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Reaction time and EMG measurement applied to human control modeling

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ABSTRACT

The final goal of this research is to analyze the human visual and force sensory feedback integration related to a manipulation task and build a control model of a human operator. In this primary work the reaction time and the EMG was measured to determine the time lag constant of each subject. The onset time, EMG-RT and the EMD delay was measured and compared to the time lag estimated from step response identification. Although a small discrepancy was found between the directly measured time lag and the estimated one, the system identification method showed a prominent and methodological approach to model the human control system.

1. Introduction

The human operator has the capability to learn, adapt and control various types of machines. It is of a great interest to understand how the human operator analyzes and processes different modalities of sensory feedback information in order to design directly or remotely operated machines. The aim of this research is to analyze the human control characteristics in respect to the visual, force and audio feedback information and build a human control model that can also represent a control strategy based on multi-sensory feedback (Fig. 1). In this primary work the time lag related to the human control model was measured using cognitive psychological experiments as single reaction time and choice reaction time. This control model would be useful to assist the design, simulation and evaluation of human–machine systems like telerobots [1] and also computer assisted systems as power-assist and drive-by-wire vehicles.

2. Human control model

Early researches have already shown that it is important to consider the human dynamic characteristics when designing and evaluating man-machines systems. The major part of the analytical theory on manual control of vehicles was developed in the sixties. One of the important results was the Crossover Model proposed by McRuer et al. [2], which showed that the human–machine dynamic characteristics presented a first order lag near the crossover frequency. Another empirical result of McRuer [3] works showed that the human operator can change his dynamic characteristics according to the operated machine. A general model of the human control can be represented as Eq. (1) (see Fig. 2).

$$H(s)G(s) \approx \frac{\omega_c e^{-\tau s}}{s} \quad (\text{where, } \omega \approx \omega_c) \tag{1}$$

Here, τ (0.1–0.4s) is the time lag due to human responses and ω_c (0.5–0.8 Hz) is the crossover frequency.

In this primary work the time lag due to human responses was measured using the single reaction time (SRT) and the choice reaction time (CRT).

3. Reaction time experiment

In order to identify the time lag due to human responses the single reaction time (SRT) and the choice reaction time (CRT) was measured with three subjects. The experiments were conducted using a master–slave type seesaw experimental device that was developed in order to analyze the human sensory feedback properties separately.

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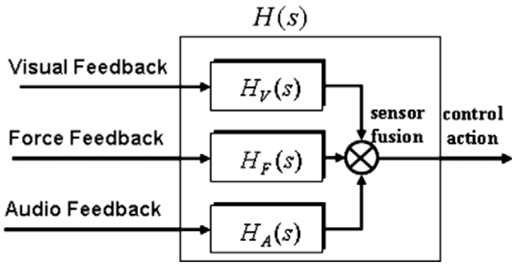

Fig. 1. Multimodal sensory feedback scheme.

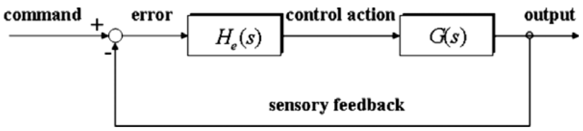

Fig. 2. Generic human–machine system.

It consists of a 1 DOF master haptic device with a force sensor that can be manipulated by rotating a dial or by gripping a joystick. The slave is an actuated linear guide that works as a seesaw with a sliding object over it. In the reaction time experiment 2 LEDs were used as visual cues, positioned at the left and right field of view of the subject (Fig. 3). In most cases the reaction time is defined as the time necessary to the subject to turn the dial more than a pre-defined angle after the visual cue is presented. Since the final goal of the proposed human control model is to obtain an operator model of a continuous manipulation task, the reaction time was defined as the movement onset time. In this case, the movement onset corresponds to the time necessary to the dial's angular velocity reach 20°/s after the visual cue is presented. This velocity corresponds to about 1% of the maximum rotation velocity achieved by the subjects. During this experiment the gaze movement, pupil diameter and the pronator/supinator muscles EMG was also measured. The proposal for this study was reviewed by the Institutional Committee for Ergonomic Experiments and approved by the Director of Safety and Environmental Protection Department.

Fig. 3. Experimental device and reaction time experiment overview.

3.1. Single reaction time experiment (SRT)

This experiment consists of moving the dial as fast as possible after the visual cue is shown to the subject. In SRT experiment the subject does not need to decide which direction to move, it is a reflexive visuomotor action. After the subject became familiar with the experiment device 10 trials were made by each subject. The visual cue was presented randomly.

3.2. Choice reaction time experiment (CRT)

In this experiment the subject has to decide in which direction to move according to the visual cue. If the right LED turns on the subject has to turn the dial in the clockwise direction. If the left LED turns on the subject has to rotate the dial in the counter clockwise direction. In this CRT experiment a computational load is added to the subject due to the decision making about which direction to move. The visual cue was shown randomly in time and direction. Here the reaction time was also defined as the movement onset time. After some training each subject performed 20 trials.

4. SRT and CRT movement onset time results

The movement onset time results of SRT and CRT experiments are shown in Tables 1 and 2. The difference between the fastest subject C (0.20 s) and slowest subject B (0.26 s) subject was about 30% in SRT and more than 33% in CRT experiments. It is interesting to notice that even though the SRT onset time of subjects A and C are very close, the CRT onset time varied considerable. Further considerations will be discussed at session Section 4.1. Figs. 4 and 5 showed typical angle and velocity profiles respectively. In both profiles a similarity can be noticed between the subjects A and C. All the subjects showed a pre-programmed target angle which is reached about 0.6–0.8 s after the movement onset (Fig. 4).

4.1. SRT and CRT EMG measurement results

From Figs. 6–9 it can be noticed that the activation of pronator and supinator muscles occurred before the actual movement started. The time necessary to send the motor command after the visual information was acquired varied from 0.15 s to 0.19 s in SRT experiments and 0.19 s to 0.28s in CRT experiments. This time includes the decision making time and motor command activation which are difficult

Table 1
SRT experiment – EMG activation and onset time.

Experiment	Subject A	Subject B	Subject C
Onset [s]	0.21 ± 0.03	0.26 ± 0.04	0.20 ± 0.03
EMG-RT [s]	0.19 ± 0.04	0.21 ± 0.04	0.15 ± 0.03
EMD [s]	0.03 ± 0.02	0.05 ± 0.01	0.05 ± 0.01