A GUIDANCE DEVICE FOR A BLIND ATHLETE*

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Abstract—The article describes an electronic device to aid the running of a blind athlete. A wire laid at the side of the track produces a magnetic field and it is by measurements on this field that the appropriate guidance signals are produced. The stability of such a system is investigated and the design of a suitable compensating network is obtained. An outline is given of the electronic circuits making up the complete system.

NOTATION

\(e\) = error \((x - y)\)
\(G(s)\) = operator loop transfer function
\(K\) = overall loop gain
\(s\) = the Laplace operator
\(T\) = phase advance time constant
\(T_L\) = phase lag time constant
\(V\) = runners velocity
\(x\) = required position of runner
\(y\) = actual position of runner
\(z\) = control signal
\(\theta\) = angle between runner's direction and his required direction
\(\tau\) = operator's time delay
\(\omega\) = angular frequency.

INTRODUCTION

This project was started in an attempt to help athletes at a school for the blind. At this school the boys were encouraged to take part in athletic events and it was hoped they could participate more fully if some form of guidance device was available. At that time the boys ran track events under the direction of a master standing at the end of the track relaying instructions to them via a loud hailer. The runner obtained his direction partly by 'homing onto the sound' and partly by following the guidance instructions given. This scheme suffered from the following disadvantages:

1. It required a member of staff to be present whenever the boys were running.
2. The boys took a long time to become accustomed to the system.
3. One could not successfully include corners in the system.

It was hoped that an electronic guidance scheme would be able to improve upon the existing system.

THE CONTROL PROBLEM

This can be best understood by reference to Fig. 1 which is a plan view of the track. The runner is required to run along a line at a fixed distance \(x\) from a reference line. At the instant shown the runner is at distance \(y\) from this line and is running with velocity \(V\) (assumed constant) in a direction which instantaneously makes

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an angle $\theta$ with the forward direction. For the runner to be suitably controlled he must be informed of the error

$$e = x - y$$

between his required position and his actual position. The signal presented to him by some form of display unit will be referred to as the control signal $z$ and it must be capable of conveying both the magnitude and sign of the error. At first sight it may appear that the runner should respond to this signal by a lateral movement. However, the runner is unaware of the direction in which he is travelling and the control signal cannot give him this information. He must change his direction and the greater the control signal the faster he must alter it. If he responded instantly this would give a relationship between $\theta$ and $z$ of the form

$$\frac{d\theta}{dt} = K_1 z,$$

where $K_1$ is a constant.

However the response of the runner to these commands will depend upon his transfer function.

The actual position $y$ can be obtained from $\theta$ by noting that

$$\frac{dy}{dt} = V \sin \theta,$$

and for small $\theta$, $\sin \theta \approx \theta$

$$\frac{dy}{d\theta} = V \theta.$$

(Note $\theta$ must be small if the runner is to achieve a reasonable running time.) These equations enable an overall block diagram of the system to be drawn and this is shown in Fig. 2.

THE HUMAN TRANSFER FUNCTION AND STABILITY

Before any attempt can be made to assess the performance of the system shown in Fig. 2 a model of the human transfer function must be obtained. Many models have been proposed for this transfer function (TuSTIN, 1947; MITCHELL, 1966) and probably the most general form of such a transfer function is given by

$$G(s) = \frac{(1 + T_a s) e^{-\tau s}}{(1 + T_b s)(1 + T_c s)},$$

where $\tau$ represents the operator's time delay,

$T_a$ represents the operator's anticipated time,

$T_b$ represents the operator's error smoothing lag,

$T_c$ represents the operator's neuromuscular lag.

The problem of giving figures to the time constants involved however is a difficult one. A well known property of the human operator is his ability to adapt to the task in hand and alter the time constants in the transfer function to those giving optimum performance. There are also the effects that suggest non-linearities, discreteness and randomness in his response. More complex models can be built to take these into account (SHERIDAN, 1962; LEONIDES, 1965) but a different approach has been proposed by BIRMINGHAM and TAYLOR (1954). They suggest rather than try to fit a given transfer function to an operator, one accepts the fact that this transfer function can vary widely and tries to design the system so that the transfer function required of the operator, to give satisfactory system performance, is the one he is most competent to play. They then go on to suggest that man performs best when doing least and probably becomes optimum

![Fig. 2. Block diagram of the complete system.](image-url)