N73-10169

Preceding page blank

5. A Hybrid Computer Program for the Visual Display of Compensatory System Model Parameters*

GLENN A. JACKSON AND GERALD BRABANT

Oakland **University**

A hybrid computer identification program has been developed which determines and displays those parameter values of a model of the compensatory control system that existed over the last fifteen seconds of operation. These values are up-dated every **0.05** sec so that a visual display of the parameters appears to be continuous. Presently, a closed loop crossover model is being used as the compensatory system model with the parameters K and τ displayed, however, any suitable model could be used in its place.

INTRODUCTION

The hydrid computer program discussed in this paper is the outgrowth of research that is dedicated to the development of a system that will meet two main specifications:

(1) Develop a parameter identification method that will quickly and accurately identify the parameters of a compensatory control system model using only short lengths of input-output data from the compensatory system under test.

(2) Convert this method into an on-line system that will continuously display to the operator the average values of his associated compensatory system model. These average values should again be calculated over as short a time span as possible so that the display will indicate to the operator essentially his present parameter state. The hybrid computer method developed, referred to as "hybrid parameter tracking" (ref. 1), satisfies both of these specifications.

Parameter identification via hybrid parameter tracking is accomplished by using short lengths of sampled input-output data from the compensatory system. These data, ≤ 15 sec in length, are used repetetively as the driving signals for a fast-time analog continuous parameter tracking system utilizing the crossover model (refs. 1 and 2). Since only 5 to 10 iterations of these data are required for parameter convergence, and since each iteration requires only 0.05 sec, parameter identification is achieved less than half a second after the data are taken. In addition, once started, the program continues sampling the compensatory system input-output signals, while simultaneously iterating these data through the continuous parameter tracking system.

The final result is that every **0.05** sec new values of the crossover model parameters, K and τ, are calculated and displayed with each calculation using only the last 15 sec of compensatory system data. The visual display is thus a running record of the K and τ values that existed over the last 15 sec of operation.

A BRIEF DESCRIPTION OF THE PROGRAM

A simplified block diagram of the overall hybrid system is given in figure 1. In this figure only main signal lines are shown. **All** sense lines and control lines have been omitted for simplicity of presentation.

The basic operation of the system is as follows:

(1) The compensatory system input and output signals, $r(t)$ and $c(t)$, are sampled via *ADC*'s

---

* This research was supported by **NASA** contract NGR **23-054-003**.

PRECEDING PAGE BLANK NOT FILMED

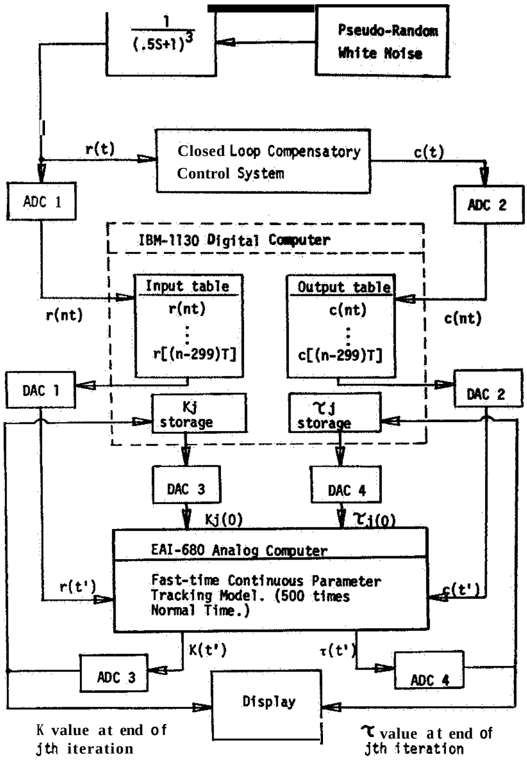

FIGURE 1.—Simplified block diagram of the identification system.

1 and 2 at a rate of 20 samples/sec with the samples stored alternately in a 600 word table in digital core.

(2) After 600 samples have been taken (300 samples of both $r(t)$ and $c(t)$), and before the 301st samples of $r(t)$ and $c(t)$ arrive, the sampled input and output values are fed via DAC's 1 and 2 into a fast-time analog continuous parameter tracking identification system. The analog time scale is 500 times normal time. At the end of this fast-time run three things occur:

(a) The parameter values present at the end of the run are recorded using ADC's 3 and 4. These values are stored so they can be analyzed later; sent to the visual display; and also used as initial conditions for the next fast-time analog iteration.

(b) The 600 values in the input-output table are moved down two words in core. This eliminates the first samples of $r(t)$ and $c(t)$ that were taken, and provides room for the next samples to be taken. In addition, the gradient gains on the K and τ integrators of the continuous parameter tracking system are adjusted. These gains are reduced systematically for five iterations and then recycled back to their initial values. This is done to ensure that a short length of high remnant data will not cause the continuous parameter tracking system to go unstable.

(c) The system waits for the next samples of $r(t)$ and $c(t)$ to arrive.

(3) At $t=15.05$ sec the 301st samples of $r(t)$ and $c(t)$ are taken and placed in the 600 word table. The program returns immediately to (2) above, and the next fast-time identification run begins.

The timing sequence used during a single period of operation is given in figure 2, with the timing intervals labeled to correspond to the word descriptions given above. In this figure it is assumed that the system has been in operation for at least 15 sec. Figure 3 presents the general functional level flow diagram of the system.

TESTS IDENTIFYING A KNOWN CROSSOVER MODEL WITH STEP CHANGES IN K AND τ

To check the accuracy and transient response of the identification method, three tests were run using a known model in place of the normal compensatory system. A crossover model with nominal values of $K_0=3.8$ and $\tau_0=0.235$ was used. The input signal $r(t)$ was pseudo random gaussian white noise passed through a third order low pass filter of the form $1/(\frac{1}{2}s+1)^3$. After the identification system was on-line, step changes

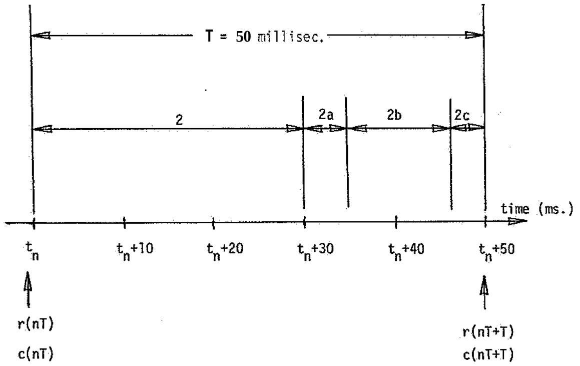

FIGURE 2.—Timing sequence for a single iteration.

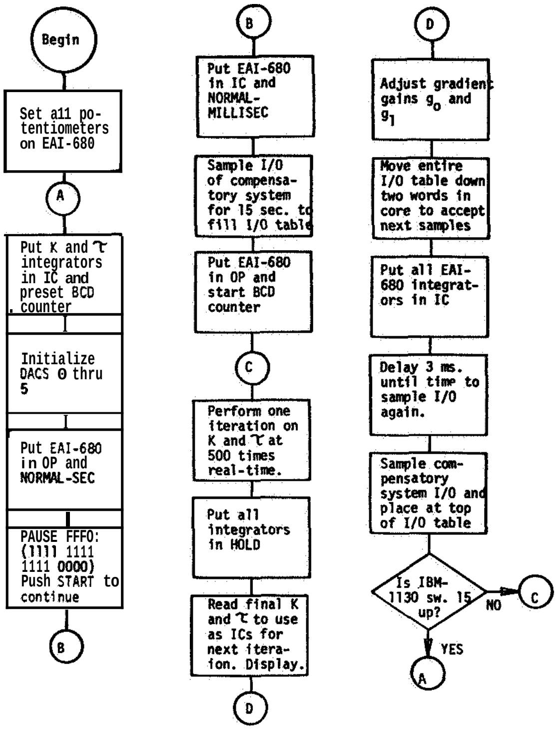

FIGURE 3.—Functional level flow chart for the hybrid parameter tracking program.

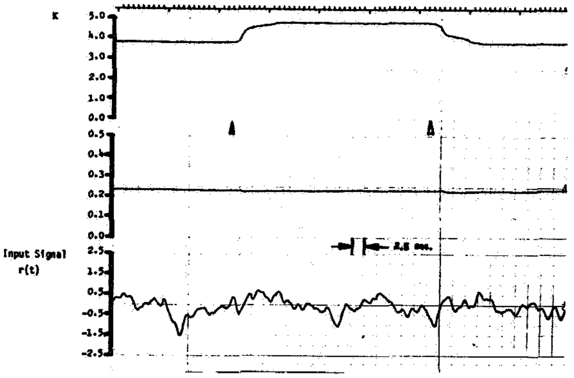

FIGURE 4.—τ_0 held at 0.235 while K_0 is step changed between 3.8 and 4.8.

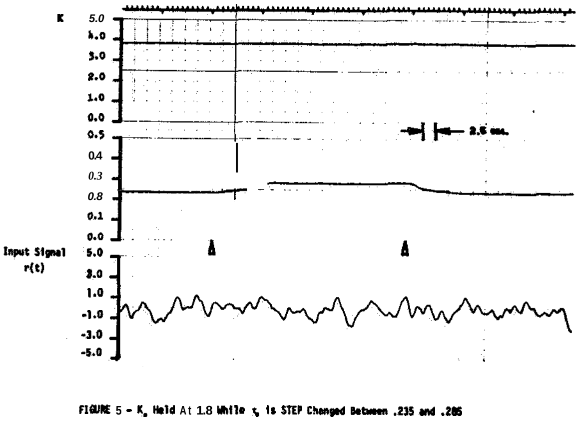

FIGURE 5.—K_0 held at 3.8 while τ_0 is step changed between 0.235 and 0.285.

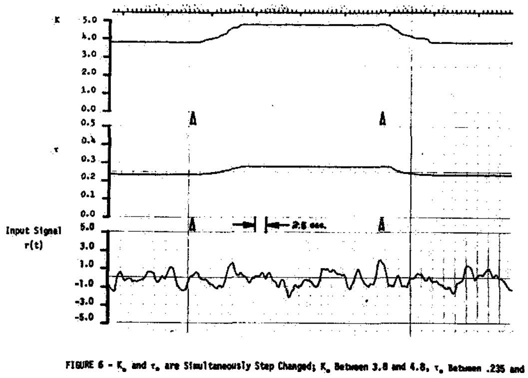

FIGURE 6.—K_0 and τ_0 are simultaneously step changed; K_0 between 3.8 and 4.8, τ_0 between 0.235 and 0.285.

in K_0 and τ_0 were made in the known model, and the resulting identified values were recorded.

Figure 4 shows the response to a step change in K_0 from 3.8 to 4.8 with τ_0 held fixed at 0.235. The total transient response time is seen to be 15 sec, which is the time it takes for the 600 word data table to be converted from "$K=3.8$ data" to "$K=4.8$ data." Figure 5 shows the response to a step change in τ_0 from 0.235 to 0.285 with K_0 held fixed at 3.8. Again, the response time is 15 sec, as expected. Figure 6 shows the system response to simultaneous step changes in both K_0 and τ_0. The responses are similar to those found following individual step changes in K_0 or τ_0. It can be seen that in these particular cases, the determination of one parameter was relatively independent of the other. This is undoubtedly not always the case.

TESTS ON HUMAN OPERATORS

Following the tests on a known model, the hybrid parameter tracker was evaluated on a standard compensatory control system. The compensatory system used an arm movement control stick, a k/s plant, and the same $1/(\frac{1}{2}s+1)^3$ filter that was used on the known model. The main point of concern prior to the running of these tests was the distinct possibility that remnant would cause high variability in the K and τ values being identified and displayed. Fortunately, these fears appear to have been unwarranbed, at least when data lengths of 15 sec are used.

Figure **7** is a typical section of data found while identifying an untrained subject. Figure 8, on the other hand, is a similar section of data obtained from a subject who had some previous tracking experience. In both cases the variability of K and τ was not large enough to degrade the visual display by any significant amount. As expected, parameter variability was greater in the untrained case (ref. **3**).

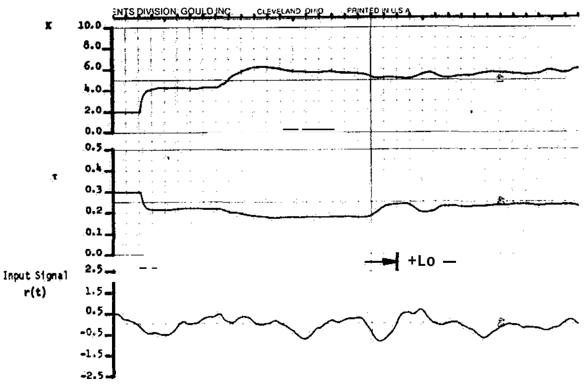

FIGURE 7.—Hybrid parameter identification of an untrained human operator.

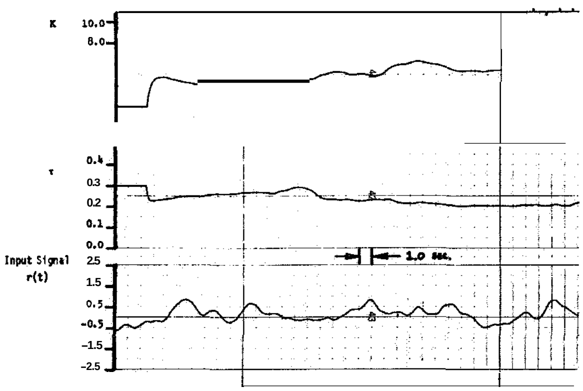

FIGURE 8.—Hybrid parameter identification of a trained human operator.

CONCLUSIONS

The hybrid parameter tracking identification method has been shown to accurately identify crossover model parameters using input-output data only 15 sec in length. Theoretical analysis indicates that with an input filter of the form $1/(\frac{1}{2}s+1)^3$ the method should be successful using data only **7** sec long (ref. **1**). This has not been tried to date. However, since the identification time, even in the present state, is relatively short when compared to the times required by other identification methods, several specific uses for the method are proposed.

(1) The method can be used as a test device to display to the human operator his present parameter state. In this manner several interesting experiments could be run: Can the operator alter his parameters on command? Can he learn his tracking task more quickly by monitoring his progress? Can he reduce parameter variability? Can he reduce remnant by reducing parameter variability? Can he adjust K and τ in some specified optimum sense?

(2) The method can be used as a data analysis device to determine the correlation between short-term parameter variability and other pertinent system variables: How does the variance of the short-term average parameter values change with practice? How does it vary between subjects? Is parameter variability a function of parameter magnitude? Is it directly related to remnant? Is it related to the plant being controlled? Some of these questions will be investigated during the coming year.

To date only a limited amount of human operator testing has been completed using the hybrid parameter tracking technique. Thus, no firm statements concerning its utility can be made at this time. However, it has the potential of becoming a valuable tool in the measurement of human performance.

NOTE ON COMPUTATION

The hybrid facility used in evaluating the hybrid parameter tracking method consists of an

IBM 1130 digital computer, an EAI **680** analog computer and an EAI **693** interface package. The digital program was written in Assembler language.

REFERENCES

1. JACKSON, G. A.: An Investigation of Two Hybrid Computer Identification Techniques for Use in Manual Control Research. Final Report on NASA/ERC contract No. NGR 23–054-003, vol. II, June 30, 1970.
2. JACKSON, G. A.: A Method for the Direct Measurement of Crossover Model Parameters. IEEE Transactions on Man-Machine Systems, vol. MMS–IO, no. 1, Mar. 1969, pp. 27–33.
3. BURGETT, A. L.: A Study of the Variability of Human Operator Performance Based on the Crossover Model. Fifth Annual Manual Control Conference, Mar. 27–29, 1969.