Robot Motion Control with Human Eye Command

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Abstract: The robot motion control with human eye command is proposed in this research. The proposed system realizes a viewing system controlled by operator eye command which is able to move the camera equipped at robot arm to capture the scene from environment in accordance with position where the operator intent to see. The eye command interpretation includes the estimation of eye viewing direction (eye gaze) to obtain the eye viewing position on computer screen as motion command, and eye blinking measurement to obtain the motion decision. The motion command is used to determine where the robot should move to (and the camera attached at the robot should point to). The motion decision is used to determine the starting time of robot to move to a new position. An image based visual servoing strategy with velocity limiter is applied to obtain high performance of motion and to minimize the blur effect when camera captures image.

Keywords: Robot control, machine vision, eye tracking, gaze estimation, human computer interface

I. INTRODUCTION

The development of robot control with human eye is one of interesting field of research with many prospective applications. This research combines the computer vision field and robot control field to realize specific application. Providing a technology for helping the disable person (which is no ability to use the hands) to do their activities is one of potential application. Another possible application is robot motion control in a remote and dangerous area.

In an application for disable person, using the eye command, a robot arm can run to do a sequence task, to take a food, and to bring it to the front of mouth. Furthermore, the eye command can be used to choose and to decide which food handled by the robot arm. The other application for disable person is the use of eye command to control the electric wheel chair movement. Here, the eye movement generates the movement path and determines movement properties of electric wheel chair.

The human eye based robot motion control can be utilized for others applications such as navigation of unmanned vehicle, monitoring of industrial process in a remote area, vehicle license plate identification for the traffic surveillance system, and remote scene capturing for television broadcasting.

There are many researchers work in the field of eye viewing vector estimation system. The Arai Lab introduced the computer input system without keyboard based on line of viewing vector estimation with iris centre detection [1]. The system utilizes display-mounted web camera for acquisition of users face and display-mounted lamp for illumination to users. It is reported that the proposed system allows user movement because moving picture of the user face acquires in a real time basis. The relation between allowable movement of the users motion and success rate and the relation between signal to noise ratio as well as contrast of the acquired users image and success rate are clarified.

In the field of robot motion control, the position-velocity-based trajectory control for robot has been proposed [2]. This technique presents a control system to move the robot arm smoothly in linear path between two designated pose (position and orientation). Two independent commands, the pose command and the velocity command, are applied as input of position-based and velocity-based control, respectively. The pose position command describes directly the desired change of robot pose from a start to a destination pose. The velocity command determines the desired robot velocity, and contributes directly to the smoothness of movement. In the inner loop of robot control system that work in every robot joint motor, the disturbance observer based technique is applied. The detail discussion about disturbance observer topic can be found in article written by Ohnishi et al [3].

The human eye based motion control system has been developed by Chatten Associates, Inc [4]. The operator wears a helmet-mounted display. When the three-axis gimbal is mounted in an unmanned vehicle, wherever he looks the gimbal slews to match, the operator's visual perception is that he is actually in the vehicle. The operator's head position can control where the remote vehicle's sensors are pointed.

In this research, the general approach to integrate the eye command interpretation and robot motion control is studied deeply. This work initiates the new applications in robot vision.

II. PROPOSED SYSTEM

In general, the robot motion control with human eye command consists of 2 main studies: eye command interpretation and robot visual servoing. Eye command interpretation discusses the methodology to provide the motion command for robot. The robot visual servoing studies the robot control system employed visual information as feedback.

2.1. Equipment and System Setup

The equipment for system realization is shown in Figure 1. A simple two degree of freedom serial link robot is utilized. The first link moves in left-right or horizontal direction, and the second link moves in up-down or vertical direction. The end effector of robot is equipped with a camera to capture the scene from environment. The captured image is transmitted to the computer screen at the front of operator. A web camera is set up at the front of operator, and it is used to capture the operator's face image. The computer connected to the webcam is programmed to interpret the eye based motion command for robot. The computer is also connected to robot actuator to deliver command and to perform the motion control for robot arm. The additional lamp is used to provide appropriate illumination to the operator's face.

The proposed system realizes a scene viewing system controlled by operator eye command. This system has ability to move the camera set up at robot arm to capture the scene from environment in accordance with position where the operator intends to see. The motion strategy consists is planned to work in step mode. Here, the robot will move with respect to the operator eye viewing direction and eye blinking mechanism.

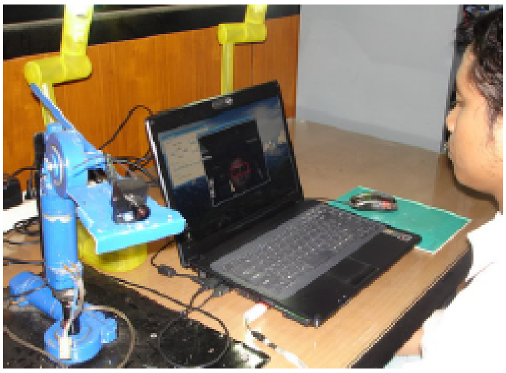

Fig. 1. Equipment setup

The eye command interpretation includes the estimation of eye viewing direction to obtain the eye viewing position on computer screen as motion command, and eye blinking measurement to obtain the motion decision. The eye viewing direction is derived from the position of eyebrow, eye edges, eyeball, and iris center. The eye blinking measurement is obtained from the measurement of eyeball area when eye in open or close condition. The motion command is used to determine where the robot should move to (and the camera attached at the robot should point to). The motion decision is used to determine the starting time of robot to move to a new position.

The camera installed at the end effector of robot used in scene capturing was a standard camera. The notebook camera was used to capture operator face. The notebook used a Pentium 1.73 GHz processor and 488 MB of RAM. The proposed system was implemented using programs written in Visual C++. The OpenCV (open source computer vision library) was used to implement the image processing and computer vision algorithm.

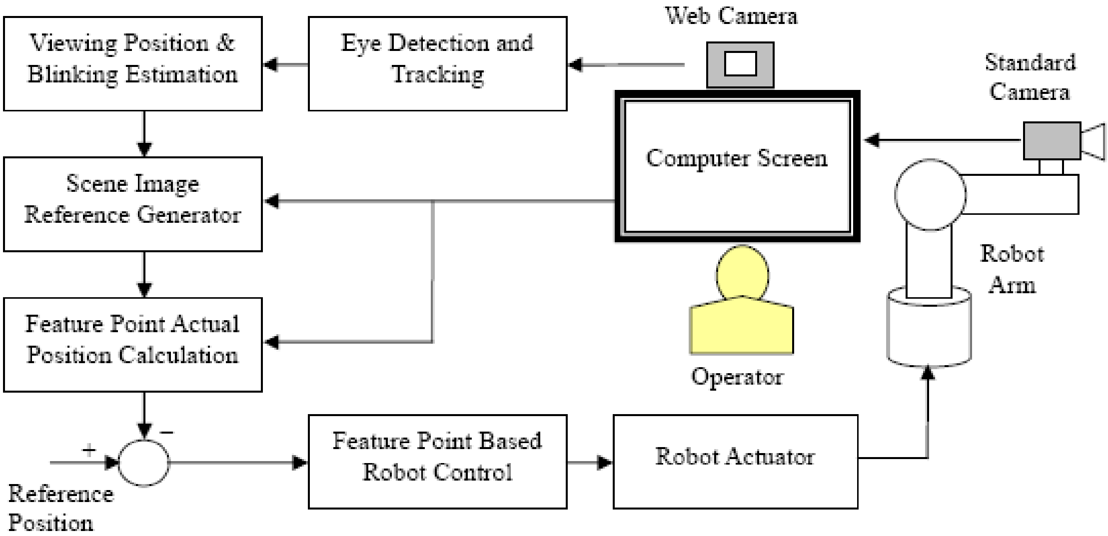

Fig. 2. Proposed System

2.2. The Structure of Proposed System

The structure of proposed system is shown in Figure 2. Two cameras are operated in this system, a standard camera and a web camera. The computer screen displays the scene captured by standard camera and a human operator monitors the scene. The eye viewing position to scene image where the operator intends to see is estimated using computer vision algorithm that acquires image from a web camera in front of operator. Next, the feature point is generated using the estimated eye viewing position and scene image information. Finally, the feature point based motion control mechanism is applied to move the robot and camera to construct a certain posture so that the center of scene image on computer screen is the position where the operator intends to see.

A. Eye Detection and Tracking

The eye detection and tracking process is designed to detect the eye position in the image and to track the change of eye position when the operator changes face position. The Haar-like classifier is applied to classify the image region as eye or non-eye. Figure 3 shows the eye classifier result.

B. Viewing Position and Blinking Estimation

After the eye region has been detected, the next process is to find the eyeball center, end point of eyebrow, and end point of eye. These eye parameters are formulated to obtain the eye viewing position. The viewing position is expressed as position in x and y coordinates in pixel unit. The eye blinking is determined using the change of eyeball area in open and close eye condition. The eye blinking feature is used to decide the validity of current value of viewing position.

Fig. 3. Eye region detection

C. Scene Image Reference Generator

This processing generates the image reference from certain area of scene image. The image reference is taken from the certain area around the viewing position.

D. Feature Point Actual Position Calculation

The feature point expressed the current position in scene image which operator intends to see. This feature point is a point position in x and y coordinate in pixel unit, and it is derived from scene image and reference image.

E. Feature Point Based Robot Control

The current actual position of feature point is compared to the reference position placed in the middle of scene image resolution to obtain the error signal for the robot controller. If the error exists, the robot will move to new position, camera will update vision information and produce the new actual position for feature point. This process will continue until the error approaches to zero. The control method employs velocity limiter to prevent image blur effect when scene image is captured in moving condition.

III. DISCUSSION AND FUTURE WORK

The experiment result on eye command interpretation shows that under normal illumination the command can be generated properly if the distance between operators and web camera is within 30 centimeters. The experiment result on robot control with human eye command shows that the system can work with minimal error under some of different scene situations.

In this research, the proposed system works in the step mode operation where eye viewing direction and eye blinking is applied for generating robot command. For the future work, the continuous mode operation will be studied deeply. In the continuous mode, robot will continuously move in accordance with where operator eye intent to see the scene displayed on the computer screen.

IV. CONCLUSION

The motion control using human eye system works normally with the operator distance to web camera within 30 cm under normal illumination. With step mode operation, this system works with minimum error.

ACKNOWLEDGEMENT

I thank to JICA (Japan International Cooperation Agency) for supporting this research project.

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