Robot Arm Utilized Having Meal Support System Based on Computer Input by Human Eyes Only

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Abstract

A robot arm utilized having meal support system based on computer input by human eyes only is proposed. The proposed system is developed for handicap/disabled persons as well as elderly persons and tested with able persons with several shapes and size of eyes under a variety of illumination conditions. The test results with normal persons show the proposed system does work well for selection of the desired foods and for retrieve the foods as appropriate as users' requirements. It is found that the proposed system is 21% much faster than the manually controlled robotics.

Keywords: Computer Input by Human Eyes Only, Line of Sight Estimation, Gaze Estimation, Robot Arm control, Image Segmentation With Clustering.

1. INTRODUCTION

There are some systems which allow computer input by human eyes only [1]. Just by sight, any desired key can be selected and determined with the system composed with a camera mounted computer display and the methods for gaze estimation with the acquired user face images [2]. The system allows users' head movements using head pose estimation by using extracted feature points from the acquired face images and also estimate line of sight vector which defined a s the line which connects between pupil center and eyeball center [3]. Thus computer input by human eyes only can be done.

There are 2.1 million of handicap persons (about 6%) in Japan. They can use their eyes; they cannot use their body below their neck though. By using the computer input system by human eyes only, they can take a meal through a selection of foods of which they want to have if they guide the robot arm by their eyes only. Using the system, users can control robot arms then users can bring foods of which they would like to have by their own choice. The current system allows to support having meal by retrieving not too hot drinkable foods and drinks with tube because it is not easy to feed the foods with folk (it is dangerous to get close the folk to user's face) for disable persons.

There are some meal feeding support systems using robotics [4],[5]. Most of the existing systems use joysticks for user interface and brain-machine interface [6]. There is commercially available meal feeding support system so called "My Spoon"[1] by Secom Co., Ltd.[7]. It uses joystick and or button for operation of robot arm. Y.Kohya et al., proposed ultrasonic motor featured robot for

[1] http://www.secom.co.jp/personal/medical/myspoon.html

meal feeding support system [8] while a meal feeding robot system with collaborative motions between robot arm and meal tray is also proposed [9].

Assuming disable persons in this research cannot use their hands and arms so that joystick interface does not work. Brain-machine interface, meanwhile, insists users a psychological impact (Sensor heads have to be attached on their head and/or face). On the other hand, there is no such impact for the proposed computer input system by human eyes only. Robot arm utilized having meal support system with computer input system human eyes only has to be robust against illumination condition changes and a various types of users eye shapes as well as seeing capabilities. Experiments with a variety of conditions have to be conducted.

In the next section, the proposed system is described followed by some experimental results with a variety of conditions. Concluding remarks and some discussions together with future works are described in the final section.

2. PROPOSED SYSTEM

The proposed system is composed with visible camera and HMD: Head Mount Display mounted glass and camera mounted robot arm. While user wears the glass, user can look at the outer world which is acquired with the camera mounted at the tip of the robot arm and also user's eye and the surrounding images are acquired with the camera mounted on the glass. System configuration is shown in Fig.1. The only thing user has to do is to look at the desired foods on the tray of the meal displayed onto the screen in the HMD of computer screen. The specification of HMD, camera and robot arm are shown in Table 1, 2 and 3, respectively. Also outlook of the HMD and camera mounted glass and the camera mounted robot arm are shown in Fig.2 and 3, respectively.

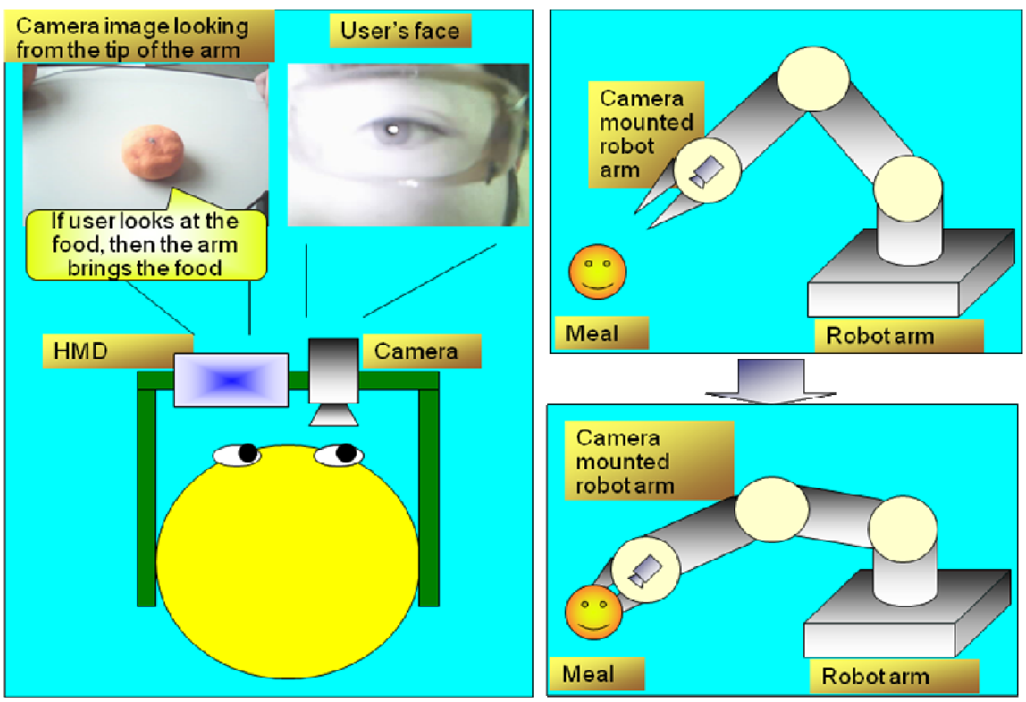


FIGURE 1: System Configuration of the Proposed System

FIGURE 2: Outlook of the HMD and Camera Mounted Glass

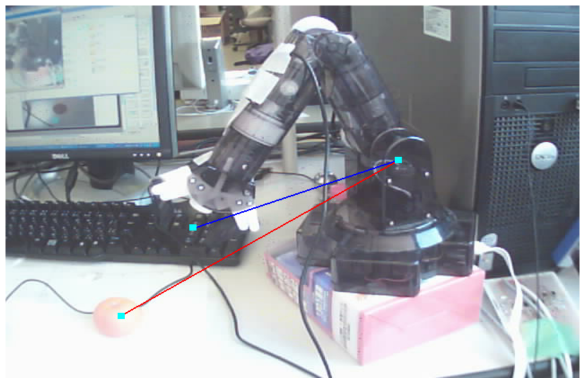


FIGURE 3: Outlook of the camera Mounted Robot Arm

Pixel size	SVGA(800 × 600)
Assumed display distance	2m
Assumed display size	60 inch
Field of view	42 deg.
Input	RGB
Working temperature	0 to 40 deg.C
Size	28mm(W) × 35.24mm(H) × 56mm(D)
Weight	20g

TABLE 1: The Specification of HMD

Sensor element	0.3 million of elements of CMOS
Maximum pixel size	1280 × 960
Maximum viewing angle	78 deg.
Frame rate	320 × 240 for 30fps
Frame rate	640 × 480 for 15fps

TABLE 2: The Specification of Camera

Power supply	Dry battery× 4
Supply voltage	±3
Maximum load weight	130g
Maximum rotation radius	360mm
Maximum height	510mm
Base plate	W180 × D180mm
Total weight	1050g
Controller weight	150g
The number of joints	5
Base rotation angle	350 °
Shoulder rotation angle	120 °
Elbow rotation angle	135 °
Wrist rotation angle	340 °
Robot finger	50mm

TABLE 3: The Specification of Robot Arm

In accordance with the estimated gaze location on the HMD through an analysis of acquired user's face images, the desired foods on the tray can be selected and determined. Tray image is acquired with the camera mounted on the tip of the robot arm. The acquired image can be used to get close to the desired foods with robot arm controls. If the user looks at the desired foods, line of sight of user's eye is pointing to the foods displayed onto HMD screen and both eyes moves simultaneously so that the desired foods can be selected and determined if user's gaze is estimated. In order to extract eye and its surrounding from the acquired face image, adaptive threshold method [10] is used.

As is shown in Fig.4, gaze location on HMD display can be estimated through the line of sight estimation with an analysis of the acquired user's face images. The line of sight is defined as the line between eyeball center and pupil center. Eyeball is assumed sphere with the diameter of 24mm (Typical eyeball size). The cornea can be detected by using the reflectance difference between cornea and sclera. Then pupil center is extracted in the cornea then it can be estimated as is shown in Fig.5. Red point in the image shows pupil center. Thus the line (line of sight) between pupil center and the eyeball center can be estimated [8]. Therefore, if user looks at the desired foods on the tray, the robot arm gets close to the desired foods automatically.

FIGURE 4: Process flow for gaze location estimation from the acquired face images

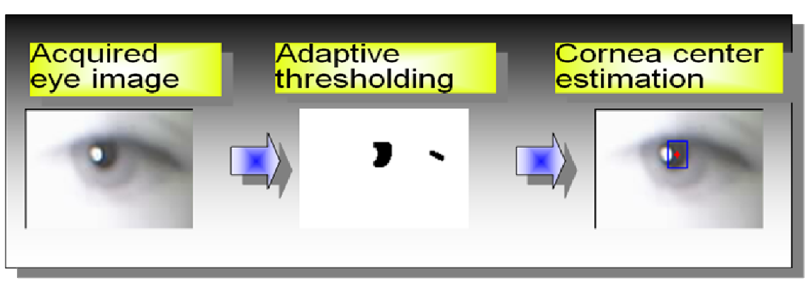


FIGURE 5: Process flow for estimation of cornea center

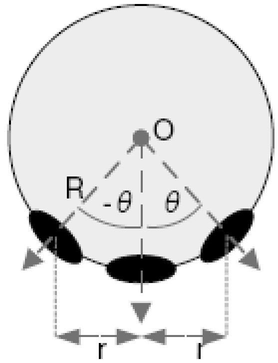
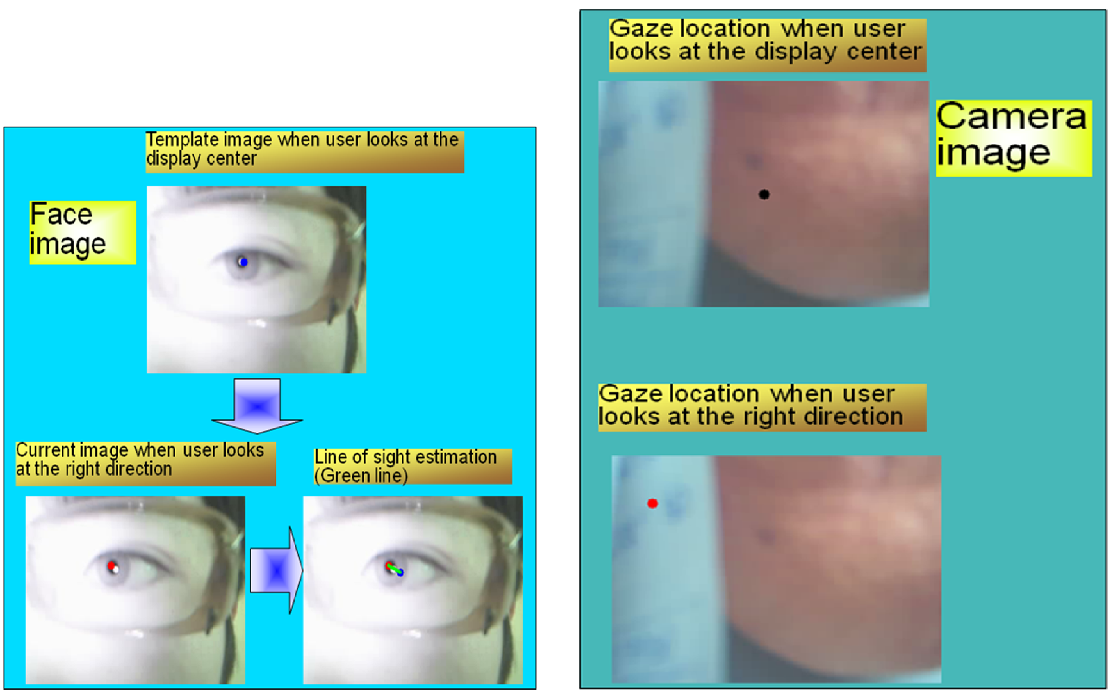


FIGURE 6: Definition of eyeball

Eyeball is assumed as is shown in Fig.6. Pupil center is estimated based on the aforementioned manner so that the eyeball rotation angle and the line of sight is estimated as is shown in Fig.7 (a). R is assumed to be 12mm and r is estimated through pupil center movement estimations. Thus gaze location on the HMD display is estimated as is shown in Fig.7 (b).

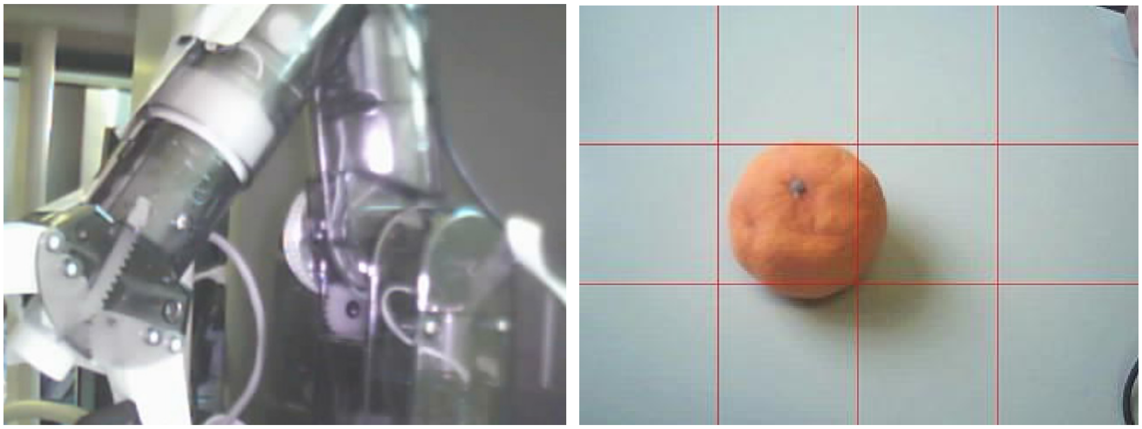
$$r = R\sin\theta \quad (1)$$
$$\theta = \arcsin(r/R) \quad (2)$$



(a) Line of sight estimation (b) Gaze location on HMD display estimation

FIGURE 7: Process flow for line of sight estimation and gaze location estimation

Fig.8 (a) shows the outlook of the robot arm and Fig.8 (b) also shows one of examples of camera image which is acquired with the camera that is mounted on the top of the robot arm. Objective target of the desired food on the tray can be selected and determined with the camera acquired image. When user is looking at the desired food, the robot arm gets close to the food automatically as is shown in Fig.9. During the food retrieval process, the desired food has to be detected and tracked because the objective target of the desired food is moving in the acquired image. Object tracking is done with optical flow [12] while the robot arm is controlled by its base location movement as well as up and down movements of its elbow and shoulder. These robot arm movements can be controlled automatically in accordance with user's gaze location (ideally the center of the desired food) estimated with the camera acquired image. Fig.10 shows the definitions of the coordinate system and base, shoulder and elbow angles.



(a) Outlook of the robot arm (b) Food on the tray

FIGURE 8: Outlook of the robot arm and an example image of food.

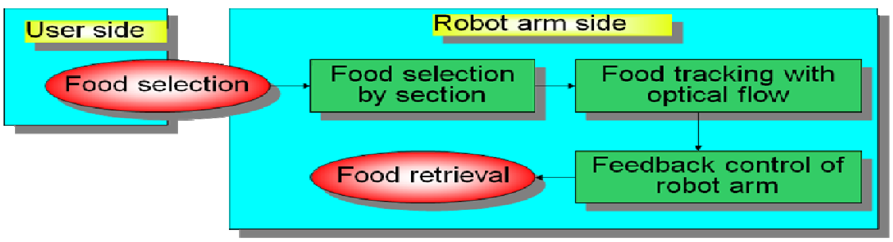
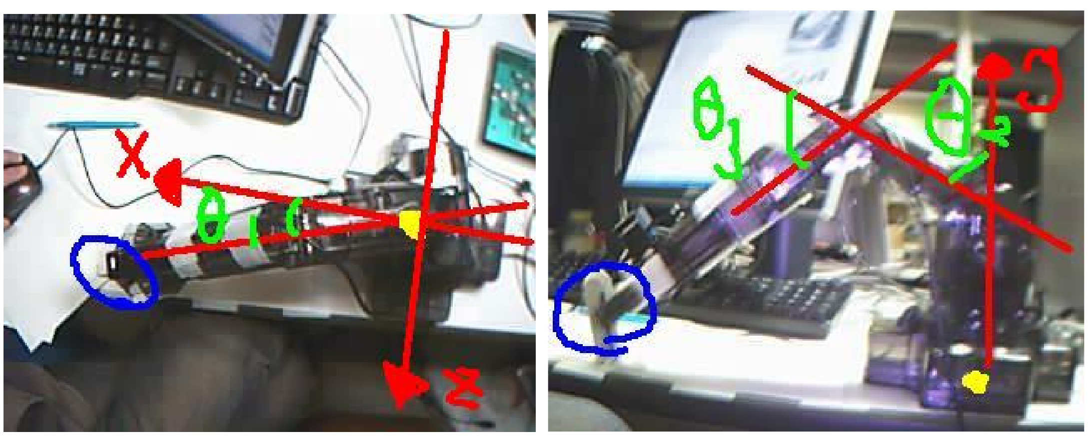


FIGURE 9: Process flow for the desired food retrievals with robot arm which is controlled by human eyes only.



θ_1: Base angle, θ_2: Shoulder angle, θ_3: Elbow angle

FIGURE 10: Definition of base, shoulder and elbow angles and coordinate system

Blue circle portion in Fig.10 denotes the camera mounted at the tip of the robot arm while yellow dot shows the location of the origin of the robot arm coordinate system.

3. EXPERIMENTS

The proposed system can be operated manually and automatically (based on human eyes only).

In the manual mode, the robot arm can be controlled by computer key in of selection processes of base, shoulder and elbow angles control as well as right, left, up and down movements using camera acquired image. On the other hand, the robot arm can be controlled by human eyes only in the automatic mode (the proposed method). Table 4 shows the experimental results for the automatic mode (the proposed method) while Table 5 shows those for the manual mode. There are two types of persons for the test, the persons who have typical eye shape and size eyes and the persons who have narrow eye shape and relatively small size of eyes. Illumination condition was changed during the day time and the night time. Illumination was measured in unit of Lux with radiance measuring instrument from the just above of the surface of the desired food. The time required for retrievals of the desired food is also measured.

There was only one failure that was happened for the person with narrow eye with a week seeing capability of eyes in the night time for relatively high illumination condition. Due to the fact that optical flow was failed so that B(1) gave up to retrieve the desired food. He tried 12 times then he gave up. Only the possible reason for failure is caused by the shape of the eye. It is rather difficult to detecting and tracking the narrow and small eye than the typical normal size of eyes. A(1), A(2), B(2) and C(1) made a success to retrieve the desired food in the automatic mode. Success rate and the required time for retrievals do not depend on illumination condition. Success rate and the required time for retrievals are not influenced by the illumination condition, if the illumination ranges from 165 to 641 Lux. The number of trials for the manual mode is greater than that in the automatic mode with human eyes only so that the required time for retrievals takes much longer. It is rather difficult to retrieve the desired food in the manual mode. Six degree of freedom is not easy to control in the manual mode. Meanwhile it is rather easy to retrieve the desired food in the automatic mode because only thing user has to do is just looking at the desired food then the feedback system control the location of the tip of the robot arm appropriately without consideration of six degree of freedom.

Person	Eye feature (Seeing capability)	Illumination condition[Lux」	Success or Fail	The number of trials	Required time for retrievals[ms]
A(1)	typical(1.5)	Night time(169)	Success	6	42085
A(2)	typical(1.5)	Day time(343)	Success	4	57579
B(1)	narrow(0.05)	Night time(336)	Fail	2	
B(2)	narrow(0.05)	Night time(338)	Success	12	29908
C(1)	typical(1.5)	Night time(186)	Success	2	21921
Average				3.2	37873.25

TABLE 4: Experimental results for the automatic mode (the proposed method).

Person	Eye feature (Seeing capability)	Illumination condition[Lux」	Success or Fail	The number of trials	Required time for retrievals[ms]
A(1)	typical(1.5)	Day time(241)	Success	12	39623
A(2)	typical(1.5)	Night time(165)	Success	7	32913
B(1)	narrow(0.05)	Day time(207)	Success	9	57048
C(1)	typical(1.5)	Day time(641)	Success	12	59535
C(2)	typical(1.5)	Day time(211)	Success	9	39989
Average				9.8	45821.6

TABLE 5: Experimental results for the manual mode.

4. CONSLUSION & FUTURE WORK

The proposed having meal support system with automatically controlled robot arm by human eyes only is approximately 21% much faster than that with manually controlled robot arm. The number of trials of the proposed system is about one third in comparison to the manually controlled robot arm. The proposed system does work in a variety of illumination condition in the day time and the night time and also work for several types of normal person with different eye shapes and seeing capabilities. It is obvious that the proposed system has to be tested with handicap persons in the near future.

5. REFERENCES

1. Arai K., Uwataki H., Computer input system by human eyes only with cornea center detection which allows users' movements, Journal of Institute of Electric and Electronics Society of Japan, 127-C, 7, 1107- 1114, 2007

2. Arai K., Yamaura M., Improvements of blink detection with morphologic filter in the computer input system by human eyes only, Journal of Image and Electronics Society of Japan, 37, 5, 601-609, 2008

3. Arai K., Yajima K., Communication aids based on computer input system by human eyes only, Journal of Institute of Electric and Electronics Society of Japan, 128-C, 11, 1679-1686, 2008

4. Yamaguchi A, Ito A., Kuroiwa S., Oikawa N., Matsuda T., Ishii S., The clinical application of meal support robots. The 1 : Role of OT on the introduction to Guillain-Barre syndrome patients. The 2 : Application of a meal robot to neuromuscular disease, Annual Report of the Research on Nervous and Mental Disorders, 131-132, 2003

5. Martens, C., Prenzel, O., Gräser, A., "The Rehabilitation Robots FRIEND-I & II: Daily Life Independency through Semi-Autonomous Task-Execution". *I-Tech Education and Publishing* (Vienna, Austria): 137–162. ISBN 978-3-902613-04-2. http://intechweb.org/downloadpdf.php?id=556. 2007.

6. Lüth, T., Graimann, B., Valbuena, D., Cyriacks, M., Ojdanic, D., Prenzel, O., Gräser, A., A Brain-Computer Interface for Controlling a Rehabilitation Robot". *In BCI Meets Robotics: Challenging Issues in Brain-Computer Interaction and Shared Control* (Leuven, Belgium): 19–20, 2003.

7. http://www.secom.co.jp/personal/medical/myspoon.html

8. Koya Y., M.Oka, T.Akashi, Y.Wakasa, M.Tanaka, Meal feeding robot system with ultrasonic motor, Proceedings of the SICE Chugoku-brunch of general assembly, 16, 116-117, 2007.

9. Kobayashi H., K.Konishi, K.Kikuchi, Development of feeding support system and its quantitative estimation, Proceedings of the Robotics and Mecha-tronics of the Society of Machinery of Japan, 1A1-H-50, 2004.

10. Paul Viola and Michael J. Jones. Rapid Object Detection using a Boosted Cascade of Simple Features. IEEE CVPR, 2001.

11. Kohei Arai, Ronny Mardiyanto: Improvement of Gaze Estimation Robustness Using Pupil Knowledge. Proceedings of the ICCSA (2) 2010: 336-350, (2010)

12. Intel Corp.: **OpenCV** (Intel Open. Computer Vision Library) , http://www.intel.com/technology/computing/opencv/