# Fundamental Study to Consider for Advanced Interface in Grasping Movement

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***Abstract*— the analysis of human grasping movement is important in developing methodologies for controlling robots or understanding human motion programs. In analyzing human grasping movement, it is advantageous to classify movements. In previous papers, classifications of grasping patterns were proposed according to the posture. Among these classifications of grasping patterns, no unified view has been reached as yet. The measured quantities in grasping have included only the posture of the hand, force and its distribution. Few have pertained to classifications based on grasping force and its distribution. This paper first tries to analyze the effect of visual information on grasping movements, and then attempts to classify grasping movements broadly according to their purpose. For the elements of the purposes of grasping movements, movements that were decided upon were those which require attention, snapping or the adjustment of the wrist or movements which do not require any special action to achieve their purpose. Secondly, we focus on the tactile information to predict with a limitation of movement. Finally, we attempted to discuss the relation between human brain activity and grasping movement on cognitive tasks.**

***Keywords-human hand; grasping force; grasping pattern; brain activity;NIRS.***

## I. INTRODUCTION

Human hands are so dexterously controlled that they can manipulate almost anything freely. Observations obtained from analyzing the grasping patterns of human hands will be useful in the control of robot hands. For example, it may be possible for industrial robots to deal flexibly with and solve unexpected problems which may occur. In the construction of more sophisticated interface systems the analysis of the grasping patterns of human hands is also suggested as an important subject for controlling robot hands by remotely.

To analyze grasping patterns, many researchers, including Schlesinger [1] have proposed and reported methods to classify grasping patterns [2][3]. However, these classifications of grasping modes depend largely on the researcher's personal definitions, and no unified view has been reached at present.

The measured quantities in grasping include the posture of the hands, and force and its distribution. However, most classifications have been based on the posture of the hands, and little has been reported on classification based on grasping force and its distribution.

From the point of the view of the grasping task, Napier broadly divided grasping patters into "power grip" and "precision grip" [4]. In addition, Cutkosky classified more grasping patterns by incorporating details of the objects and the precision of the task in Napier's concept [5]. Meanwhile, Kamakura et al. presented a classification cased on the contact pattern between the grasped object and grasping hand [6]. Kang et al. proposed the technique of the "contact web" which estimated information and classified grasping based on the resulting contact pattern [7]. For the theory of multi-fingered hands Yokokawa is proposing the dynamic multi-fingered manipulability measurement under the concept of the dynamic manipulability [8]. Another new approach to control the robots is the Programming by Demonstration done (PbD). A late report is proposed by K. Bernard in et al [9]. Shimizu et al. described the Sensor Glove MKIII which is useful in analyzing grasping patterns and shows the potential of measuring grasping force distribution for classification [10].

Many reserch works exist on the classification of grasping movements. However, there are only a few areas using these classifications, such as the industry, indicating a need for a more useful grasping classification to be used in engineering. We thus considered using new elements to broadly classify grasping movements. We set grasping movement purposes for the new elements, elements which are movements that require attention, snapping or adjustment of wrist or do not require any special action to achieve their purpose. Therefore, it was necessary to find a place in which position and direction had little effect when measuring grasping movements. We subsequently deliberated the possibility of broadly classifying grasping patterns according to the purpose of the grasping movement. A report about the importance of grasping task is proposed by Shiraishi, et al. [11], too.

This paper first tries to analyze the effect of visual information on grasping movements and then considers the potential for using the elements described above in classification. Lastly, we focus on the tactile information to predict with a limitation of movement.

 **ISBN: 978-1-61208-250-9** 

## II. Experiment for Measuring Grasping Movement with Considering Effect of Wrist Direction

### A. Experimantal Method 1

To measure grasping movement with minimal effect from the position and object's direction for classification, it is necessary to ascertain the proper position and direction from which to do so. The next step is to discover the role visual information plays in grasping patterns. In this experiment, USB cameras from three directions measured grasping patterns. The cameras used had a resolution of over 0.3 megapixels.

### B. Range of Movement

To find the area which would not need to be considered in regard to its effect on grasping shape; subjects were made to grasp a pointer directed toward them. Then the area in which they could move without changing the direction was measured. Fig. 1 shows the range of movement. Subjects were four healthy, right-handed men aged 22 to 24.

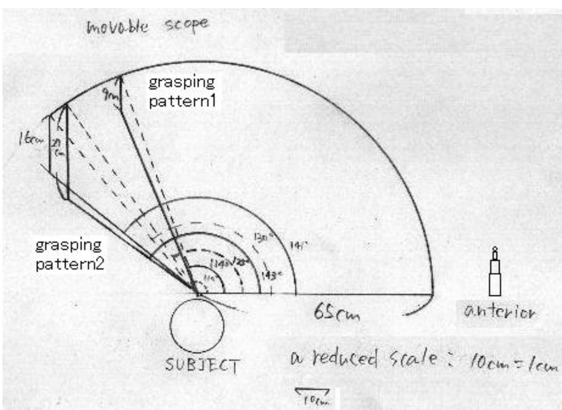


Figure 1. Range of movement (object: pointer)

The range of movement seems to depend on their flexibility and grasping patterns. As can be seen in Fig. 1, a 15 cm margin has been set, and the objects have been placed to check their effect on grasping. Fig. 2 shows the position in which the objects were placed. Grasping patterns differed little according to position; here, Position C was used for classification. However, if the object is placed in direction (4), the grasping patterns change for right-handed people. The next step was to look at the relationship between direction and grasping

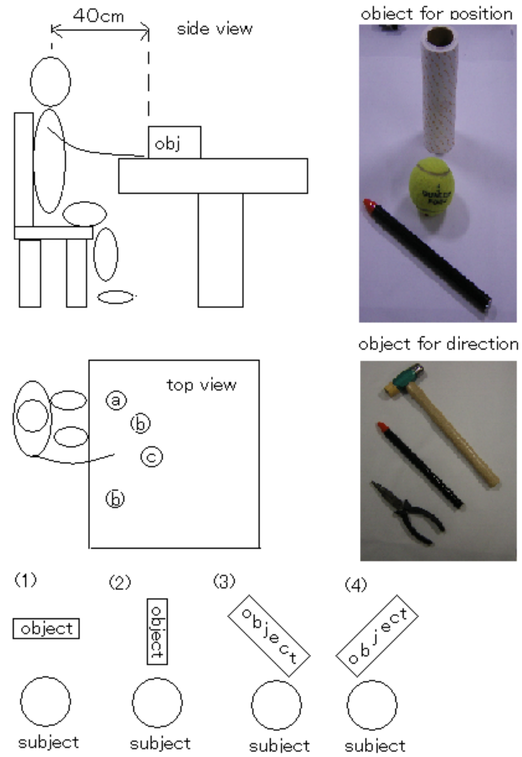


Figure 2. object's position and direction

### C. Effect of Direction on Grasping

To analyze the relationship between direction and grasping pattern, the angle of the underarm and the angles in Fig. 3 were measured by changing the object's direction. The directions of (1) to (3) were measured by changing the angle 30 degrees. Subjects were told to grasp the object and put it onto another table. The subjects were five right-handed healthy men aged 22 – 24.

Increases in the angle of the wrist and the angle of the finger baseline are seen to be related to the angle of the object. The angle of the underarm decreased as the angle of the object increased. However, as the angle of the underarm is influenced by reaching, the displacement is not uniform. Fig. 4 exemplifies the difference between grasping patterns and the object's directions.

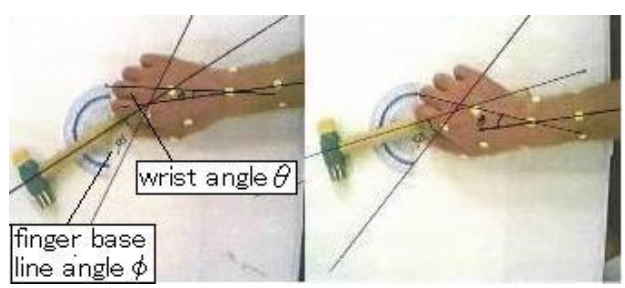


Figure 3. angle measured, θand φ

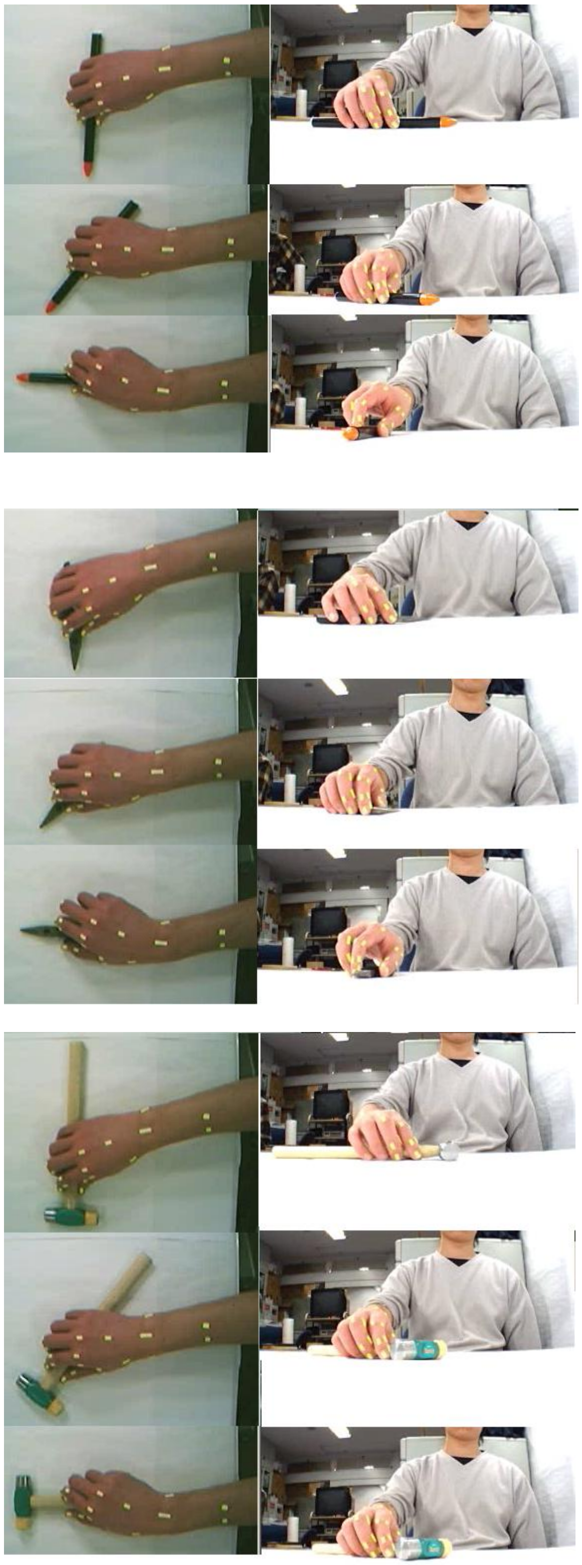

Figure 4. grasping patterns for each object

(Top: pointer, Middle: pincher, Bottom: hammer)

## III. EXPERIMENT OF CLASSIFICATION OF GRASPING MOVEMENTS

### A. *Experimental Method 2*

We compared the difference of grasping movement based on “purpose of grasping movement”. We set elements which are movements that require attention, snapping or adjustment of wrist or do not require any special action to achieve their purpose. We considered the potential for using the elements described above in classification [12].

### B. *Experiment for the Classification of Grasping Movements*

To classify grasping movements, the purpose of grasping was used as an element that is determined at a certain point, i.e., before or after grasping. In this experiment, five kinds of tasks were used to consider the relation between grasping patterns and their purpose. The tasks are to move the object to another place (Task 1), to put the object onto a small box (Task 2), to throw the object (Task 3), to make the object pass through a small hole (Task 4), to use the object as you usually do (Task 5) after grasping. These tasks were created to measure a simple grasping movement (Task 1), a movement requiring attention (Task 2), the movement which requires snapping (Task 3), a movement which requires attention and adjustment of wrist (Task 4), a movement that is imagined to be associated with the object (Task 5). And checked that the grasping movements would change with there tasks.

The purpose of the first experiment was to measure grasping shapes according to their purpose. The next step was to measure grasps without a prescribed purpose. The purpose was given only after the subject first grasped the object. The subjects were six right-handed healthy men aged 22 – 24.

### C. *Result of Classfication Experiment*

The results showed two movements involved in grasping and taking action when checking the difference between the first grasping shape and the next grasping shape. One is a change in grasping shapes before picking up. The other one is a change in the grasping shapes after picking up. Fig 6 shows the first movement; the grasping shape changes according to its purpose. T shows the second movement; the grasping shape changes according to its purpose. Such cases might be difficult to classify only by force distribution. Such movements were not seen in the case of every object. Therefore we attempted to discover out the difference between them and use it with the force distribution to classify grasping movements.

This experiment showed that one seems to make space between the palms and object or change the grasping shape into a more flexible form when they try to do something sensitive like Task 4. Probably, such a tendency has some relation to degree of freedom in movement.

 ISBN: 978-1-61208-250-9

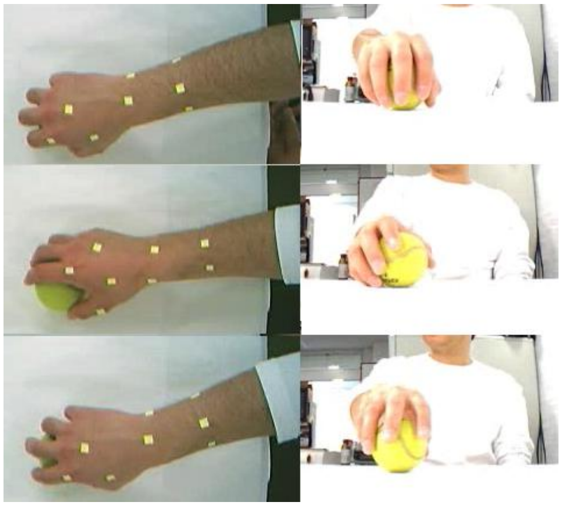

Figure 5. changing the shape when grasping

(Top: Task 1, Middle: Task 3, Bottom: Task 4)

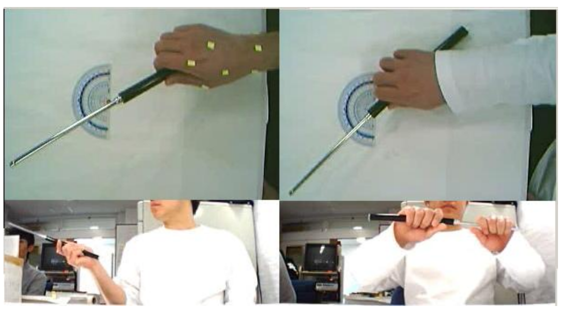

Figure 6. changing the shape after grasping

(left:task4, right:task5)

## IV. TACTILE INFORMATION

Looking into the tactile information and degree of freedom in hand movement, we first tried to check how correctly we could imagine the shape only from tactile information. Therefore, the relation of such information to the degree of freedom in movement was considered in conducting this experiment [13].

### A. *Experiment Method for Tactile Information*

Three limitations were made to analyze the effect. One was wearing an eye mask to shut out the visual information. Another one was a pinching movement to control the tactile information. The last one aluminum fingertip cover to reduce the tactile information and to make the surface like robot hand because we are thinking to use the results for robot's hands. The fingertip cover used in this experiment was enclosed in aluminum sheeting and the finger cushion's side was flattened. Limitations in pinching movement are shown in Fig 7.

The test was to guess the object with eyes masked and fingertip limitations. After that, same tests were conducted without using the fingertips. Fig 7, 8 and 9 shows the objects used. Objects in Fig. 8 were stuck to board. The objects in Fig. 8 (lower right) can be spun using the stick that is standing on the small plate. The objects in Fig. 9 can be pinched freely.

TABLE I. LIMITATION OF PINCH

| freedom degree number | Limitation |
|---|---|
| 1 | Not allowed to pinch again |
| 1' | allowed to grasp again just a little |
| 2 | allowed to move up and down |
| 3 | allowed to go over lateral side |
| 4 | allowed to grasp freely |

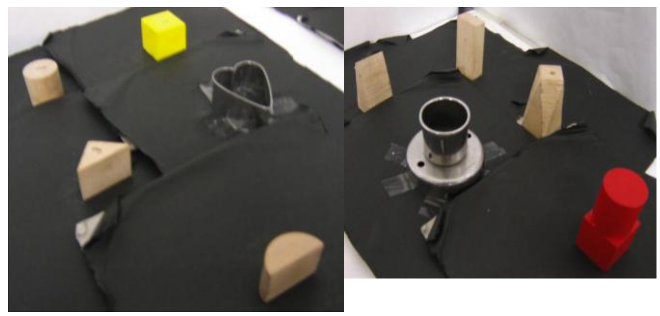

Figure 7. object for tactile information test

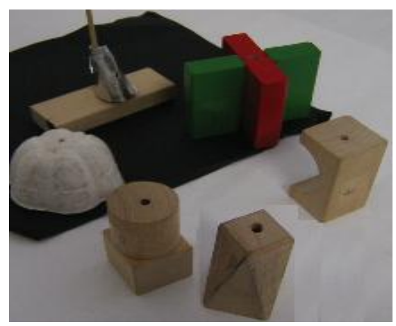

Figure 8. Object for tactile information test

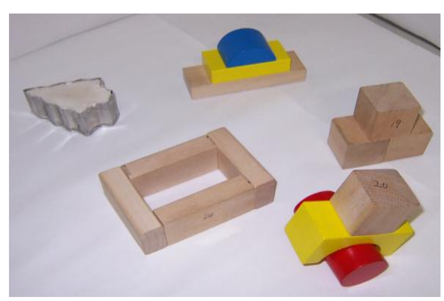

Figure 9. Object for tactile information test

### B. Result of the Experiment in Tactile Information

Fig. 10 shows the result of this test. The answers were checked by a majority decision of three observers. The subjects for this experiment were six men and two women, all healthy, right-handed and aged 20 – 60.

In Fig. 10, the accuracy rate was higher when the fingertip covers were not used, and the accuracy rate basically increased with the degree of freedom, but it increased only slightly when the fingertip covers were not used, or when there was a high degree of freedom. From the aspect of object identification only with tactile information, the difference in fingertip cover suggests the importance of the ridges in the fingers' skin and the plasticity of the finger surface, probably because they are enhancing the signals. Furthermore, Degree of Freedom 4 was lower than that of 1 when they tried without the fingertip cover. This seems to have occurred when they lost track of direction when they moved their hands. This suggests that the relation between accuracy rate and freedom digger is not a simple proportional relation.

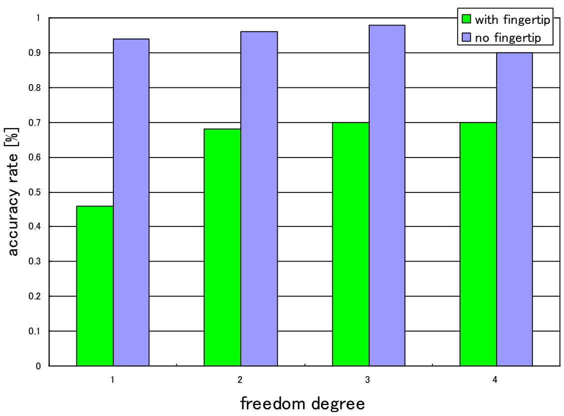


Figure 10. degree of freedom and accuracy rate

## V. GRASPING MOTION AND HUMAN BRAIN ACTIVITY

We are trying to process experimental measuring and discuss human brain activity on grasping movement and cognitive task. So, we measured brain activity from the viewpoint of blood flow changes when subject performed grasping movement including reaching. Six subjects were healthy males who were right handed. They were asked to read and sign an informed consent regarding the experiment. In measurement, f-NIRS(Functional Near Infrared Spectroscopy ) made by SHIMADZE Co. Ltd. were used.

### A. Experimental Method

Subjects were asked to grasp the piece of wood, pointer, column-shaped metallic bar and hammer based on instructions from operator (Fig. 11). Brain activity was measured under four conditions. Subjects grasped objects actively with their eyes open (1) or close (2), and passively with their eyes open (3) or close (4). In addition, subjects were told to perform simple grasping motion or do it with imaging motion for using object.

Subjects took a rest during 10 seconds at least with their eye close before starting task and the time design was rest (5 seconds) – task (10 seconds) – rest (5 seconds). Finally, subject closed their eyes for 10 seconds again after task. Then, the brain activity was recorded from the first eyes-closed rest to the last eyes. The part of measurement was the frontal lobe.

### B. Experimental Results

Fig. 12 shows one subject's measuring result. At the first, Hb-oxy was increased in overall frontal lobe after start of grasping task. This tendency was common among subjects. After that, Hb-oxy was increased and decreased in synchronization with task and rest. Also, there was remarkble tendency like this during task with imageing and their eyes open.

Analysis was performed one-sample t-test and sample was variation in brain activity during about four seconds after starting tasks.

As a result, there was not significant differences at frontal lobe. However, it was shown as common tendency among subjects that there was adifference in variation of oxy-Hb density due to presence or absence of existence or non-existence imaging motion and eyesight. It was thought that this result was derived from planning for grasping and visuals timulation.

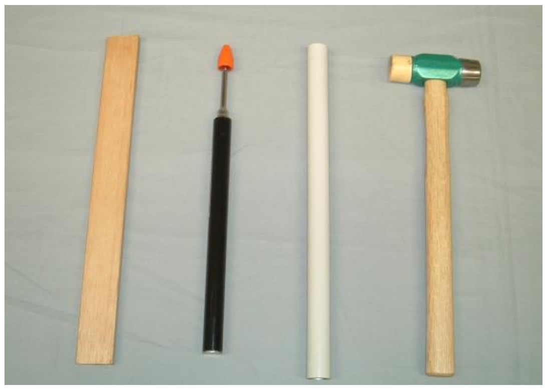

Figure 11. Grasping object

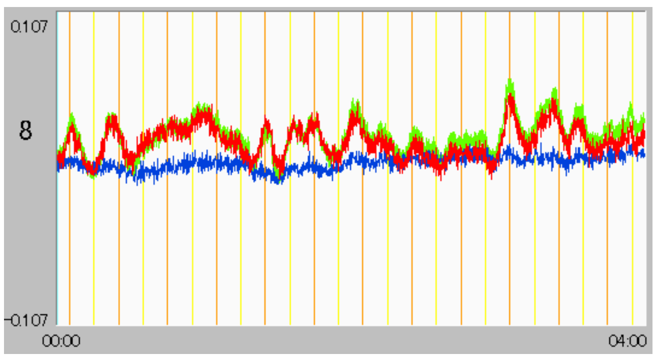


Figure 12. Measuring Result of grasping steering wheel

## VI. Conclusion and Future Work

In this study, we performed three experiments. The analysis of human grasping movement is important in developing methodologies for controlling robots or understanding human motion programs. In analyzing human grasping movement, it is advantageous to classify movements.

This paper first studies that the grasping angle changes. From the results, it was determined that basically the wrist angle and finger baseline angle are proportionally related. In this report we attempted to classify the grasping patterns based on “purpose of grasping movement”. In the results described in Section III.B, we found two movements related to the “purpose of grasping movement”. Some grasping movements change when you give them a purpose before grasping, but some grasping movements do not change until the object is lifted and the action accomplished. These results suggest the possibility of the classification of grasping movements according to “purpose of grasping movement”. Furthermore, it would be useful to classify the grasping movements that have similar grasping forms or distributions, but have different actions after grasping. At a later stage, we would like to classify grasping movements according to the "purpose of grasping movement" and use the results of the distribution in grasping patterns to create more useful classifications for grasping movements in engineering.

The results in Section IV.B are important, in using the classification. The relation between accuracy rates basically increases with the degree of freedom, but if the degree of freedom increases with no useful feedback, the results would differ from expectation. Therefore, the challenge which lies ahead is to find effective ways to use the tactile information.

In terms of measuring brain activity, we plan to examine change of brain activity due to shape of hand and object as well as a review of experimental design.

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