On the Characteristics of the Human Operator in Simple Manual Control System

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Manual control system are important class of control systems. On the manual control system, boundary region between human and machine system consists of displays to receptors and controls to effectors. Human performance in the manual tracking system which is governed by machine dynamics become one of the most difficult problems in the boundary region.

In 1947, *A*. Tustin suggested that the human operator considers the differential, proportional and integral term of the presented time dependent data yielding a transfer function of the form

$$H(S)=\{AS+B+C/S\}e^{-\tau s},$$

where the constants A, B and C indicate separate gains on each term, and τ indicates the time lag between the display of the signal and the initial response.

Mathematical representation of the human transfer characteristics proceeded under the assumption that the operator's behavior was time-invariant and linear with respect to single input-signal stimulus. Under such rather sever constraint, there was a hope of finding some expressions which might prove to be useful in the design of control systems.

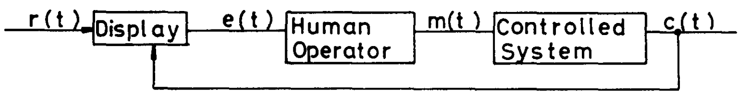

Fig. 1 A simple control system

Fig. 1 establishes the notation which will be used in describing simple control system. $r(t)$ is the reference signal provided to the system, $c(t)$ is the controlled variable which describes the actual performance of the system, $e(t)$ is the error signal computed and presented by the display, and $m(t)$ is the manipulated variable which describes the operator's time response. Human transfer function is given by

$$H(S)=\frac{M(S)}{E(S)} \quad .$$

where $M(S)$ and $E(S)$ are laplace transform of the manipulated variable and the error variable $e(t)=r(t)-c)t)$. Using the human transfer function, the relation of different perceptual display method, i.e., pursuit display and compensatory display, and characteristics of the human operator was made clear by the analog simulator.

Human operator behaves differently in different control situation (a control situation is a particular combination of input signal, system dynamics and performance criteria.) The results obtained were as follows,

1. In the complex controlled system (system dymamic), human transfer function consists of first order differential, proportional and first order integral action and time lag between the display of the signal and the initial response.

2. Human operator's differential action becomes the physical, physiological and psychlogical load on the human operator, so it is of care for the design of control system such that are not appearance of differential action in human behavier.

3. The stronger, the second order integral characteristics of controlled system, the larger the differential action of human gets.

4. And human operator behavior follows such that a loop transfer function is formed of first order integral or proportional transfer function.

Human operator's behavior of the pursuit tracking was analyzed by two input (reference input and error input) and one output, (opepator's manipulated output) as model in Figure 2.

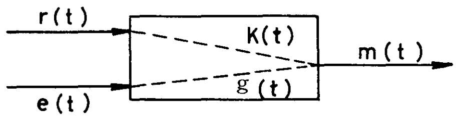

Fig. 2. Two input and one output model of human operator's dynamics

The results that if controlled system in figure 1 is proportional, input signal is a gaussian stochastic process, and tragectory of input signal is not smooth, main control action of learned human operator is open loop action, i.e., gain of $K(S)$ is the larger than the gain of $G(S)$, where $K(S)$ and $G(S)$ are laplace transform of $k(t)$ and $g(t)$, and closed loop action is manipulating action of system were obtained so far (see, Table 1).

Table 1. Transfer function of $K(S)$ and $G(S)$

input rad/sec	transfer function	total correlation coefficient
$W=1$ (cutoff freq.)	$K(S)=-0.030/S-0.515+0.191\,S$	0.765
	$G(S)=\ 0.062/S+0.519-0.568\,S$	0.965
$W=4$ (cutoff freq.)	$K(S)=\ 0.253/S+2.272-0.242\,S$	0.987
	$G(S)=-0.253/S-0.316+0.539\,S$	0.558