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Performance analysis of Teleoperation systems with different Haptic and Video time-delay

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Abstract: Teleoperation is the extension of a person's sensing and manipulation capability to a remote location. When teleoperation is performed over a great distance, a time delay is incurred in the transmission of information from one side to another. So far, many researchers try to reduce the effect of time-delay in several ways. [1-3] Our novel concept is to find out a relationship between performance of system and a matrix of two independent delay with the system has two modalities(channels) which are video and haptic. Especially, we expected to be able to bear witness in the case has same two channels' time-delay. There is no other previous work in general (only specific tele-surgery task [4]), till now. We proposed and achieved experiments to evaluate the performance with 10 subjects. Finally, result was different from we expected. When two channels' delays are same, the performance was poorer. Haptic-delay had made the system unstable. Accordingly, we need to complement this effect in future work.

Keywords: Haptic, Teleoperation, Time-delay, Video.

1. INTRODUCTION

Haptic technology refers to technology that interfaces to the user via the sense of touch by applying forces, vibrations, and/or motions to the user. This mechanical stimulation may be used to assist in the creation of virtual objects (objects existing only in a computer simulation), for control of such virtual objects, and to enhance the remote control of machines and devices (teleoperators). This emerging technology promises to have wide-reaching applications as it already has in some fields. For example, haptic technology has made it possible to investigate in detail how the human sense of touch works by allowing the creation of carefully controlled haptic virtual objects. These objects are used to systematically probe human haptic capabilities, which would otherwise be difficult to achieve. These new research tools contribute to our understanding of how touch and its underlying brain functions work. The word ***haptic***, from the Greek ἁπτικός (*haptikos*), means pertaining to the sense of touch and comes from the Greek verb ἅπτεσθαι *haptesthai* meaning to "contact" or "touch".

Nowadays, there are many fields we can apply this technology. For example, to explore remote places, to inspect nuclear pile, to remove bombs and so on replace human works. Especially, 'Tele-surgery', 'Micro/nano robot', 'Entertainment (Video game)', and 'Molecular docking'. [7]

For example, some simple haptic devices are common in the form of game controllers, in particular of joysticks and steering wheels. At first, such features and/or devices used to be optional components (like the Nintendo 64 controller's *Rumble Pak*). Now many of the newer generation console controllers and some joysticks feature built in devices (such as Sony's DualShock technology). An example of this feature is the simulated automobile steering wheels that are programmed to provide a "feel" of the road. As the user makes a turn or accelerates, the steering wheel responds by resisting turns or slipping out of control. Another good example of this is Guitar Hero's guitar controller. The Wii wireless remote uses a simple "bump" for feedback (e.g. moving over an onscreen button). Another concept of force feedback was that of the ability to change the temperature of the controlling device. This would prove especially efficient for prolonged usage of the device.

In 2007, Novint released the Falcon, the first consumer 3D touch device with high resolution three-dimensional force feedback, allowing the haptic simulation of objects, textures, recoil, momentum, physical presence of objects in games, and much more. This device is set to revolutionize the way gamers interact with their games by providing not only the aforementioned haptics feedback, but also by allowing for three degrees of freedom in terms of movement, done through the utilization of x, y and z axes.

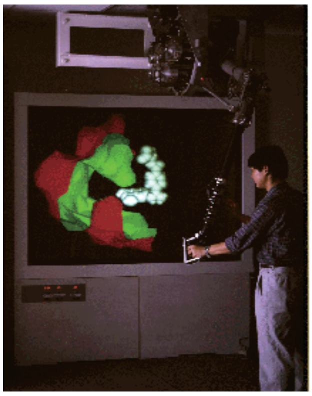

Fig.1 Molecular modeling : That system also had the first interactive 3-D hidden line elimination.

Teleoperation is integrated technology with mechanics, electronics, control, and so on. To realize the

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tele-presence, still many researches are active.

As we mentioned above, teleoperation have challenging issue, time-delay. So researchers around the world already had studied to solve this issue. Passivity and Scattering matrix were used. The definition of Passivity is "*Energy supplied BY the network can never exceed the energy which has been fed TO it*". This is principle of conservation of energy. PO is passivity observer, PC is Passivity Controller.[3,8]

Our approach differs comparing other researches. It could not to remove the effect of result of delay, to avoid the original effect.

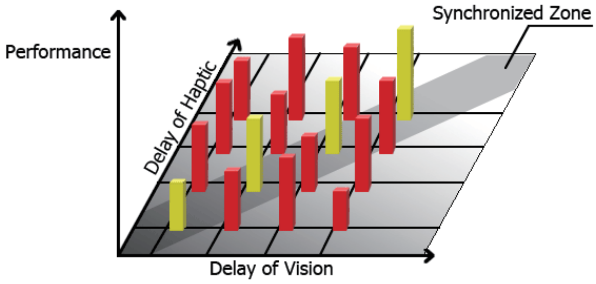

Fig.2 A surface with haptic and video time-delay

Usually, teleoperation system configured with 2 channels. Visual information and force feedback information apply to improve human ability to control remote place. On the tele-operation system has each two channels which have two independent time-delay, we have assumption like as below.

Time-delay is inescapable problem of the system. In case of two time-delay coincided, it assumed the system improve the performance.

So, if we can fix the amount of each delay-haptic and video, depend to two variances (fig.2), there'll be some relationship to its performance.

2. EXPERIMENT

2.1 Experiment configuration

As we mentioned above, we configure the system has two channels. And define different conditions..

The experiment combined as Fig.3 was improved. Subject use haptic device as a master. Subject can feel and touch an object on the virtual space. Subject move the cursor and finish the task allowed. There are two channels We experiment with 10 subjects. Each subject did experiment 50 times.

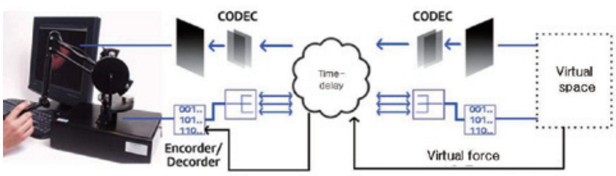

Fig.3 The experimental setting

Experiment task was simple. User just draws a circle. (fig.4, using haptic device PHANToM) The 'exploring time' and 'error sum' were measured.

$$\sum error = \sum_{t=0}^{f} \left|(R - r)\right| \qquad (1)$$

So, we got the average data. User can feel virtual circular wall. If there is haptic information, subject can draw circle easily. The force was generated proportion to distance across the circle.

$$\vec{F}_x = -k \cdot (R - |\vec{r}|) \cdot \frac{\vec{x}}{|\vec{r}|}$$
$$\vec{F}_y = -k \cdot (R - |\vec{r}|) \cdot \frac{\vec{y}}{|\vec{r}|} \qquad (2)$$

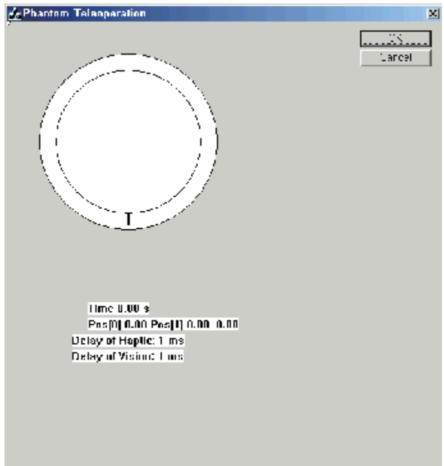

Fig.4 Drawing circle task program

2.2 Result

We have five experimental situations as Table.1. We can get two kinds of graph-Time Completion and Sum of average error. At first case, haptic information probe human ability to complete the task.

Table 1 list of experiments.

	Haptic delay	Video delay
1	No haptic delay	Varying 0-400ms
2	Varying 0-400ms	No Video delay
3	Varying 0-400ms	Varying 0-400ms
4	Fix 100ms	Varying 0-400ms
5	Varying 0-400ms	Fix to 100ms

In case 1(fig.5), there was little change. The performance was proportion to a magnitude of feedback force. K means strength of feedback force during test. K=0.1 give force back to user smaller than k=0 condition. Subject draw circle, and then completion time checked.

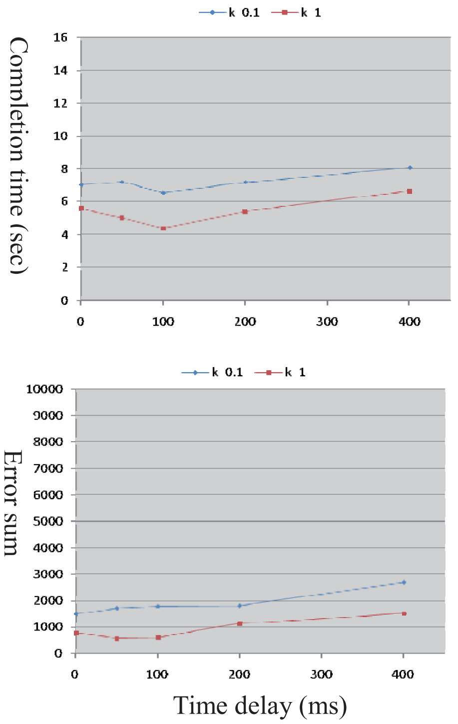

Fig.5 Upper graph shows average data of completion time of task of Case 1. Below one is representing error sum.

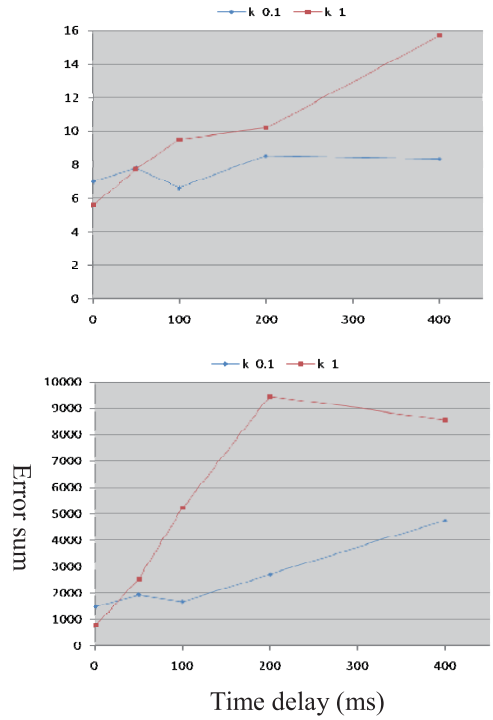

Fig.7 Upper graph shows average data of completion time of task of Case 3. Below one is representing error sum.

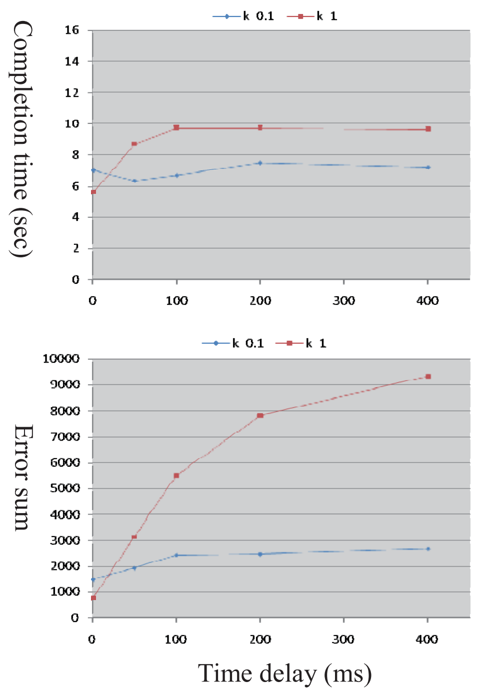

Fig.6 Upper graph shows average data of completion time of task of Case 2. Below one is representing error sum.

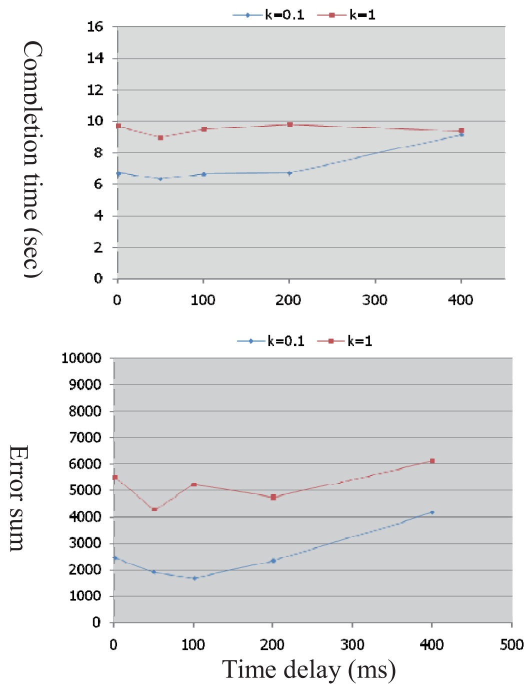

Fig. 8 Upper graph shows average data of completion time of task of Case 4. Below one is representing error sum

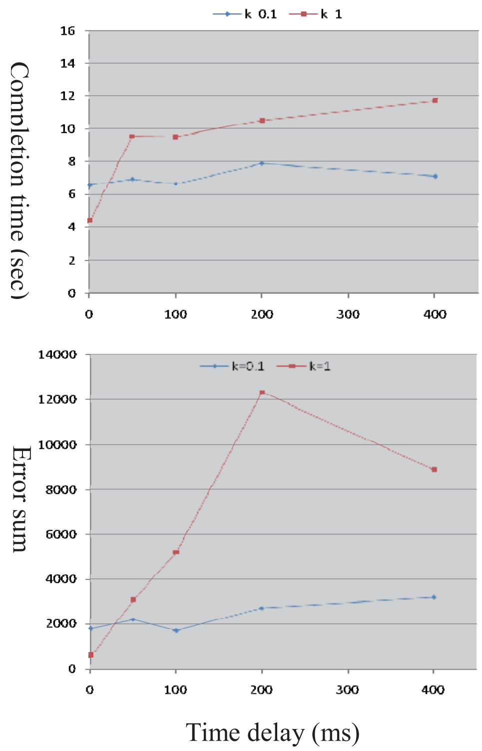

Fig.9 Upper graph shows average data of completion time of task of Case 5. Below one is representing error sum

In common, upper graphs' first figure's Y axis means the time(s) to complete task. And second one is average of error during task.

We know the exact circle diameter and we can record the user's track. Difference of information is the error sum. It represents the performance of system. Small number means poor to maneuver it.

Our interested graph is Fig.7. This graph explain performance of tele-operation system has same time-delay of two channels is poorest. And we could not find a strong point.

The whole data gather at one 3D space showed as Fig.10-13. When K is over 1(same as haptic information fully given), performance changing suddenly.

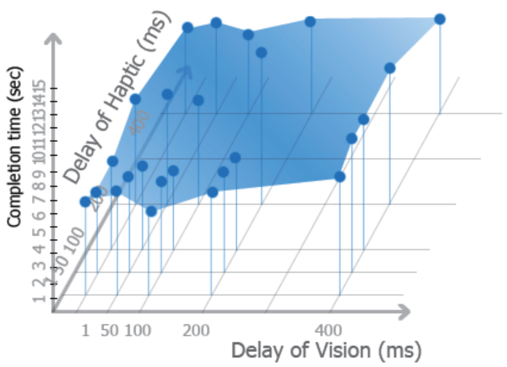

Fig.10 Completion time graph of all conditions (k=0.1)

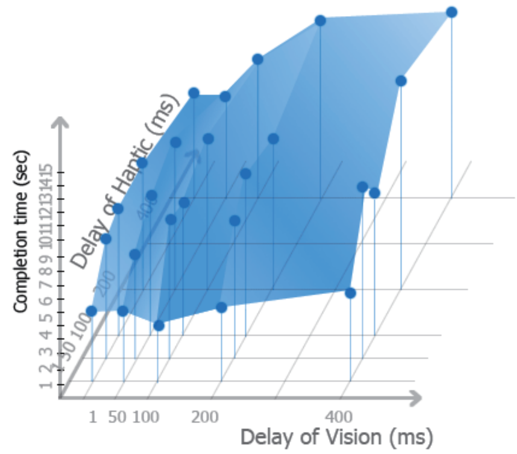

Fig.11 Completion time graph of all conditions (k=1)

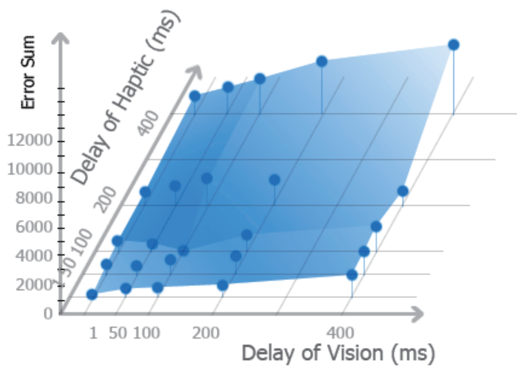

Fig.12 Error sum graph of all conditions (k=0.1)

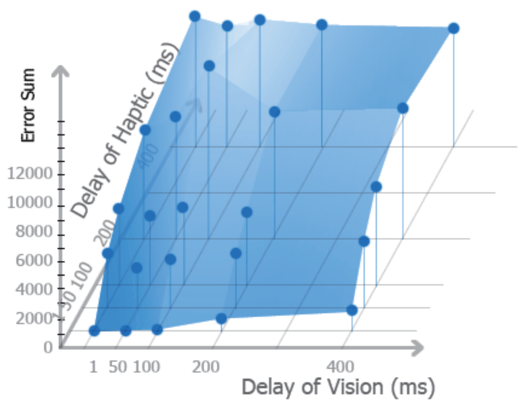

Fig.13 Error sum graph of all conditions (k=1)

3. CONCLUSIONS

We could conclude as follow,

(1) haptic information is critical to the performance and sensitive. Depends on the magnitude of force feedback, there is difference change range.

(2) It was proved synchronous force feedback let performance of system reduce. It has better performance

when we adjust the haptic time delay to minimum value than synchronize two time delay.

(3) under 200 ms, there is no effect of video delay to the performance of system within average of errors and completion time criterion.

For future work, we need to reorient to human factor our topic. Similar experiment did in medical field.[4] They did tele-surgery task with two signals-video and force feedback. They had got similar answer, synchrony time-delay condition couldn't help surgeon to do operation. Instead, asynchrony condition had a better performance. This is very inspiring to study more about this topic. But, we cannot make a decision yet. We will design another detail task to prove this assumption. Since, tasks had weak criteria and plan, and lack of subject data. This topic is still too general and ideal. However, what if this assumption give a way to solve problem of time-delay on tele-operation, it will be most efficient method.

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