ON STABILITY OF LOCOMOTION AUTOMATA

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One of the basic problems in the synthesis of bionic locomotion automata is the problem of stability. In its most complex form, the problem appears in bipeds.

Through this communication we present an approach to the problem of automaton stability in motion.

We assume first that a locomotion automaton is composed of the body and the legged locomotive system. Now, let us pose the following question: is it possible to synthetize such a control system that can keep the automaton upright, the force produced by the legged locomotive system being the control variable?

In order to get even a crude answer to this question, a very simple model of biped automaton was simulated on an analog computer and search for an adequate control scheme was carried out. The model consists of a heavy lever sitting on an ideally smooth horizontal plane with the force applied to the support point as a control variable (Fig. 1). For the sake of simplicity we studied the model in the vertical plane (in two-dimensional space). This system is described by the following differential equations:

$$M\ddot{x} + Ml\cos\varphi\cdot\ddot{\varphi} - Ml\sin\varphi\cdot\dot{\varphi}^2 = F$$

$$Ml\cos\varphi\cdot\ddot{x} + (J + Ml^2)\ddot{\varphi} - Mgl\sin\varphi = 0$$

where

- M is the inertia of the lever,
- J is the inertial moment
- l is the center of gravity-to-support point distance
- φ is the angle of the lever to the vertical line
- x is the coordinate of the support point.

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Assume also that the angle φ is so small that the following approximation holds:

$$\sin \varphi \approx \varphi$$

$$\cos \varphi \approx 1$$

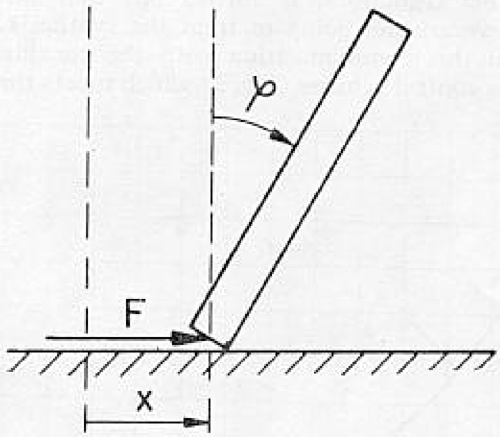

Figure 1.

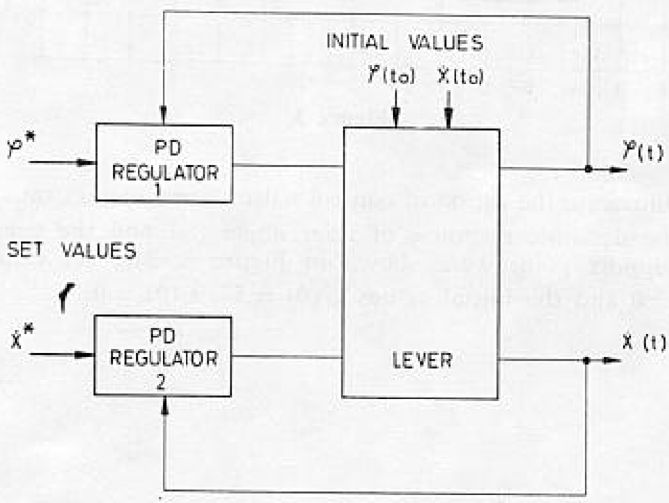

Figure 2.

In case of homogeneous lever, the mathematical model reduces to:

$$\ddot{x} + \ddot{\varphi} \quad \dot{\varphi}^2 \varphi = f$$

$$\frac{3}{4} \ddot{x} + \ddot{\varphi} - \frac{3}{4} k \varphi = 0$$

where

$$\frac{x_{old}}{l} = x \qquad \frac{F}{Ml} = f \qquad k = \frac{g}{l}$$

We investigated the control scheme shown in Figure 2 which comprises two PD regulators. It turned out that this scheme was adequate. Since we are not going to treat the synthesis of the control in detail we end this communication with the conclusion that there exists at least one control scheme (Fig. 2) which meets the requirements.

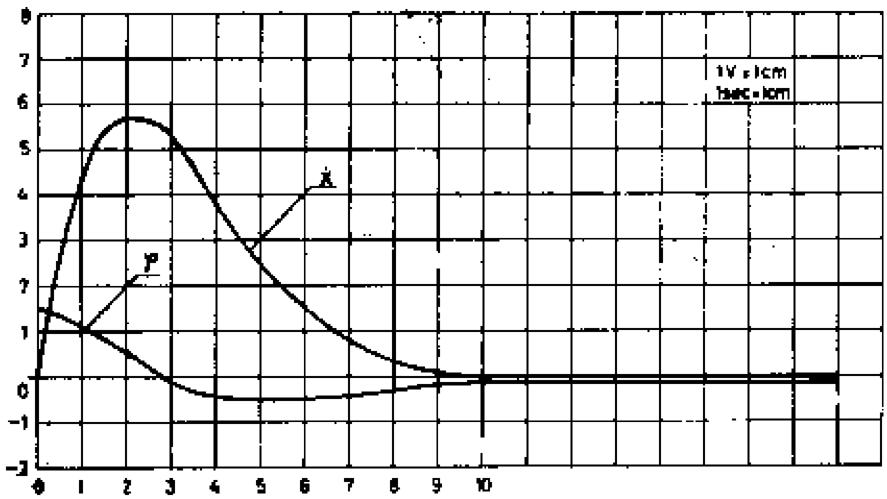

Figure 3.

To illustrate the action of control with its parameters satisfactorily chosen the dynamic response of lever angle (φ) and the velocity ($\dot{x}$) of the support point were shown in Figure 3. The set values were $\varphi^* = \dot{x}^* = 0$ and the initial values $\varphi(0) = 5°$, $\dot{x}(0) = 0$.