논 문
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Saccade 眼球運動系의 시뮬레이션

A New Approach for the Saccadic Eye Movement System Simulation

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Abstract

Various simulation techniques were developed in the modeling of biological system during the last decades. Mostly analog and hybrid simulation techniques have been used. The authors chose the Digital Analog Simulation (DAS) technique by using the MIMIC language to simulate the saccadic eye movement system performances on the digital computer. There have been various models presented by many investigators after Young & Stark's sampled-data model. The eye movement model chosen by the authors is Robinson's model III which shows the parallel information processing characteristics clearly to the double-step input stimuli.

In the process of simulation, the parameter and constants used were based on the neurophysiological data of the human and animals. The analog model blocks were converted to the corresponding MIMIC block diagrams and programmed into the MIMIC statements. The program was run on the CDC Cyber 72—14 computer.

The essential input stimulus was double-step of 5 and 10 degrees, and target durations chosen were 50, 100 and 150 msec. The results obtained by the DAS technique were in good agreement with analog simulation carried out by other investigators as well as with the experimental human saccadic eye movement responses to double-step target movements.

1. Introduction

There has been much interest in the last decades in modeling the eye movement control systems. Various models were developed after the sampled-data model of Young and Stark[10]. Robinson[7] revised the model of Young and Stark and proposed new models predicting the correct experimental responses when the target moved in a ramp, a step-ramp and in double-steps in rapid succession. This Robinson's models are also compatible with neurophysiology and the general characteristics of parallel processing of visual informations.

In model building, various simulation techniques were developed and mostly analog and hybrid techniques were used. In this paper, the authors chose the Digital Analog Simulation (DAS) technique by using the MIMIC language which was developed by Peterson and Sanson[6] to simulate the saccadic eye movement system performances on the digital computer. In order to obtain meaningful results, one must choose a model which accurately depicts the characteristics of the visual information processing and the dynamic shape of saccadic eye movement. The eye movement model chosen by the authors is Robinson's model III. The input stimuli were double-step and various target durations were chosen. Our research revealed the applicability of MIMIC language to the biological systems, especially for the simulation of central nervous systems. The results are discussed with experimental human saccadic eye movement responses.

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2. METHODS AND TECHNIQUES

Figure 1 shows the Robinson's model on the saccadic eye movement control system. In order to simulate the model, the analog model blocks were converted to the corresponding MIMIC block diagrams and programmed into the MIMIC statements.

2.1 Conversion Processes

(1) Dead Zone (DZ) block

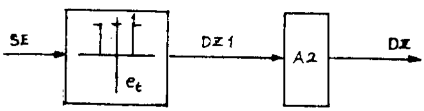
By definition DZ mean that

$|e| \geqq e_t$ DZ has 1

$|e| < e_t$ DZ has 0

and then,

MIMIC block:



where initial value of A2 is 1.0
initial value of THR1 is FALSE
initial value of THR2 is FALSE

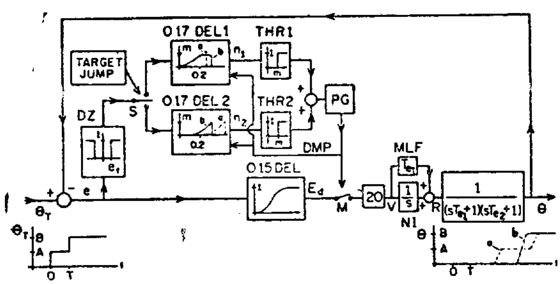


Fig. 1. Robinson's Model Ⅲ (1973)

MIMIC statement:

DZ1 FSW(ABS(SE)−ET,ϕ.,1.,1.)

DZ DZ1∗A2

(2) Delay Filters (DEL) block

The DEL element's transfer function is given as,

$$DEL(s)=\frac{1}{(1+0.6sT_d)\,(1+0.4sT_d+0.16(sT_d)^2)} \qquad (2.1)$$

where T_d value in 0.17DEL has 0.17, in 0.15 DEL has 0.15, and then MIMIC block:

$$\xrightarrow{y} \boxed{\frac{1}{1+sT_d+0.4s^2T_d^2+0.096s^3T_d^3}} \xrightarrow{x} \qquad (2.2)$$

$$x+T_d\dot{x}+0.4T_d^2\ddot{x}+0.096T_d^3\dddot{x}=y$$

$$\dddot{x}=(y-0.4T_d^2\ddot{x}-T_d\dot{x}-x)/0.096T_d^3$$

$$\ddot{x}=\int\dddot{x}dt$$

$$\dot{x}=\int\ddot{x}dt$$

$$x=\int\dot{x}dt$$

MIMIC statement:

X33 Y−0.4∗TD1∗TD1∗X2−TD1∗X1−X

X3 X33/(0.096∗TD1∗TD1∗TD1)

X2 INT(X3, ϕ.)

X1 INT(X2, ϕ.)

X INT(X1, ϕ.)

(3) Threshold (THR) blocks

MIMIC statement: THR1 FSW (N-M, FALSE, TRUE, TRUE)
THR2 FSW (P-M, FALSE, TRUE, TRUE)
THR IOR (THR1, THR2)

(4) Switch M

MIMIC statement: A1 MMV (THR, B)
M LSW(A1, 1.0, 0.0)

where A1 has THR initially, if THR has TRUE, and then A1 has TRUE, if THR set FALSE, and then A1 remains TRUE until B seconds,

A3 MMV (THR2, B)

when pulse is generated by THR 2, then THR1 prevents generation.

A3 A2 ϕ, ϕ (if A3 has TRUE, and then A2 has ϕ)

(5) Plant dynamics

MIMIC block:

$$R\cdot\frac{1}{Te_1Te_2s^2+(Te_1+Te_2)s+1}=\theta \qquad (2.3)$$

$$R=Te_1Te_2\ddot{\theta}+(Te_1+Te_2)\dot{\theta}+\theta$$

$$\ddot{\theta}=(R-Te_1+Te_2)\dot{\theta}-\theta)/Te_1Te_2$$

$$\dot{\theta}=\int\ddot{\theta}$$

$$\theta=\int\dot{\theta}$$

MIMIC statement:

2T R−THETA−(TS1+TS2)∗1T

2TT 2T/(TS1∗TS2)

1T INT(2TT,0.0)

THETA INT(1T, 0.0)

These MIMIC statements make up the computer program.

2.2 Model Implementation

The program was run on the CDC Cyber 72-14 computer. In the process of simulation, the parameter and constant used were based on the neurophysiological data of the human and animals chosen by Robinson[7]. The following are input data for each block.

(1) DZ: 0.24 degree

(2) DEL: the T_d value in the transfer function of DEL (s) in Equation (2.1) was 0.17 (at 0.17 DEL blocks) and 0.15 (at 0.15 DEL block)

(3) THR: m was chosen 0.54

(4) PG: M set 50 msec

(5) MLF: Te_1=150 msec

(6) Plant: Te_1 was chosen as 150 msec and Te_2 was 7 msec.

The input stimuli (angular displacements) were 5° (O-T) and 10°(after T). The stimulus durations T were chosen as 50, 100, 150 msec, and threshold values were varied from 0.32 to 0.76.

3. Results and iscussions

Figures 2 through 4 show the saccadic eye movement model behavior while varying the threshold values m from 0.32 to 0.76 and the stimulus duration was fixed to 50, 100 and 150 msec.

The results indicate that the model did not always respond to the initial displacement (O-T) of target, but some time responded only to the second displacement (after T).

The model responded to the double-step target displacements with either one (B-type) or two (A-type) saccades depending on the interval between the target steps T. The first result to be considered is the percentage of A-type responses. In case of Figure 2 (T=50 msec), all responses are B-type and reaction times were 180 msec (m=0.32), 190 msec (m=0.41) and 220−270 msec (m =others). When T is 100msec (Figure 3), A-type responses occur 40% of the time, B-type responses, 60% of the time (m=0.54, 0.65, 0.76).

In Figure 4, B-type response occurs only when m is 0.76 (i. e. 20% of the time) while 80% are of A-type.

It is observed that the percentage of occurrences in which model respond to the initial displacement increase as the stimulus duration increases from 50 to 150 msec. This result is similar to the Wheeless et al[3], Komoda et al[4] and Robinson[7], although the present results do not show the percentage of response reported at the stimulus duration of 50 msec.

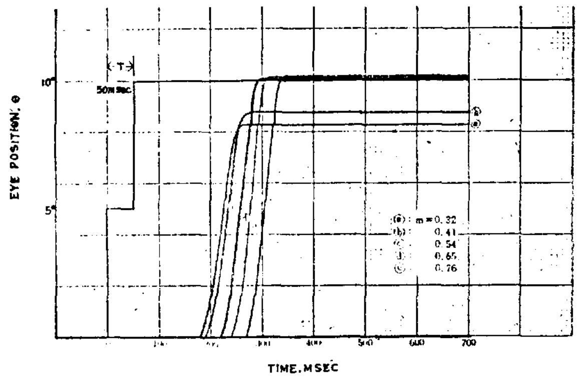


Fig. 2. Eye Movement Response at T=50msec

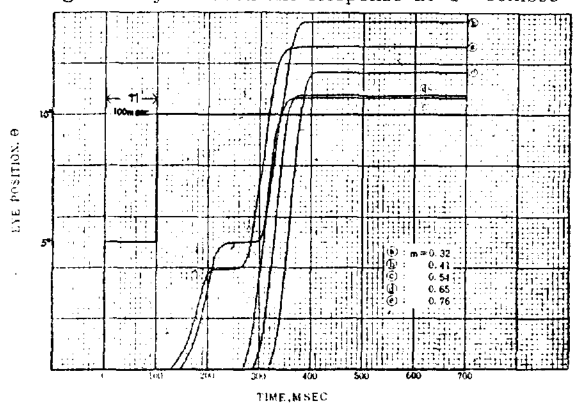


Fig. 3. Eye Movement Response at T=100msec

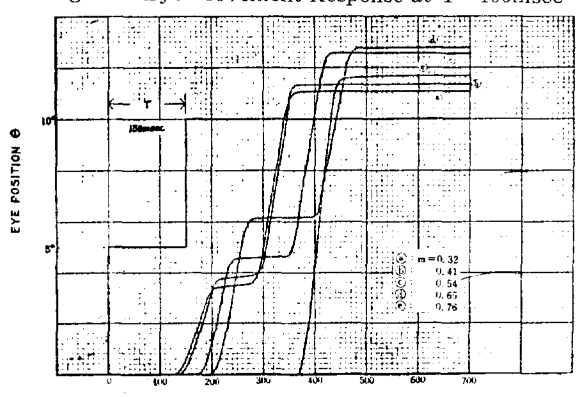


Fig. 4. Eye Movement Response at T=150msec

This difference in results may be due to the approximation to a 0.15 DEL filter. Of course this model is not to offer exact behavior of saccadic eye movement control system as suggested by Robinson, but to suggest that the inclusion of spatial processing is the appropriate way to develop neural models.

The results obtained by the DAS technique are in good agreement with analog simulation carried out by other investigators as well as with the human saccadic eye movement responses to double-step target displacements.

The use of the DAS technique using the MIMIC language is straight forward and more convenient than analog techniques. Our research revealed the applicability of MIMIC language to the biological system modelling, especially for the simulation of central nervous systems. This research will be extended to the advanced models of saccadic eye movement system which has spatio-temporal characteristics.

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