Basic Experimental Verification of Grasping Information Interface Concept, Grasping Force Increases in Precise Periods

Sigeru Sato[1], Muneo Kitajima[1], and Yukio Fukui[2]

[1] Institute for Human Science and Biomedical Engineering, AIST,
1-1, Higashi 1-chome, Tsukuba, 305-8566, Japan
[2] Department of Computer Science, University of Tsukuba,
1-1-1, Ten-no-dai, Tsukuba, 305-8573, Japan
{sato-s,kitajima.muneo}@aist.go.jp
fukui@cs.tsukuba.ac.jp

Abstract. In human-human communications, especially in face-to-face communication, sub-verbal and non-verbal messages have more importance than messages transported by words. On the other hand, in traditional man-machine interfaces, machines only understand pre-defined operations, and never understand operators' sub-verbal and non-verbal messages. This causes some usability problems in machine operations. We have proposed elsewhere that Grasping Information Interface Concept (GIIC) is the key idea to alleviate the above-mentioned communication gap between man and machine, and this paper verifies GIIC experimentally. GIIC regards grasping-and-moving as a fundamental hand operation necessary for performing tasks using modern man-machine interfaces, and behavioral measures associated with grasping, such as force, posture, etc., should have much potential in developing task-adaptive and operator-adaptive interfaces because it is known that how people grasp devices is dependent on the purpose of these tasks. GIIC provides machines with a communication channel to understand operators' intents more through the grasping information.

Keywords: silent messages, grasping force, pointing device, Fitts' law.

1 Introduction

1.1 Difference Between Human-Human Communication and Man-Machine Interfaces

In human-human communications, especially in face-to-face communication, it is known that most of information is communicated through sub-verbal and non-verbal messages. 55% of communications depends on non-verbal messages, such as facial emotional expressions, and 38% on sub-verbal messages such as vocal tone. They are called "silent messages." Only 7% of whole information is communicated by words [1]. On the other hand, in traditional man-machine interfaces, machines only understand pre-defined operations, and never understand operators' sub-verbal and non-verbal messages.

M.J. Smith, G. Salvendy (Eds.): Human Interface, Part I, HCII 2007, LNCS 4557, pp. 180–188, 2007.

This means that in man-machine interfaces, operators must express 100% of their intents in verbal channel which is used only 7% in human-human communication. This causes some usability problems in machine operations.

Table 1. Comparison of usage of communication channels in human-human communication and man-machine interface

Channel	Example	Human-human communication	Man-machine interface
Non-verbal	facial	55%	0%
Sub-verbal	vocal	38%	0%
Verbal	word, switch	7%	100%

1.2 Grasping Information Interface Concept (GIIC)

Grasping-and-moving is one of the fundamental hand operations necessary for performing tasks with modern man-machine interfaces. We have proposed Grasping Information Interface Concept (GIIC) in our previous papers that “grasping” could be used as an expression of operator’s sub-verbal and non-verbal messages [2-5]. The key ideas came from Napier’s observation and our characterization of pointing tasks. This paper verifies GIIC experimentally.

Grasping Expresses Operator’s Intention. Napier’s study indicates that a grasping posture is adaptive, and depends not only on the shape of the grasped object but also on the purpose of grasping [6]. This means that a grasping posture can be an indicator of the operator’s intent. One can detect the operator’s intent, through analysis of grasping form, grasping force and other grasping factors.

However, behavioral measures associated with grasping, such as force, posture, etc., have not been utilized for traditional interfaces. They can convey “silent messages” in man-machine interfaces.

This leads to a claim that we can identify the operator’s intent if we can appropriately associate a set of features of a grasping posture such as grasping form, grasping force, etc. with a certain operator’s intent. We call this claim as Grasping Information Interface Concept (GIIC). Though GIIC seems to be a promising idea for alleviating the communication gap between man and machine shown in Table 1, it has not been utilized for traditional interfaces.

Application of GIIC to the Designing of Remote Pointing Devices, Especially a New Computer Mouse. We applied GIIC to design a novel computer mouse for remote pointing tasks [2]. We suggest that a pointing task consists of two phases: approaching and positioning, which differ significantly in terms of the above-mentioned behavioral measures associated with grasping.

In approaching phase, the operator performs a rough task with faster and less accurate operation on the computer mouse, whereas in positioning phase, he/she performs a precise task with slower but more precise operation. The latter requires a higher value of stiffness and robustness in hand positions, which is caused by higher tensioning of hand and arm muscles, than the former does. Namely, the operator would grasp the mouse firmer for the precise task in positioning phase than he/she would do for the rough task in approaching phase. We argue that this is done intentionally. And thus operator's intention is represented by grasping information.

In precision tasks, a higher value of stiffness and robustness in hand positions are necessary than those required for rough tasks. Naturally, hand and arm muscles are tensioned to a higher degree in order to keep sufficient stiffness and robustness when in the hand position.

A remote pointing device consists of a pointing terminal and an operation terminal. A pointing terminal is driven and controlled with an operation terminal. There are many kinds of remote pointing terminals, such as industrial robot manipulators, cranes, surgery manipulators, etc., which are usually called as "pointing devices." A computer cursor on the screen is a type of remote pointing device. These pointing terminals are driven and controlled by operation terminals, such as, keyboards, joystick switches, levers, pedals, etc. The computer mouse is a type of operation terminal.

Grasping operation terminals such as joystick switches, levers, computer mouse, etc., are naturally expected to be grasped stronger in the positioning phase than in the approaching phase [2-5]. Therefore, by using grasping force as an indicator to make a real-time prediction on which phase a pointing task is in, automatic real-time adaptive gain adjustment can be realized without increasing complexity on the part of operators. This is the main argument of this paper, which we would further investigate by showing experiments for its verification in section 2 and its validation in section 3.

1.3 A Measurement Method to Validate GIIC: Easiness of a Pointing Task

A remote pointing device consists of a *pointing terminal* and an *operation terminal*. There are many kinds of remote pointing terminals, such as industrial robot manipulators, cranes, surgery manipulators, etc., which are usually called as "pointing devices." A computer cursor on the screen is a type of remote pointing device. These pointing terminals are driven and controlled by operation terminals, such as, keyboards, joystick, switches, levers, pedals, etc. Computer mouse is a type of operation terminal.

The time necessary for accomplishing pointing tasks is one of measures to evaluate the usability of remote pointing devices. The less time a pointing device requires for a user to accomplish a pointing task, the better the usability the device has. According to Fitts' law [7-8], the time T necessary for pointing a target of the size S located at a distance D is given by the following formula:

$$T = a + b \times \log_2 \left(D/S + 1 \right) \tag{1}$$

In this formula, the log term, $D/S + 1$, is called Index of Difficulty (ID), and a and b are experimentally determined constants. The former, ID, defines the feature of a pointing task, namely, a pointing task becomes easier for a larger target, a larger S, located at a shorter distance, a smaller D; whereas the latter, especially b, is related to the usability of a pointing device. The smaller the estimate of b becomes, the shorter the pointing time results for a given task with a fixed value of ID.

2 An Experiment to Verify GIIC

To confirm experimentally the discussion above, an experiment was conducted. Differences in grasping forces in various conditions and phases of pointing tasks as described earlier were observed. The experimental task is remote pointing task on the computer screen. A mouse with a force sensor was used. The subjects were adults, skilled in computer usage and have no hand disabilities. Both male and female test subjects were used. The size of the test pool was 25.

Fig. 1. Appearance of the mouse used in the experiment

2.1 Apparatus

A mouse with a force sensor developed by [2] was used. Fig. 1 shows its appearance. To detect a grasping force, a thin, flexible pressure sensor was used as shown by the black part of the sidewall of the mouse body. Fig. 2 shows the grasping force sensor, constructed with a two-stripe electrode, printed on a flexible printed circuit sheet, and a pressure sensitive conductive rubber sheet. The amount of movement of the mouse was transferred to an A/D converter, then to a PC through a USB port. The amount of movement of a mouse cursor on the monitor was reduced by a predefined factor when the pointing task was judged to be in positioning phase.

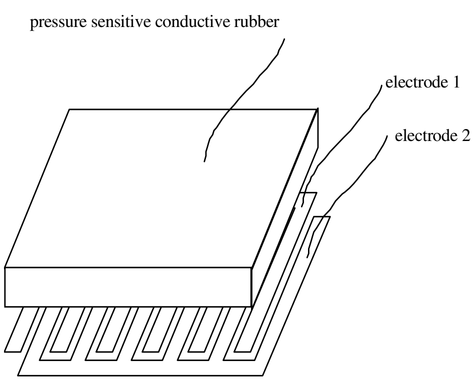

Fig. 2. Construction of grasping force sensor

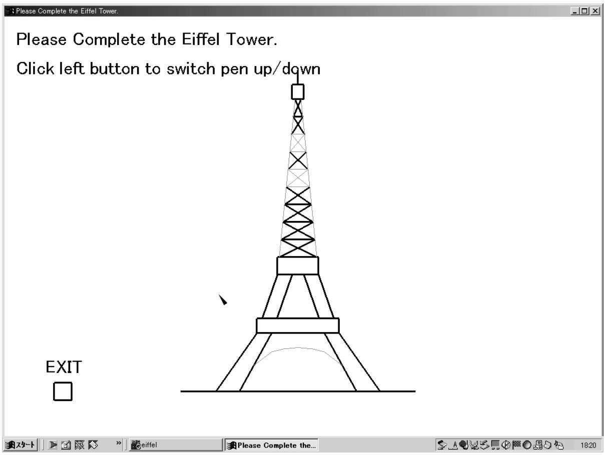

Fig. 3. The picture used in the experiment (The light gray lines are to be traced and drawn)

2.2 Experimental Tasks and Data Collection

The experimental task was to complete an illustration of Eiffel tower by adding some lines to a displayed picture shown in Fig. 3. There were both precise periods (pen-down to draw a line with an arrow-shaped cursor) and rough periods (pen-up to move the pen position with a plus-shaped cursor).

The subjects' operations were recorded every time a mouse movement event and/or a mouse button event were detected. Each record consisted of mouse position, mouse motion, cursor position, status of the left button, status of the phase detector, status of the cursor (arrow or plus), status of the drawn picture, and operation view.

2.3 Results

Fig. 4 and 5 show the trajectory of the cursor in one task and the corresponding grasping force, respectively. As shown in Fig. 5, grasping force changed significantly in a drawing task, and it looks like that there were two distinguishable periods with higher grasping force and lower grasping force, presumably corresponding to precise periods and rough periods, respectively.

The grasping force was varied between these precise and rough periods. In particular, the grasping force increased near the end of drawing each line. Especially, this point was conspicuous to the subjects who grasp the mouse loosely in rough periods. This suggests that the grasping force increases before the cursor reaches the goal or end point. By observing Fig.5 closer, we found another tendency that the grasping force increased near the end of a line-drawing. The grasping force increased before the cursor reaches the goal or end point. In order to examine this, we compared the average grasping force while drawing a line to the grasping force a half second before clicking mouse button to terminate the line-drawing. As shown by open

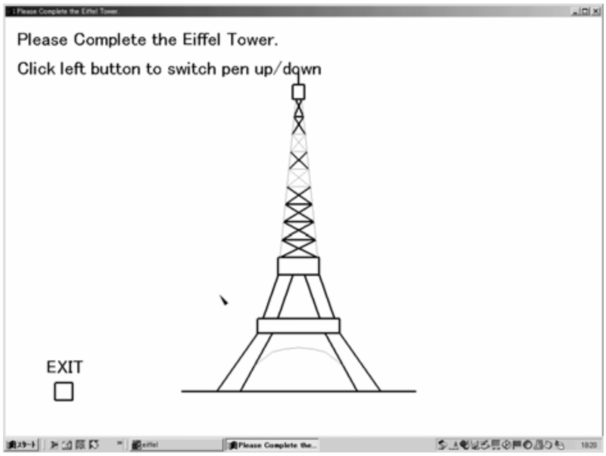

Fig. 4. Cursor trajectory in a drawing task

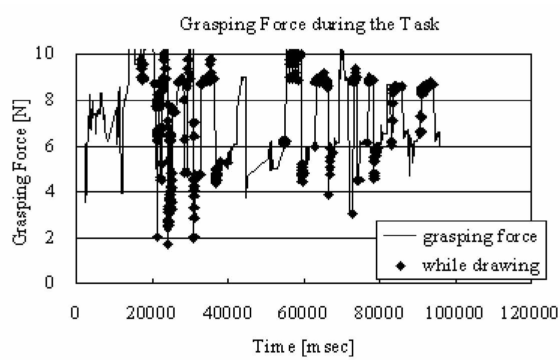

Fig. 5. Grasping force in a drawing task

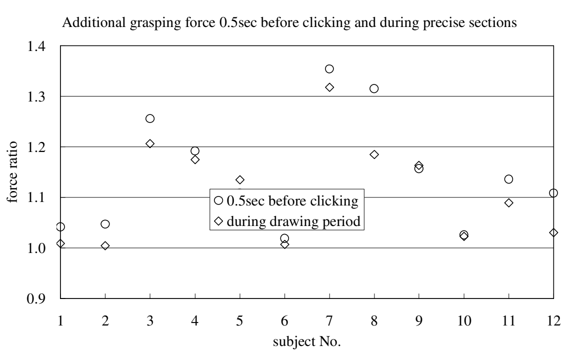

Fig. 6. The result of the experiment

diamonds in Fig. 6, the average grasping force in drawing periods, i.e., precise periods, was 111% of that in moving periods, i.e., rough periods. Just before clicking shown as open circles in Fig. 6, the average grasping force increased remarkably to an average of 114% of that in rough periods. This feature was observed in all of the subjects, without any exception. The average grasping force in drawing periods (= precise periods) is 103% of that in moving periods (= rough periods). Just before clicking, the average grasping force increases remarkably to an average of 114% of that in rough periods.

3 An Experiment to Validate GIIC

To validate GIIC, a set of experiments was conducted. There were 8 pointing tasks on a computer screen in a set, some of them were without GIIC, and others were with GIIC. With GIIC, the cursor speed decreased half when the mouse was grasped stronger than pre-defined threshold. The targets were displayed on the computer screen. The size of each target is randomly produced, ranging from four to 40 pixels. The positions of the targets are also randomized. The subjects are instructed to click all of the targets as quickly as possible. Each pointing operation was started from the starting square at the left, low part of the screen,

Fig. 7 shows the result. With GIIC, operation times *T*s (indicated with open squares in Fig. 7) were located under the regression line of the "non GIIC" group (indicated with filled diamonds in Fig. 7). This difference indicates the effect of GIIC. The amount of improvement is represented as the decrease in the index *b* in Fitts' law: it was 0.20081 for the without-GIIC condition and 0.10861 for the with-GIIC condition.

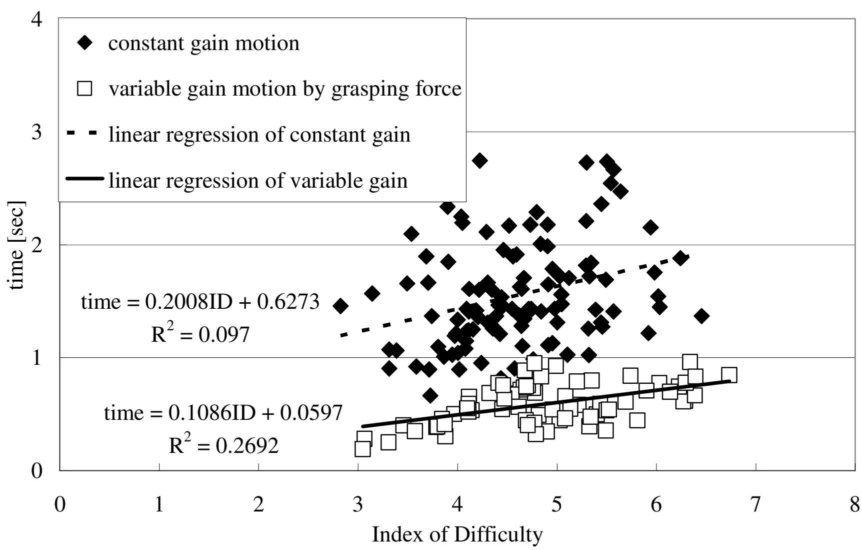

Fig. 7. An effect of GIIC

4 Discussion

The grasping force of the mouse is confirmed to be increased in precise periods, especially just before clicking.

As an example of GIIC, a new computer mouse with a real-time adaptive Mickey ratio adjuster is to be proposed as a typical remote pointing device. The grasping force of the mouse is confirmed to be increased in precise periods, especially just before clicking. The effect of real-time adaptive gain adjustment was also confirmed.

To apply the proposed concept to pointing tasks on the computer screen by mice, it is suggested that real-time gain (Mickey ratio) adjustment would be effective. Remote pointing tasks are separated into approaching and positioning phases. The use of real-time adaptive gain adjustment has advantages that make pointing tasks much easier than conventional pointing devices with a fixed gain. This is because, although there are two factors that decide the easiness of a remote pointing task, the distance D to the target and the size S of the target, they are not simultaneously effective. The distance D to the target is the major parameter in the approaching phase and the target size S is the major parameter in the positioning phase.

Because the purpose of real-time adaptive gain adjustment is to increase the easiness of pointing tasks, it must be added without any new gears or complexity.

With general pointing tasks, these two phases could not be known before the task is finished. Because the boundary between two phases exists only in the operator's mental or psychological processes, it is also difficult to detect.

GIIC has the potential of providing a natural usability with remote pointing devices by installing a real-time adaptive gain adjustment for grasped operation terminals. Grasping information has the potential to increase the usability of remote pointing devices.

Adapting the proposed concept, grasping information can be an indicator of the operator's intent. They include operators' "silent messages" for machines.

GIIC regards grasping-and-moving as a fundamental hand operation necessary for performing tasks using modern man-machine interfaces, and behavioral measures associated with grasping, such as force, posture, etc., should have much potential in developing task-adaptive and operator-adaptive interfaces because it is known that how people grasp devices is dependent on the purpose of these tasks. GIIC provides machines with a communication channel to understand operators' intents more through the grasping information.

References

1. Mehrabian, A.: Silent Messages. Wardworth, Belmont, CA (1971)
2. Sato, S., Kitajima, M., Fukui, Y.: A New Mouse with Cursor Speed Control by Grasping Force. Proc. HCI2001, New Orleans, Poster Sessions, pp. 291–292 (2001)
3. Sato, S., Kitajima, M., Fukui, Y.: A Mouse with Realtime Adaptive Mickey Ratio Adjustment by Grasping Force. Proc. UIST2002, Paris, pp. 53–54 (2002)

4. Sato, S., Kitajima, M., Fukui, Y., Proposal, A.: A Proposal of Grasping Information Interface for Remote Pointing Task. Proc. IEEE ISATP2003, Besançon, pp. 175–180 (2003)
5. Sato, S., Kitajima, M., Fukui, Y.: A Concept of Grasping Information Interface for Remote Pointing Task. Proc. IEEE ICRA2004, New Orleans, LA (2004)
6. Napier, J.R.: The prehensile movement of the human hand. Journal of Bone. and Joint Surgery 38-B, 903–912 (1956)
7. Fitts, P.M.: The Information capacity of the human motor system in controlling the amplitude of movement. Journal of Experimental Psychology 47, 381–391 (1954)
8. Fitts, P.M., Peterson, J.R.: Information capacity of discrete motor responses. Journal of Experimental Psychology 67, 103–112 (1964)