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Development of a System to Provide Different Fields of View to Eyes with a Function to Generate Rapid Movements

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***Abstract*— We developed a system that provides a human user with the artificial oculomotor ability to control their eyes independently, which was named Virtual Chameleon after Chameleons. Virtual Chameleon consists of two independently controlled CCD cameras, a 3D tracking sensor system and a head-mounted display. The Virtual Chameleon control independently postures of two cameras to follow the sensors of the 3D tracking system smoothly. The successful users of the system were able to actively control visual axes by manipulating 3D sensors held by their both hands, to watch independent view fields presented to the left and right eyes, and to look around as chameleons do. Although it is thought that those independent fields of view the user of Virtual Chameleon corresponds to smooth movements on human eye movements, the system did not have functions to control angles of cameras rapidly in way corresponding to saccadic eye movements and compensatory movements as numerous animals including human do. In this paper, we implemented functions to control angles camera rapidly corresponding to saccadic eye movements in Virtual Chameleon, and we performed fundamental experiments to evaluate effects on the user's visual capabilities.**

I. INTRODUCTION

Some species of reptiles, herbivores and fish are capable of conscious moving their eyes independently and perceiving images of the surrounding environment for the purpose of watching prey or avoiding danger. Among these species, chameleons have a specialized visual ability to follow their prey and catch it with a precise stroke of their long tongues[1]. They can locate their prey with the large and independent saccades oftheir highly mobile eyes.

In contrast with chameleons, humans cannot consciously control both eyes independently, except for unconscious convergences or divergences, and cannot perceive independent fields of view. The anatomical characteristics and patterns of monocular movements of chameleons are similar to higher primates, in that the eye has a central fovea, performs saccadic fixation movements[2], and obeys Listing's Law[3], but the oculomotor system and cognitive functions of humans differ greatly from those of chameleons.

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Giving a normal person the same oculomotor ability to control both eyes independently as chameleons is expected to induce binocular rivalry. Humans have the capability to flexibly adapt to visual stimulation, such as spatial inversion in which a person wears glasses that display images upside down for long periods of time[4]-[7]. As with adaptation to spatial inversion, it is assumed that humans can also adapt when given the ability to control both eyes independently.

To investigate the flexible adaptation of the human visual system, we developed a portable device that provides independent fields of view to the eyes for extended periods of time[8]-[10]. The device, Virtual Chameleon, consists of two independently controlled CCD cameras and a head-mounted display (HMD). The Virtual Chameleon enables the user to vary the directions of the visual axes of both eyes to arbitrarily directions and to perceive each field of view simultaneously. The successful users of the system were able to actively control visual axes by manipulating 3D sensors held by their both hands, to watch independent fields of view presented to the left and right eyes, and to look around as chameleons do.

Although it was thought that those independent fields of view provided to the user were formed by eye movements control corresponding to smooth eye movements on human, the system did not have control systems to perform saccadic movements and compensatory movements as numerous animals including human do. Fluctuations in dominance and suppression with binocular rivalry are irregular, but it is possible to bias these fluctuations by boosting the strength of one rival image over the other[11][12]. It was assumed that visual stimuli induced by various eye movements affect predominance.

Therefore, in this research, we focused on influenced of patterns of eye movements on visual perception with binocular rivalry, and implemented functions to produce saccadic movements in Virtual Chameleon.

II. VIRTUAL CHAMELEON

A. System Configuration

An exterior view of the Virtual Chameleon is shown in Fig.1. This system is composed of a 3D tracking sensor system, momentary switches, a camera positioning system and a display system. The camera positioning system independently controls the postures of the two CCD cameras to follow the positions of the sensors of the 3D tracking system only when corresponding momentary switch is in the on state. Images taken by the cameras are processed and projected onto the head-mounted display (HMD) in real time.

The HMD consists of two independent monocular display modules (SVGA resolution in natural color, PC analog RGB display signal) set in front of each eye. Therefore, the user can control the tracking directions of the two cameras with corresponding sensors in each hand so that the user can control independent arbitrary fields of view for each eye.

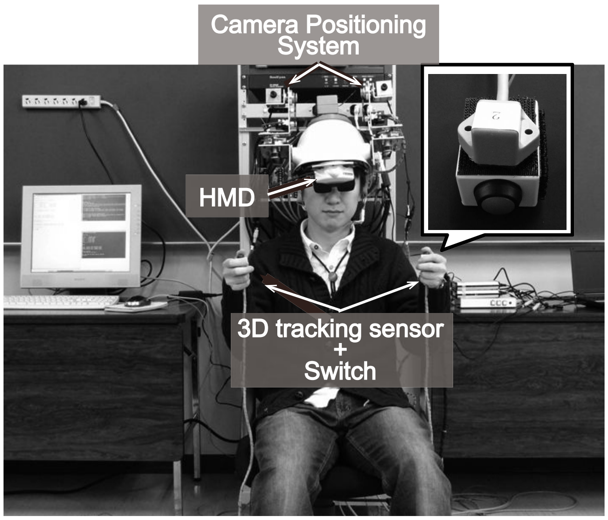
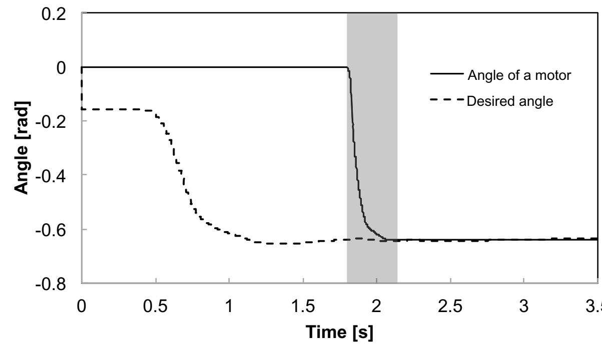


Fig. 1. Exterior view of the Virtual Chameleon

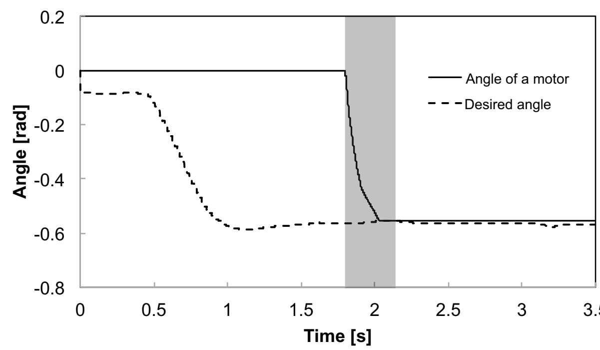
B. Camera posture control

Two camera platforms driven by two motors were mounted in right and left both side of a helmet. Each camera platform had 2-degrees-of-freedom (DOF), which was a gimbal to obey Helmholtz rotation. Ultrasonic motors were adopted as actuators and controlled by using positioning proportional control. Desigred angles were computed from positions of 3D tracking sensors[8][9]. Postures of cameras were controlled only when the state of momentary switches equipped with 3D tracking sensos were on. In this paper, we assummed the timing of on-off actions of switches generate artificial saccadic motions. We conducted control experiments to evaluate controllability of the system. As experiments on artificial saccadic movements, we moved the 3D sensor random positions and then push the button of the momentary switch attached to the sensor. As experiments on virtual smooth movements, we moved the sensor random position with pushing the button. Results of artificial saccadic movements are shown in Fig.2 which indicates desigred angles computed from the position of 3D sensor and the rotational angles of the ultrasonic motor, and results of smooth movements is Fig.3.

A maximum velocity of camera angle was about 900 deg/s at the artificial saccadic movements. The camera angle was controlled to follow the sensor at the virtual smooth movements. Therefore, posture angles of two cameras were controlled as saccadic eye movements and smooth eye movements by changing states of momentary switches.

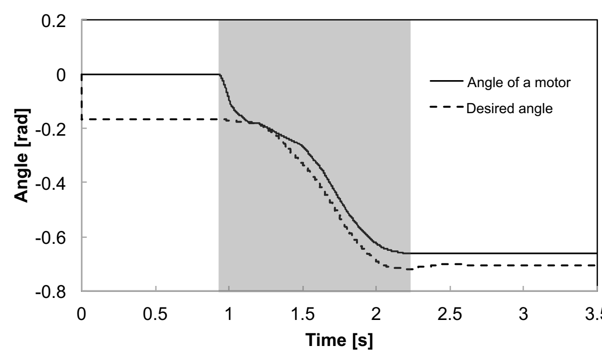


(a) Tilt angle

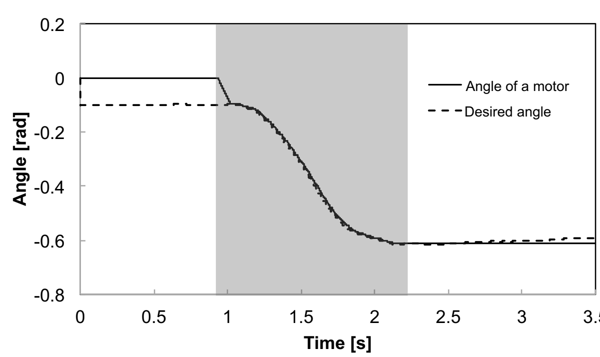


(b) Pan angle

Fig. 2. Artificial saccadic movement

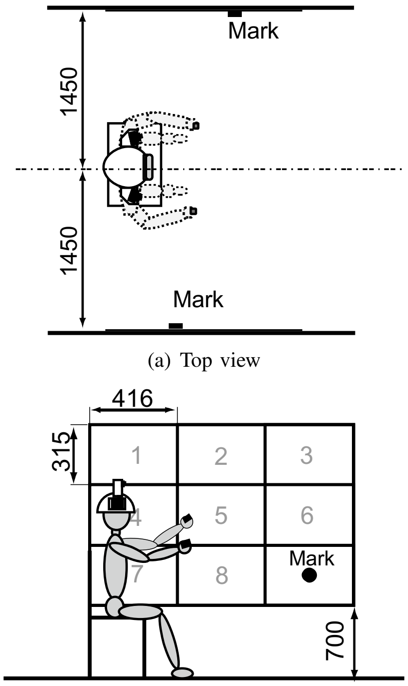


(a) Tilt angle



(b) Pan angle

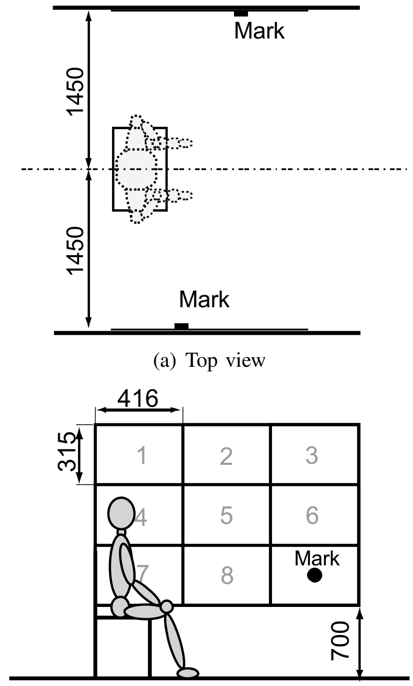
Fig. 3. Artificial saccadic movement



(a) Top view

(b) Side view

Fig. 4. Experimental environment for using Virtual Chameleon



(a) Top view

(b) Side view

Fig. 5. Experimental environment for normal condition

III. EXPERIMENTS

We performed experiments for simple situation to assess a human performance under a condition of using Virtual Chameleon. The subjects were seven healthy volunteers with normal or corrected-to-normal vision (Subject A: 21 year-old male, B: 18 year-old male, C: 19 year-old male, D: 21 year-old male, E: 21 year-old male, F: 22 year-old male, G: 22 year-old male). All volunteers gave informed consent. We adopted two experimental conditions; with and without the use of Virtual Chameleon. The details of the experimental setup are described below.

A. Condition Using Virtual Chameleon

The experimental configuration was employed as shown in Fig.4. Static targets were put on grids numbered from 1 to 9 on both sides of the subject. The subject put on the Virtual Chameleon device, sat on a chair, and found the positions of targets with the use of Virtual Chameleon. The experimental procedure is as follows:

1) Each set of targets was set on random positions on the grid.
2) The HMD was turned on to project CCD images onto screens in front of the eyes.
3) The subject searched for the marks and their positions using Virtual Chameleon as quickly as possible.
4) The subject reported the position numbers of right and left marks verbally.
5) The HMD was turned off to blank the HMD screens.

During the experimental procedure described above, the subjects kept full-faced posture and were only allowed to move their arms to control Virtual Chameleon. This experimental procedure was repeated twenty times for each subject.

In this setup, we conducted two types of experiments in the case where the user of Virtual Chameleon control angles of cameras with "only smooth movements" and with "combination of saccadic and smooth movements".

B. Control Condition

To compare performance using Virtual Chameleon to that without Virtual Chameleon, experiments in which subjects were not accoutered in Virtual Chameleon were performed. Here, the experimental setup without Virtual Chameleon is referred to as the control condition. The employed experimental configuration is shown in Fig.5.

The subject sat on achair and found the positions of targets. The procedure is as follows:

1) The subject sat with eyes closed.
2) Each set of marks was set on random positions.
3) The subject opened his eyes and looked around for targets and their positions as quickly as possible.
4) The subject reported position numbers of right and left targets verbally.
5) The subject closed his eyes.

During the experimental procedure described above, the subjects were allowed to move the upper half of their bodies. The experimental procedure was repeated twenty times for each subject.

IV. RESULTS

Table I shows the rates of correct answers for each subject. In this experiment, the number of correct answers was calculated as the number of cases in which both positions reported

TABLE I

ACCURACY RATES COLLECTED FROM EXPERIMENTS EACH SUBJECTS

Subjects (Age, gender)	A (21,M)	B (18,M)	C (19,M)	D (21,M)	E (21,M)	F (22,M)	G (22,M)
Use of Virtual Chameleon (Only smooth posture control)	0.93	0.95	0.98	0.93	0.98	0.90	0.93
Use of Virtual Chameleon (Smooth and saccadic posture control)	0.98	0.93	1.00	0.98	0.93	0.93	0.88
Normal condition	0.95	0.75	1.00	0.90	1.00	0.88	0.88

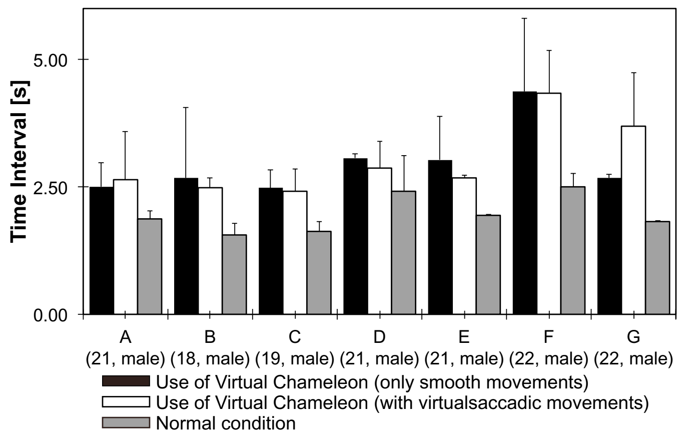


Fig. 6. Time intervals under the condition with use of Virtual Chameleon and the normal condition

by the subject were correct, and the rate of correct answers as the number of correct answers divided by twenty. Table I suggests that all subject could look around discern between right and left views, find target and determine their positions while independent views were given to both eyes. The funcion to generate artificial saccadic movements did not affect accuracy rates. Fig.6 shows the mean values of measured response times with standard deviations. It suggested the use of Virtual Chameleon caused 25-80% delays of response times compared to normal conditions. Implementation of the function of artificial saccadic movements improve the delay of up to 11.7% on some subjects.

V. CONCLUSIONS

We suggested a method to control camera postures of Virtual Chameleon as saccadic eye movements and implemented the function in Virtual Chameleon. In this work, we also performed fundamental experiments in a simple situation and evaluated the change in human performance while using Virtual Chameleon. Experiments on seven volunteers reveal that subjects were able to control visual axes independently and understand two different fields of view even though perceiving independent fields reduces human performance in discerning and responding to the independent views. The function to switch timing of control of motors and generate saccadic eye movements improve up to 11.7% human performance on some volunteers. Further studies are necessary toidentify effect of added function in various situations.

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REFERENCES

[1] W. Kirmse, Visuomotor operation in transition from object fixation to prey shoting in chameleons," Biol. Cybern., 71:209-214, 1994

[2] M. Ott, Chameleons have independent eye movements but synchronise both eyes during saccadic prey tracking. Exp. Brain Res., 139:173-179, 2001

[3] T. S. Peteret et al, Chameleon eye position obeys Listing ' s Law," Vision Research, 141:2245-2251, 2001

[4] G. M. Stratton, Vision without inversion of the retinal image — 1," The Psychological Review, 4, 341-360, 1887

[5] G. M. Stratton, Vision without inversion of the retinal image — 2," The Psychological Review, 4, 463-481, 1887

[6] P. W. Ewert, A study of the effect of inverted retinal stimula-tion upon spatially coordinated behavior, Genetic Psychology Monographs Child Behavior, Animal Behavior, and Comparative Psychology, 7, 177-363, 1930

[7] F. W. Snyder and N. H. Pronko, Vision with spatial inversion. Witchita, Kansas: University of Witchita Press, 1952

[8] F. Mizuno, T. Hayasaka and T. Yamaguchi,Virtual Chameleon - A System to Provide Different Views to Both Eyes, IFMBE Proceedings, Vol. 25, pp.169-172, 2009

[9] F. Mizuno, T. Hayasaka and T. Yamaguchi, A Portable Device to Represent Different Views to Both Eyes. Proc. the 32nd Annual International Conference of the IEEE EMBS, 3210-3213, 2010

[10] F. Mizuno, T. Hayasaka and T. Yamaguchi, A fundamental evaluation of human performance with use of a device to present different two-eyesight both eyes, 5th European Conference of International Federation Medical and Biological Engineering 2011, Proc. of IFMBE, Vol. 37, pp. 1176-1179, 2011

[11] R. Blake and N. K. Logothetis, Visual Competition, Nature Re-views Neuroscience, Vol.3, pp. 1-11, 2002

[12] B. B. Breeze, Binocular Rivalry, Psychol. Rev., Vol. 16, pp. 410-415, 1909