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Daily support system for care prevention by using interaction monitoring robot

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Abstract—**Recently, the number of elderly people increases in Japan, and the need of caring elderly people is also increase. Lack of exercise and falling down are the cause of making elderly people need care. For prevention of the situation above, the authors propose daily support system for elderly people using an interaction monitoring robot. Daily support system use the robot to implement both exercise support function and fall down sensing function. Exercise support function includes an interaction module which is for encouraging person exercise by action and utterance. Fall down sensing function use a monitoring module to detect human motion and tell user who fells down. This interaction monitoring robot has both interaction module and monitoring module. The authors develop both synchronous action function and instruction action function for the interaction module, and human motion recognition function for the monitoring module. The authors evaluated user's stress of experiment of exercise support function.**

I. Introduction

RECENTLY, the number of elderly people increases in Tokyo, Japan, and elderly people needing care increase. In Tokyo, Japan, the number of elderly people is more than 20 percent of the population. According to "Tokyo elderly health and welfare plan [1]", 80 percent of elderly people don't need care. So, it is important that elderly people keep healthy enough to live alone.

Lack of exercise and falling down are the causes of making elderly people need care. 12 percent of the causes of making elderly people need care is falling down. Cerebrovascular disease is 26 percent of the causes of making elderly people need care, but health maintenance can prevent cerebrovascular disease. Joint disease can be prevented as well by health maintenance. Therefore, it is important to let them keep exercising regularly, and not to make them need serious care. The authors call it "care prevention".

For care prevention, the authors propose daily support system for elderly people using an interaction monitoring robot. Daily support system uses the robot to implement both exercise support function and fall down sensing function. Exercise support function includes an interaction module which is for encouraging person exercise by action and utterance. Fall down sensing function uses a monitoring module to detect human motion and tell user who fells down. This interaction monitoring robot has both interaction module and monitoring module. The authors develop both synchronous action function and instruction action function for the interaction module, and human motion recognition function for the monitoring module.

Section II describes the robot system of monitoring which use "Kukanchi" for monitoring elderly people. Section III describes the robot action for the interaction module. Section IV describes human motion recognition for the monitoring module. Section V describes the structure of daily support system for elderly people using the robot. Section VI describes experiment of this system. And the conclusion is described in Section VII.

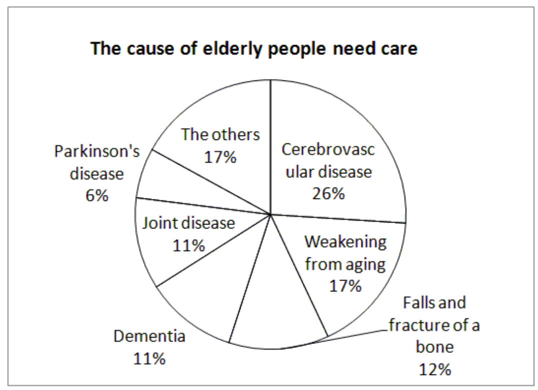

Fig.1. The cause making elderly people need care [2]

II. THE ROBOT SYSTEM OF MONITORING

The authors research and develop the robot system to apply in "Intelligent Room". Intelligent Room is a space that has a lot of sensors and cameras. Sensors and cameras can make the robot intelligent. The robots share information from sensors and cameras. This concept is called "Kukanchi".

A. Kukanchi

The robot technology becomes possible that is because it uses the techniques of arranges knowledge in the environment, distributing it and providing with appropriate service that by referring necessary knowledge according to the change of scene. It is necessary to unite not only robotics but also the knowledge of sensibility engineering and the information engineering, and etc. to achieve the goal of developing and researching as a new area. Between human-robots, robot-environmental system, and human-environmental system, A: The person searches for the real world and the information space because of the smooth interaction, B: An artificial thing is a search for the real world and the

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information space because of the smooth interaction, C: Search for information space function design standard because of smooth interaction of man wisdom and population ground, D: Clarification and proof of achievement technique of real world information space, it works from the above-mentioned four aspects (Fig.1.) [3][4].

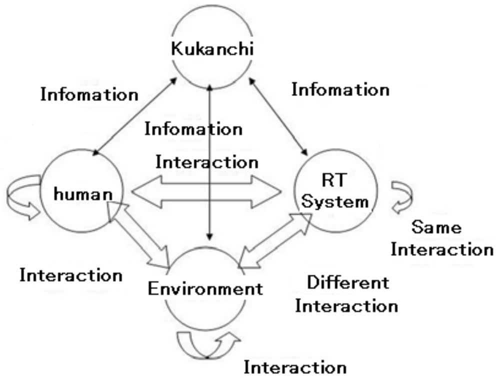


Fig.2. Kukanchi: Interactive Human-Space Design and Intelligence

B. Intelligent Room

In this research, Kukanchi is used in Intelligent Room. Intelligent Room is a space that has a lot of sensors and cameras. This concept is shown in Fig.3. Sensors and cameras can make robot intelligent. The robot shares information from sensors and cameras. Based on the shared information, the robot utters and acts. Sensors and cameras supplement an insufficient part only with the robot.

In Intelligent Room, the robot supports user using interaction module and monitoring module. For example, exercise support, fall down sensing, health management, supervised administration and so on. So the robot detects user from various viewpoints.

And the authors research and develop the synchronous action function and instruction action function that authors explain in Section III and the human motion recognition function that authors explain in Section IV for the robot system in Intelligent Room.

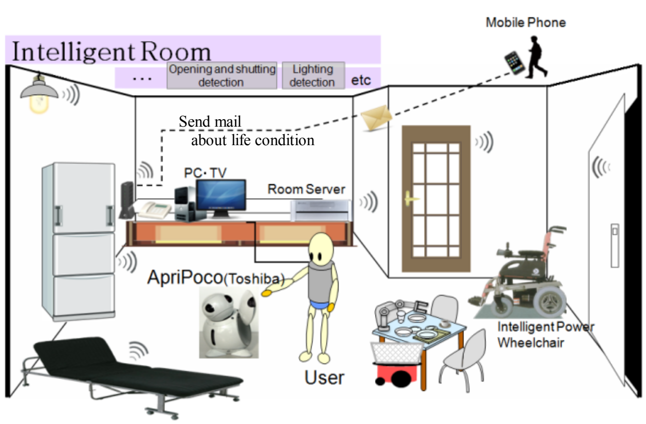


Fig.3. Intelligent Room

III. Robot Action

This section describes the functions which use in interaction module. First the authors develop human recognition using image processing. When using human recognition, the robot can provide service at communicating. Generally, when we take a communication, both synchronous rhythms of body and gestures are important, because we almost communicate not only utterance but also body rhythms and gesture [3].

The authors also develop both synchronous action function and instruction action function for using interaction module which targets on exercise support.

A. Image Processing for Human recognition

An interaction robot has to recognize human intention. The human intention often expresses by a gesture. When implementing the robot synchronous actions by person's action, the function that makes the robot recognizes person's head and hands is needed. Therefore the field of Japanese skin color is extracted from image of robot's camera. Extracted fields calculate by a labeling algorithm. The labeling algorithm is given a number in ascending order to fields (Fig.4). The result is created by the detected face, left hand, or right hand. Next, the person's head is calculated using Haar-like features. When the person looks at the face of robot, the right hand is defined at the left side of the head position, and the left hand is defined at the right side of the head position.

A field which done labeling has five data using API of Masata Imura [7].

1) Pixel count of a field [pixel]
2) Coordinates at the center of a field [pixel]
3) Height and width of a field [pixel]
4) Minimum and maximum coordinates of a field [pixel]
5) Barycentric coordinates of a field [pixel]

The result of image processing is shown in Fig.5(b).

0	0	0	0	0	0	0	0
1	1	0	0	0	0	0	1
1	0	0	0	0	0	0	1
1	1	1	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	1	1	1	1	0
0	0	0	0	1	0	0	0
0	0	0	0	1	1	1	0

0	0	0	0	0	0	0	0
2	2	0	0	0	0	0	3
2	0	0	0	0	0	0	3
2	2	2	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	1	1	1	1	0
0	0	0	0	1	0	0	0
0	0	0	0	1	1	1	0

Fig.4. Labeling

(a) Captured image

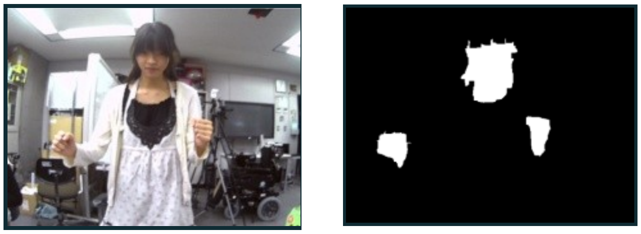
Technique for recognizing person's head and hands

Step 1: Capture image (a)

Step 2: Detect person's head H=(h_x, h_y)

Step 3: Calculate skin fields F^i=(f^i_x, f^i_y).

Step 4: The nearest field F^i to H is head. The left side on F^k_x is right hand, and the right side on F^j_x is left hand.



(b) Image resulting face detection (c) Image resulting labeling algorithm

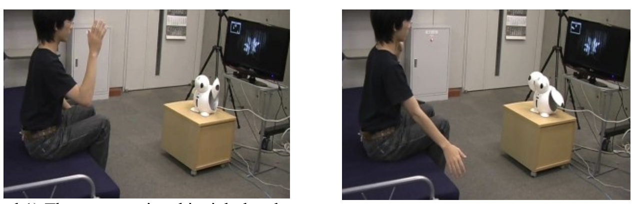
Fig.5. Recognize person's head and hands

B. Synchronous Action (using image processing)

Person's transition action is measured based on the barycentric coordinate obtained from previous section A. The robot moves based on the transition. It is synchronous action. That the robot follows a person's face is show in Fig.6(a). That the robot does synchronous action is show in Fig.6(b).

a1)The person looks at the face of robot a2) The robot follows a person's face

(a) The robot follows the angle of the person's face



b1) The person raises his right hand b2) The person raises his hand

(b) The robot follows the motion of the person's hand

Fig.6. Synchronous Action

C. Instruction Action (using image processing)

The robot might instruct user's action based on the information obtained from Intelligent Room. At that time, the robot uses the instruction action. Fig.7 shows the procedure of the instruction action. First, the robot confirms a situation and schedule. And the robot confirms whether user do as a situation from schedule. If the user doesn't do as a situation from the schedule, the robot will instruct user using utterance and instruction action.

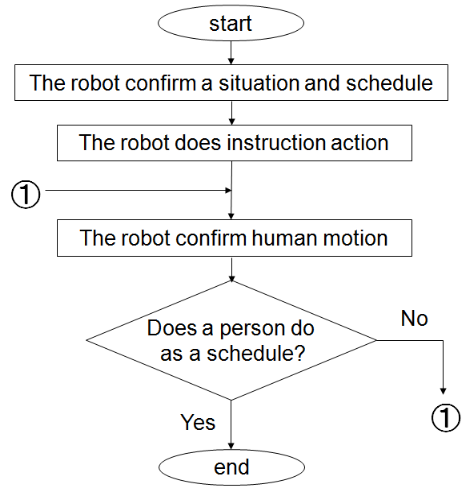


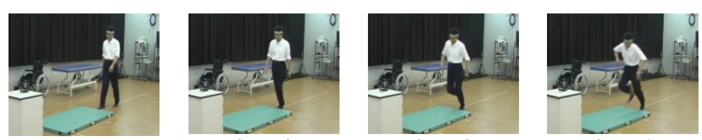
Fig.7. Flow chart of Instruction action

IV. HUMAN MOTION RECOGNITION

The authors develop human motion recognition function for using monitoring module.

Human motion on daily life means the behavior which takes in the house every day, like to rise or lie in bed, walk, sit down, or etc. The accident which may happen in elderly person's daily life is like to fall from the bed or bump against something. And the falling accident sometimes becomes the result which let elderly person have to confine to bed over a long term.

The authors implement the time series analysis of human position and develop the estimation process to detect motion pattern. Fig.8 shows the grabbed images which were for measuring falling motion by using VICOM. The points of measurement are the forehead and the back of the left and right hand. The Fig.9 shows the coordination when the examinee is falling.



Scene 1 Scene 2 Scene 3 Scene 4

Scene 5 Scene 6 Scene 7

Fig.8 Experiment to measure falling motion

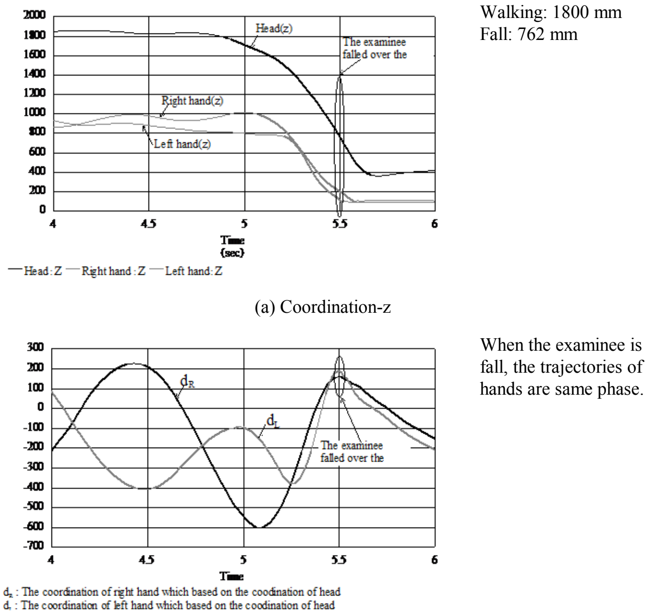


Fig.9. Example data when the examinee is fall over the block

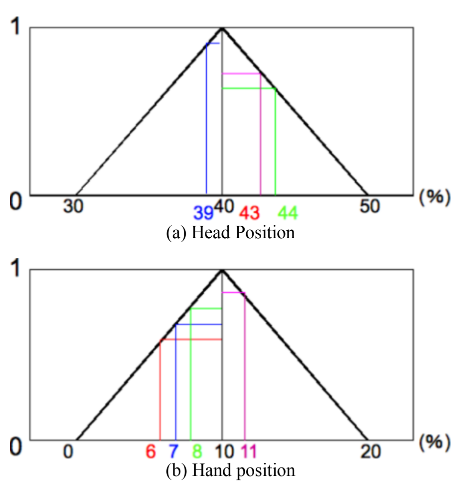


Fig.10. Antecedent of fuzzy membership

The authors utilized the results which were gotten from the experiments that are shown in Fig.9 to find the fuzzy membership. The graph of fuzzy membership is shown in Fig.10. For examination the certainty of the experiment, the authors extracted the experiment data of the four examinees as the antecedents to calculate. The result of certainty factor is presented in Table 1. As the table, the certainty of using the human motion recognition function to detect falling accident is over 0.6.

Table 1. Result of the falling examinee

Examinee	Certainty factor
A	0.7
B	0.6
C	0.6
D	0.7

V. DAILY SUPPORT SYSTEM

This section describes the daily support system for elderly people using an interaction monitoring robot. This system includes exercise support function and fall down sensing function. Exercise support function uses interaction module which are synchronous action and instruction action. Fall down sensing function uses monitoring module which is for human motion recognition.

A. *System Outline*

The interaction monitoring robot which the authors use in the research is "ApriPoco" which is made by Toshiba. ApriPoco has seven movable points (the head, the arm, the waist). And, ApriPoco has voice recognition, the utterance function, and the camera function. The room server controls ApriPoco, stereo camera, schedule management and life log database. (Fig.11). ApriPoco's camera is used for interaction module. Stereo camera is used for monitoring module.

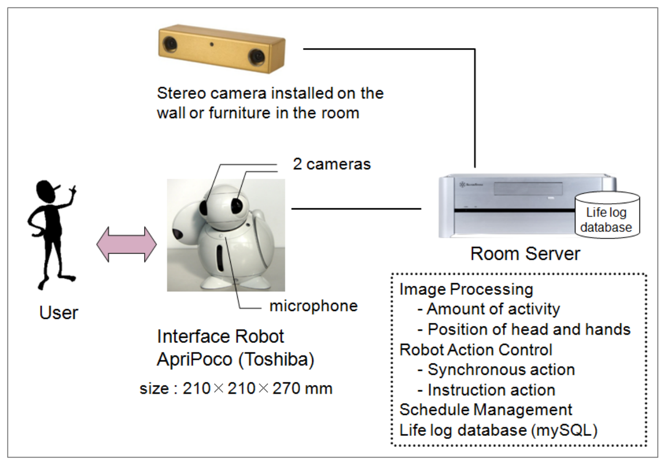


Fig.11. Daily support system outline

B. *Exercise support function*

Care prevention includes the health promotion and the lifestyle improvement. Therefore, taking exercise regularly is effective in care prevention. The authors develop the robot system of exercise support function. When it became the decided time by a schedule, ApriPoco encourages the user to exercise and faces the user at the same time. The exercise supports that ApriPoco can propose now are "arm raising exercise" and "exercise using a movie". Arm raising exercise is that ApriPoco does synchronous action. Exercise using a movie is that ApriPoco does instruction action. ApriPoco encourages the user using utterance and actions when the user takes exercise. The user takes exercise with ApriPoco is shown in Fig.12.

(a) Arm raising exercise

(b1) Retroflexion

(b2) Forward bend

(b3) Lateroversion

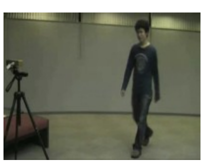
(b4) Rotation

(b) Exercise using a movie

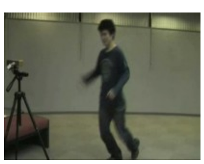
Fig.12. Exercise support using the robot

C. *Fall down sensing function*

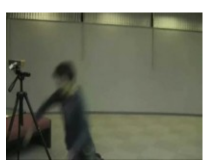
Fall down sensing function detects that the user falls down by using monitoring module of human motion recognition. If this system detects that the user falls down, life log of room server records "falling down" and ApriPoco tells user. If user doesn't respond, ApriPoco informs helper of it. Fig.13. shows that grabbed image at experiment of fall down sensing function. This function can detect the user's falling down, but cannot prevent the user's falling down. So, the authors plan to find a sign of user's falling down.



a) Scene 1



b) Scene 2



c) Scene 3

Fig.13. Grabbed image at experiment

VI. EXPERIMENTS

This section describes experiment about exercise support function. The result of experiment and consideration are described.

A. *Experiment of exercise support function*

People need take exercise regularly for physical strength. Taking exercise regularly is effective in care prevention. For exercise regularly, People shouldn't feel stress. In this experiment, the authors evaluated user's stress when user use exercise support function. Stress is measured by amylase activity. Amylase activity is good indicator for measuring stress [8]. The number of examinees is 6. Each examinee takes exercise alone using a dumbbell for 60 minutes in a silent room. Experimental environment is shown in Fig.14(a). The pattern of the experiment is shown below.

Case 1) Take exercise alone.
Case 2) Take exercise with virtual robot (shown in Fig.14(b)).
Case 3) Take exercise with actual robot (ApriPoco).

Virtual robot and actual robot do inducting action without calling.

Each examinee was measured amylase activity before examinee exercised. Each examinee was measured amylase activity every 20 minutes while exercise: the measured data are described as v^k_{0}, v^k_{20}, v^k_{40}, and v^k_{60}. "k" is number to distinguish examinees. When body tiredness and a mental stress are high, the value of the amount of the amylase activity rises. In this experiment, the measurement of a mental stress was an aim. So, the authors prepared for this experimental environment because of body tiredness did not occur easily. The reason why the exercise time is one hour is that the time of other experiments measuring the stresses is about one hour. It is difficult to compare stresses if experiment doesn't do over one hour. The measurement of the amylase activity should go to examinee's place by authors and obtain examinee's saliva. It takes about three minutes to measure the amylase activity of one time. When the amylase activity is measured, the authors meet the examinee. Therefore, the frequency of the measurement was reduced.

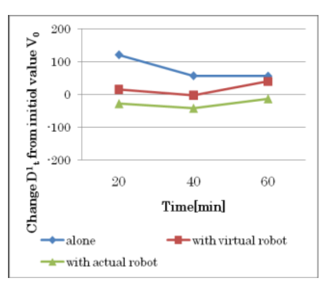
At the end of the experiment, a free impression was said to the examinee for the authors. The authors requested examinee to speak free impression of this experiment.

(a) Experimental environment with actual robot (ApriPoco)

(b) Virtual robot

Fig.14. Experimental environment and virtual robot

The result of 2 examinees amylase activity is shown in Fig.15. Fig.15 is the different value from initial value v_0: the measured data are described as D^k_{20}, D^k_{40}, and D^k_{60}.



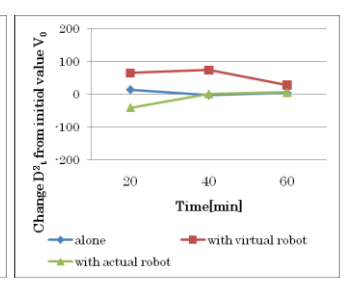


Fig.15. Different value of the amylase activity

Fig.16 shows the average of different value of the amylase activity: the measured data are described as D^{ave}_{20}, D^{ave}_{40}, and D^{ave}_{60}. Average is calculated by equation (1).

$$D^{ave}_{t} = \frac{1}{6}\sum_{i=1}^{6} D^{i}_{t} \qquad (1)$$

t : 20, 40,60

When examinees took exercise with the actual robot, their amylase activity decreased by comparison with taking exercise alone.

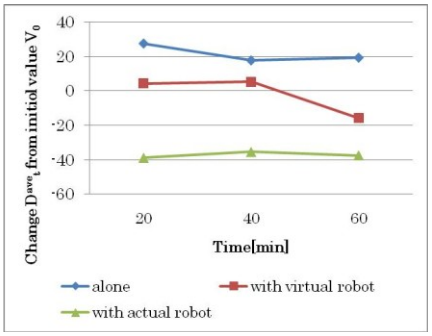


Fig.16. The average of difference value of the amylase activity

The result of free impression is shown in table.2. When examinees took exercise alone and with virtual robot, they were bored. But, when they took exercise with actual robot, they were not bored.

Table.2. Free impression by examinees

Take exercise alone	• I was bored, and I wanted to stop exercise. • My pace is down and instability.
Take exercise with virtual robot.	• I tired of virtual robot action. • I couldn't synchronize virtual robot action. • I became sleepy, because of virtual robot action was monotony.
Take exercise with actual robot	• I wasn't bored. • I feel that the robot took exercise with me.

B. Discussion

In the exercise support system, the authors experiment to verify effective of care prevention. The authors evaluated examinee's stress with 3 cases. As a result, when examinees took exercise with actual robot, their mental stress decreased by comparison with taking exercise alone. Thus, it is possible that people continue exercise at a long term by using exercise support system. Virtual robot can execute very complex motion exercise than actual robot. From this point of view, virtual robot is useful than actual robot. However, in the exercise, it is the most important is to continue even if it is short time. So the authors think that actual robot is useful than virtual robot.

The authors consider that 2 functions are added. These functions are funny motion and telling user about health maintenance.

VII. CONCLUSION

For care prevention, the authors developed daily support system for elderly people using an interaction monitoring robot. Daily support system is applied in Intelligent Room as an experiment. The system has both exercise support and fall down sensing function that are implemented by the robot. The exercise support function includes an interaction module and the fall down sensing function includes a monitoring module. The authors developed human recognition, synchronous action and instruction action function for the two modules, and use the robot to implement those functions.

Then, the authors show the experiment results after evaluating users' stress experiment of exercise support function and the utility of the fall down function for testing and verifying the ability of the system. In experiment of exercise support system, examinees mental stress were compared with 3 cases which were taking exercise alone, taking exercise with virtual robot and taking exercise with actual robot. When examinees took exercise with actual robot, their mental stress decreased by comparison with taking exercise alone. So, exercise support system has possible that people continue exercise at a long term.

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REFERENCES

[1] Tokyo metropolitan government (2009), "Tokyo elderly health and welfare plan". Available: http://www.metro.tokyo.jp/INET/KEIKAKU/2009/03/70j3u100.htm

[2] Ministry of Health, Labour and Welfare (2001), Comprehensive Survey of Living Conditions of the People on Health and Welfare, Available: http://www.mhlw.go.jp/toukei/saikin/hw/k-tyosa/k-tyosa01/index.htm .

[3] Tomomi Shibano, Kazumasa Murakami, Yasunari Fujimoto, and Toru Yamaguchi, "Support system for mental and physical functions by utterance and synchronous action using a robot," SICE System Integration Division Annual Conference (SI2009), pp1193-1194, 2009.

[4] Eri Sato, Toru Yamaguchi, Fumio Harashima, "Natural Interface Using Pointing Behavior for Human-Robot Gestural Interaction," IEEE Transaction on Industrial Electoronics, Vol.54, No.2, 2007.

[5] Tomio Watanabe, "Embodied Communication Technologies and Their Applications, Systems, control and information," 49(11), pp.431-436, 2005.

[6] OpenCV Programing Book Seisaku-Team, "OpenCV Programming Book," 2007.

[7] Masataka Imura (2009). Labeling Class. Available: http://oshiro.bpe.es.osaka-u.ac.jp/people/staff/imura/products/labeling

[8] Hitomi Tuji, Masahiro Kawakami, "An examination of the relationship between saliva amylase activity and the psychological rating, Profile of Mood Scale, using a portable stress meter," The human science research bulletin of Osaka Shoin Women's University, Vol. 6, pp.63-73, 2007.

[9] Bureau of Social Welfare and Public Health, Tokyo Metropolitan Government. (2009). 2009 Social Welfare and Public Health in Tokyo. [Online].p.18.Available: http://www.fukushihoken.metro.tokyo.jp/ joho/koho/tokyo_fukuho_e09/index.html.