usually camera comes with internal defect due to the manufacturing such as lens distortion, lens misalignment and the alignment of two cameras in stereo camera. To understand the calibration process, first we need to understand the model of the camera (Fig.2). We will start with a single camera algorithm then we will move to the stereo camera.

Fig.2 shows the simple camera model, where the camera coordinate (0,0,0) C is the center of the camera and the image plane has its own coordinate (u,v). (U_0,V_0) is the point intersects with the Z axis of the coordinate of the camera and the image plane. f is the distance from the center of camera to the image plan which called the focal length.

p is a point in front of the camera plane with attached coordinate (x,y,z). In the image plane, this point p is present in 2D coordinate (U_p , V_p). Applying a right triangle trigonometry analysis, the following equations (1) and (2) are established.

$$\frac{u_p}{X} = \frac{f}{Z} \quad (1)$$