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# An Implementation of Humanoid Vision - Analysis of Eye Movement and Implementation to Robot

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## 1. Introduction

Humanoid robots are becoming like human and imitating human behaviour (HONDA ASIMO)(NAGARA-3). They usually have cameras (Onishi et al., 2005), and then we consider that eyes for the humanoid robot have to be "Humanoid Vision" (Mitsugami et al., 2004).
Humanoid Vision is the vision system which is focused on human actions of the robot, and emulation of human beings. We considered that the human beings is optimized for human frameworks, thus the Humanoid Vision will be the best vision system for humanoid robots which has human like. We used a humanoid robot "YAMATO" which is installed two cameras on his eyes.
We analyzed the human action of tracking an object by the eyes and head. Then, based on this analysis, we made a model for the humanoid robot, and we implemented the obtained features which are tracking actions of the human.
From implementation results, the actions of the humanoid robot became natural motion such like the human beings, and we show the effectiveness of the Humanoid Vision.

## 2. Humanoid vision

### 2.1 Introduction of YAMATO

Humanoid robot "YAMATO" is shown in Fig.1 to implement the humanoid vision. Its height is 117cm, and it has 6 DOF on the arms, and 9 DOF on the head. Table 1 shows the detail of DOF on the arm and the head (Mitsugami et al., 2004). It can act various expressions with all 21 DOF.
The humanoid robot has twelve SH2 processors and one SH4 processor. Twelve SH2 processors control motors, and one SH4 processor is main control unit. We can control the robot by a PC through the RS-232C. Then we send the angle of each joint to make him posture or motion.
Magellan Pro is used in the lower body. It has sixteen sonar sensors, sixteen IR sensors and sixteen tactile sensors. Its size is 40.6 cm in diameter and 25.4 cm in height. Linux is installed on it. It can move forward and backward, and traverse.



Source: Computer Vision, Book edited by: Xiong Zhihui,
ISBN 978-953-7619-21-3, pp. 538, November 2008, I-Tech, Vienna, Austria


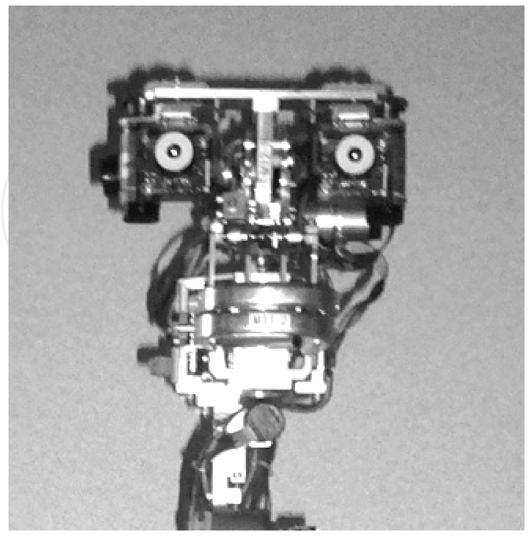

Fig. 1. Humanoid robot "YAMATO"

| Part | | Degree of Freedom |
|---|---|---|
| Arm | Shoulder | 3 |
| | Elbow | 2 |
| | Hand | 1 |
| Head | Eye | 3 |
| | Neck | 4 |
| | Mouth | 2 |

Table 1. Title of table, left justified

## 3. Analysis of eye and head movement

### 3.1 Camera setting

First, we analyzed how to move eyes and head to track an object. Fig. 2 shows overview of our camera system setting. In this, we used two screens. The moving marker was projected by a projector on a screen (screen1). Another screen (screen2) was used to observe the head movement.

Fig. 3 shows a camera which can take only eyes movement even if his/her face moves. We call this camera as "Eye coordinate camera". This camera system consists of a small camera and a laser pointer which are mounted on a helmet. A laser points on screen2 surface. We can observe the head coordinate by using this screen as shown in Fig. 4. Lines on this screen are written every 10 degrees from center of screen. We took the movement of laser by using another camera. We call this camera as "Head coordinate camera".

Fig. 5 shows the moving marker that is presented for subjects. This is projected on the screen1. To capture human movement, moving marker was moved left or right after stop for several seconds. Its movement speed was 20, 30 and 40deg/s, and its movement range was set from +60 degrees to –60 degrees.

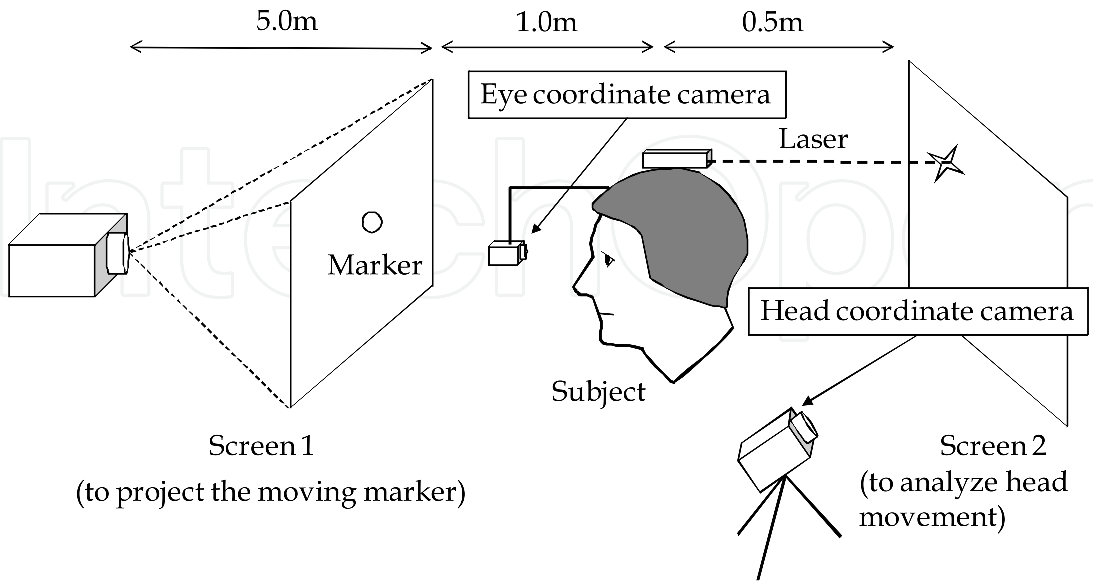


Fig. 2. Experimental setting

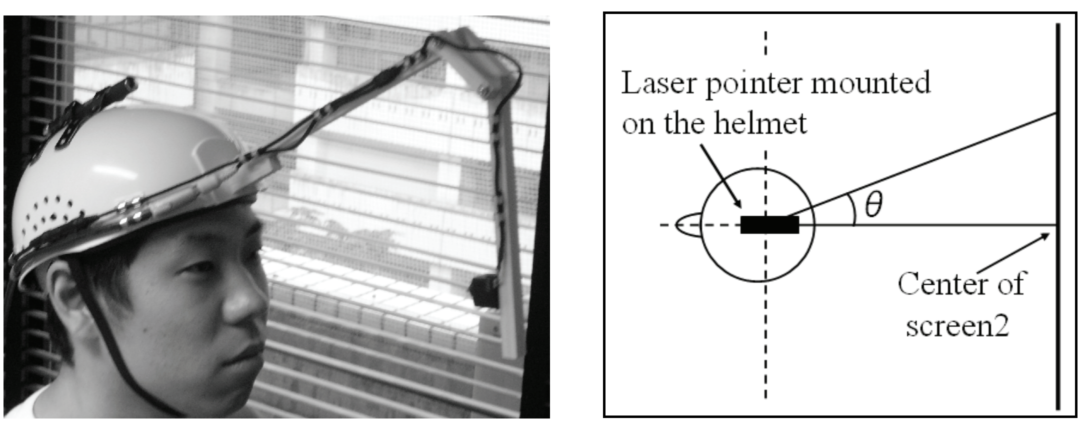


Fig. 3. Eye coordinate camera system (θrange is from +60 degrees to -60 degrees.)

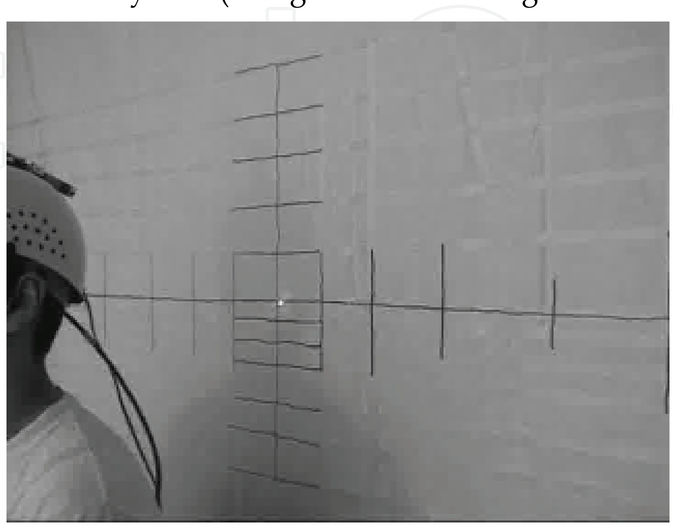

Fig. 4. Screen2 (to analyze head movement)

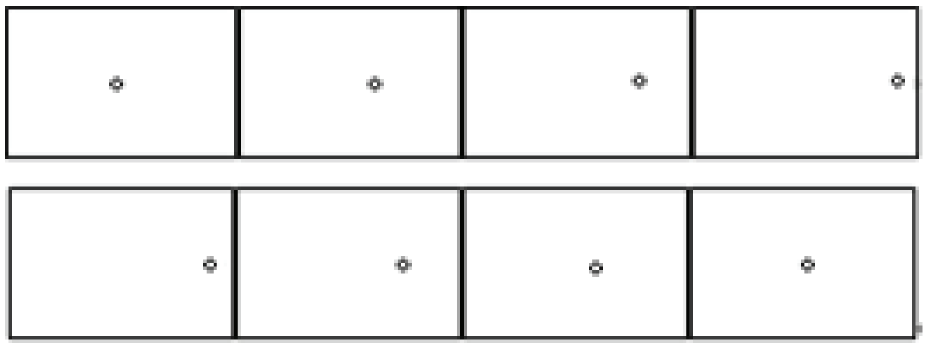

Fig. 5. Example of moving marker images

### 3.2 Analysis of eye and head movement

Fig. 6 shows images that were taken from the head coordinate camera. White point of images is a point which is illuminated by the laser. From these images, we can measure that the laser pointer is moved on the screen 2. Fig. 7 shows images that are taken from the eye coordinate camera as Fig. 3. The face doesn't move in these images, and these images obtain only changes of eyes and background. Each image as shown in Fig. 6 is corresponding to images as shown in Fig. 7.

We analyzed that how to track an object from these images. Facial movement was analyzed a position that the laser illuminates on the screen2. Eyes movement was analyzed center of the right iris. Eyes movement is assumed that both eyes are same movement. In this analysis, we extracted only x-coordinate of left and right movement. X-coordinate is head angle or eye angle.

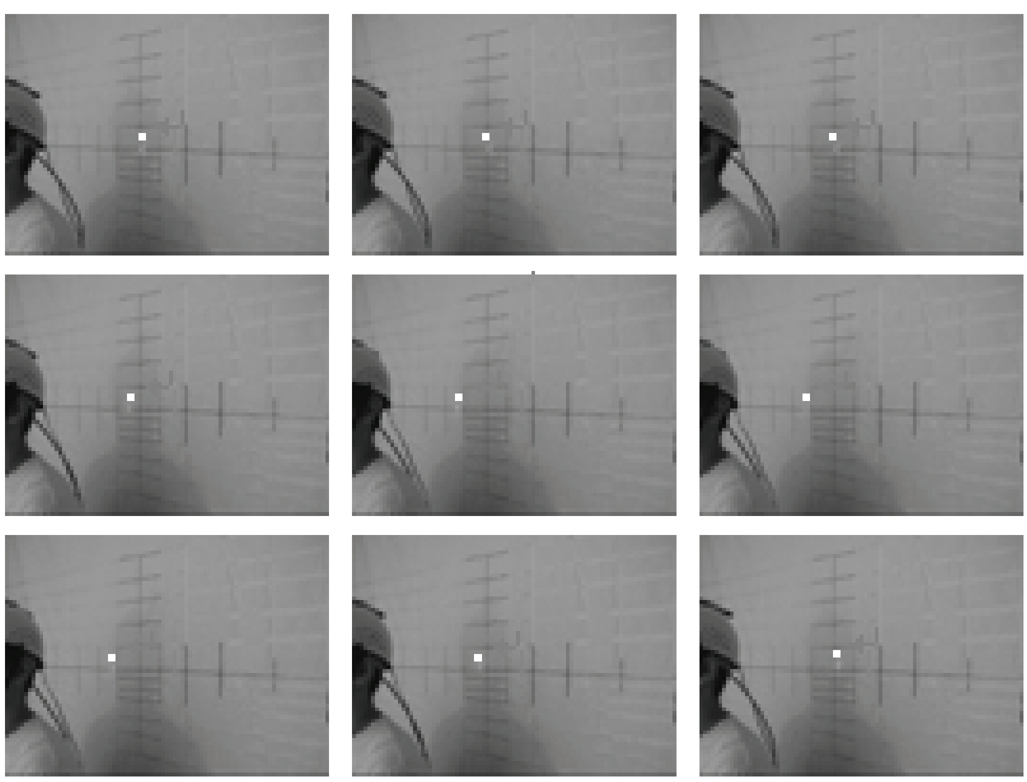

Fig. 6. Head coordinate images

Fig. 7. Eye coordinate images

## 4. Consideration of eye and head movement

Fig. 8 shows a graph that is observed 20deg/s of moving marker speed. Horizontal axis shows number of frames, and vertical axis shows the head's and eye's x-coordinate in each frame. Each coordinate of frame 0 is defined as baseline. If values are smaller than the value of frame 0, it shows that the subject is moved his face to the right. If values are rather than 0, it shows that he moved his face to the left. In this graph, line of the head is changed after eye is moved. This shows that the moving marker is tracked by using only head after tracking by using only eyes. When the moving marker returned to center, it was tracked by using only eyes again. The moving marker was tracked by using head after eyes returned. From these results, as the moving marker speed was slow, we understood that eyes were used preferentially and tracked it. This velocity is understood that smooth pursuit eye movement is possible.

Fig. 9 shows a graph that is observed 30deg/s of moving marker speed. First, the eyes move to some extent, and next the head started to move. This movement shows that the moving marker was tracked by using the head. In this time, the eyes were holding on the left. When the moving marker returned to the center (after frame 50), eyes moved slightly faster than head. In the graph, eye is used preferentially to track. From these results, some features are given corresponding to the moving marker speed.

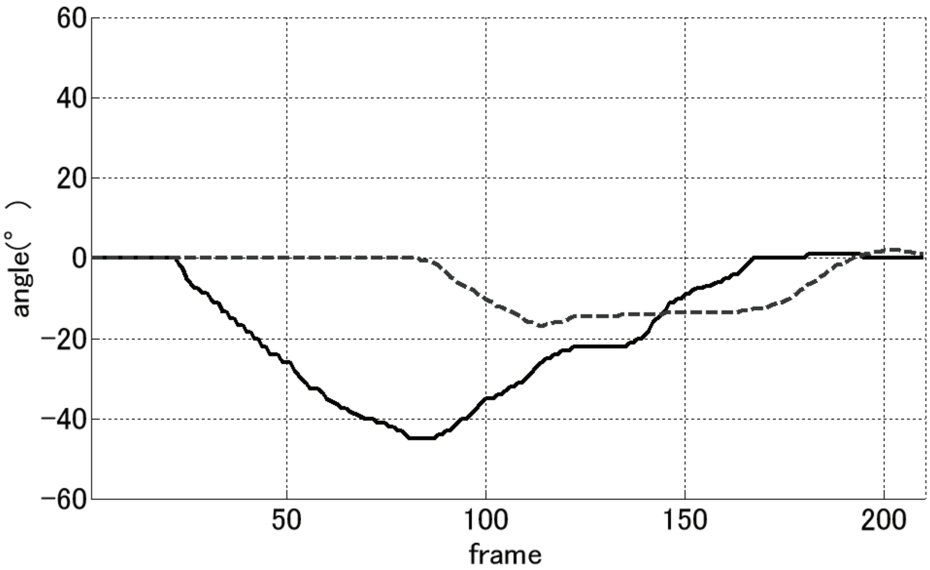


Fig. 8. Movement graph of experiment 20deg/s

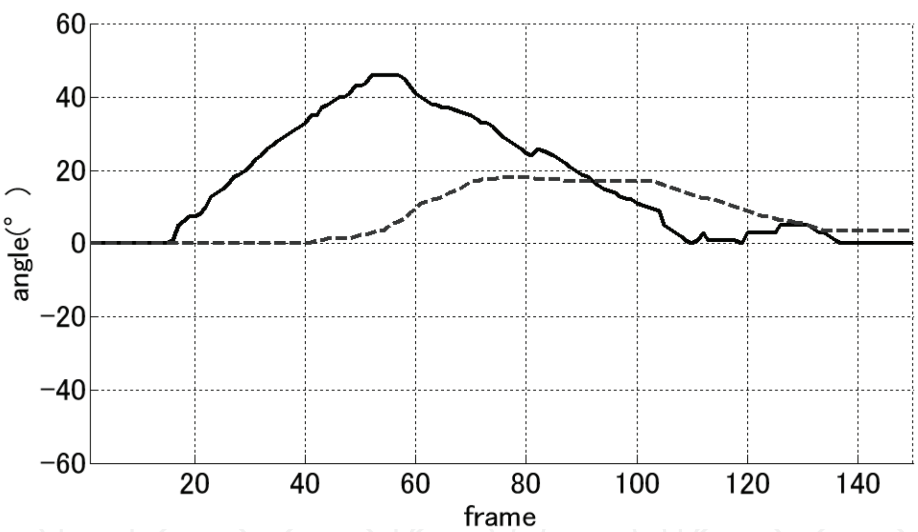


Fig. 9. Movement graph of experiment 30deg/s

Fig. 10 shows a graph that is observed 40deg/s of moving marker speed. In this graph, the eyes move to some extent, and after the head started to move. Between frame 0 and frame 35, change of graphs is similar to Fig. 8 and 9. This shows that the moving marker is tracked by using only head after tracking by using only eyes. But when the moving marker returned to center (after frame 35), head and eye values are changed at the same time. It shows the human uses both face and eyes to track an object (Nakano et al., 1999). Change of eye movement is smooth because of he used both face and eyes to track an object. From this result, smooth pursuit eye movement is possible at 40deg/s (Sera, & Sengoku, 2002) (Tabata et al., 2005).

As the above results, two kind of features of 20~30 deg/s and 30~40 deg/s were obtained.

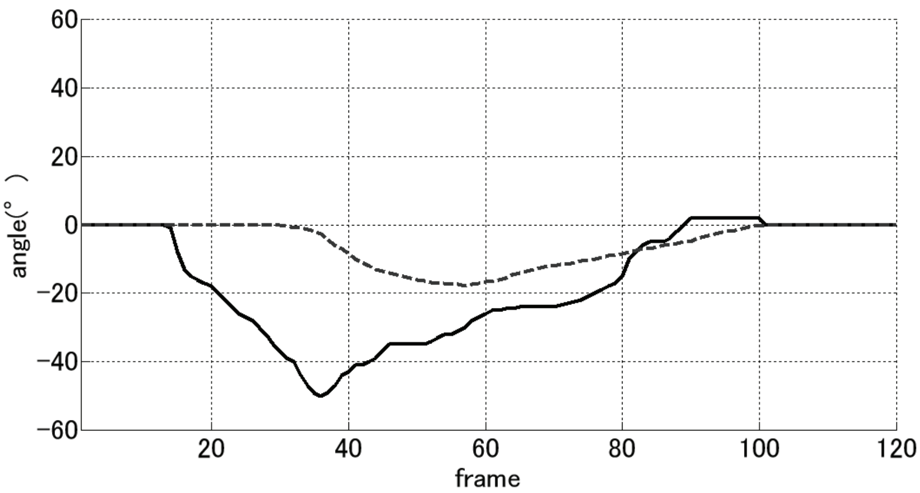


Fig. 10. Movement graph of experiment 40deg/s

## 5. Making of object tracking model

We made a model based on features obtained by analysis of eye and head movement. This model is shown in Fig. 11. We implemented the humanoid vision with this model to the humanoid robot YAMATO. In conditions, there is an object in the center of the image, and smooth pursuit eye movement is possible. YAMATO detects an object and determines its speed. In the feature of 20~30deg/s, eyes are used first to track an object, and head is used to do it. When an object is returned, eyes are used again. In the feature of 30~40deg/s, eyes are used first to track an object, and head is used to do it. When an object is returned, eyes and head are used to track it in the same time.

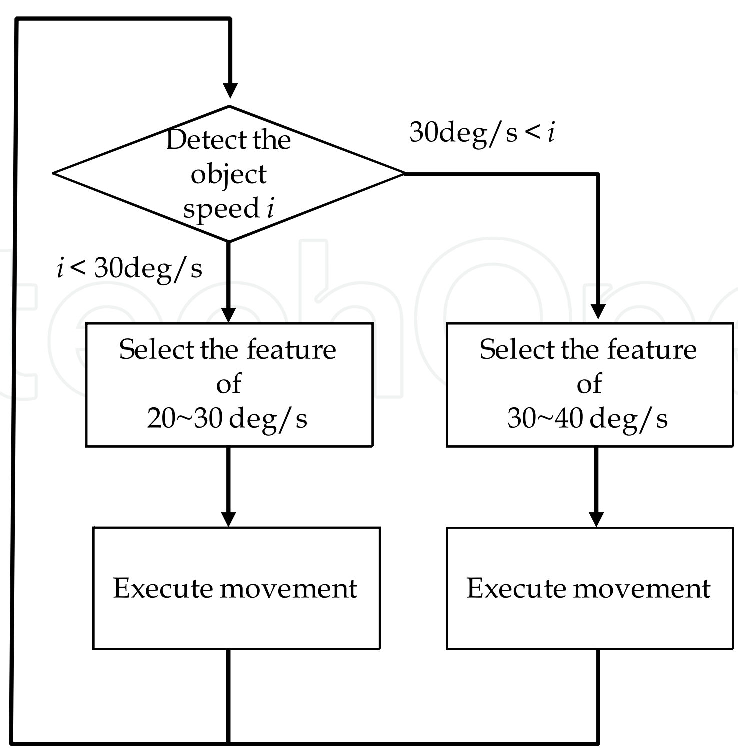


Fig. 11. Implementation model

## 6. Implementation to the robot

We implemented a model introducing at the previous section. We used a red ball as the target object. A ball was moved sideways, constant speed, and 60 degrees to the left. We repeated it. The distance from YAMATO to a ball was around 1m. Fig. 12 shows a scene of an experiment.
Fig. 13 shows images of movement that YAMATO expressed features of 20~30deg/s. In these images, YAMATO moved his eyes in the first. After he finishes moving his eyes, then head is moved. When a ball was returned to the front, the head and eyes were moved in the sideway.
Fig. 14 shows images of movement that YAMATO expressed features of 30~40deg/s. In these images, YAMATO moved eyes and head. These results show that YAMATO expresses the implementation model.

Fig. 12. A scene of an experiment

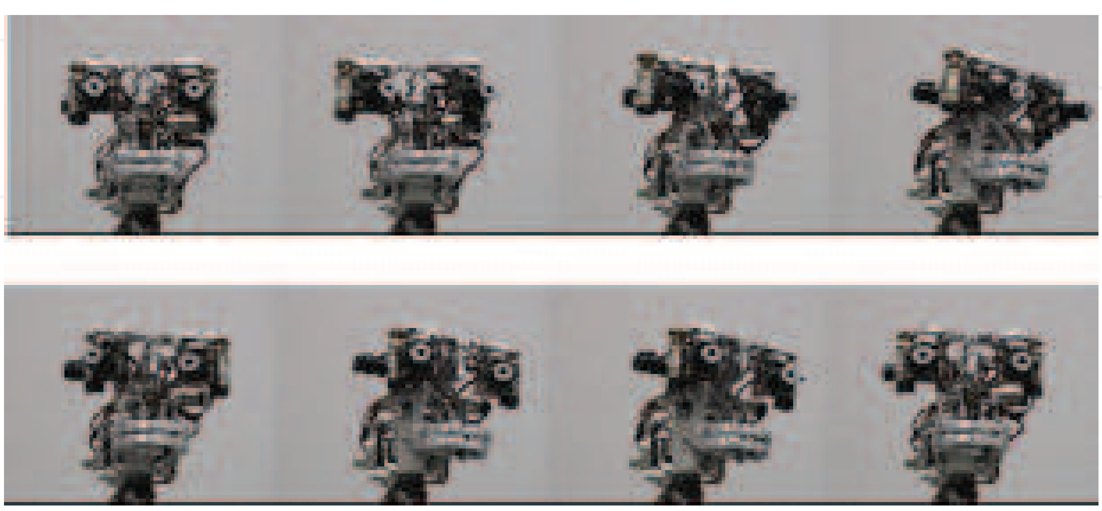

Fig. 13. Expression of 20~30deg/s

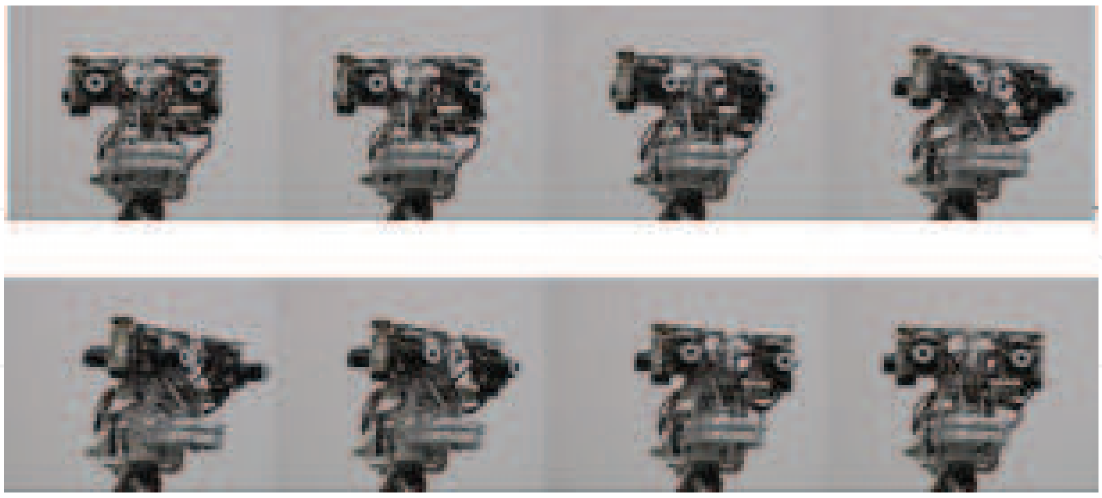

Fig. 14 Expression of 30~40deg/s

## 7. Conclusion

In this research, we considered that “the humanoid robot has to have humanoid functions”, and eyes for humanoid robot have to be “Humanoid Vision”. Therefore, we analyzed the human action of tracking an object by the eyes and implemented the obtained features to a humanoid robot “YAMATO”. From implementation results, we showed the effectiveness of humanoid vision. Our future works are analysis of longitudinal movement and complicated movements to movement of a robot.

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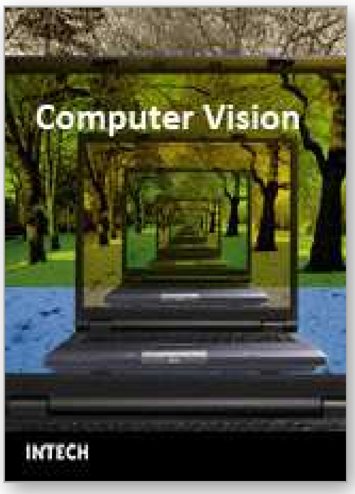


**Computer Vision**
Edited by Xiong Zhihui

ISBN 978-953-7619-21-3
Hard cover, 538 pages
**Publisher** InTech
**Published online** 01, November, 2008
**Published in print edition** November, 2008