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ABSTRACT

This note outlines the design of a model vehicle, which can be used in the control laboratory.

Contents

1. THE BASIC VEHICLE

A simplified picture of the vehicle is shown in Fig. 1. It consists of a chassi with two wheels or two pairs of wheels which both can be steered. At least one of the wheels is also a driving wheel

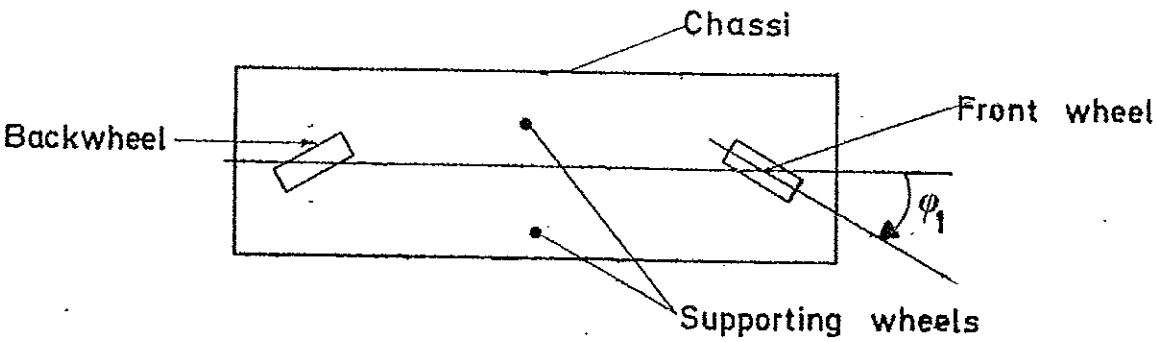

Fig. 1. Schematic diagram of vehicle.

By fixing one of the wheels to the center position the vehicle can be used as a car simulator.

2. ADAPTION AS A SHIP SIMULATOR

The basic vehicle can also be adapted as a ship simulator. The chassi is then covered with a body which looks like a ship. By providing the wheels with servos for rotating both wheels and suitable electronics, it is possible to make the vehicle behave as a ship. The equations describing ship dynamics are

$$\frac{dv}{dr} = a_{11}v + a_{12}r + b_1\delta$$

$$\frac{dr}{dr} = a_{21}v + a_{22}r + b_2\delta \qquad (1)$$

where v is the sway velocity, r the yaw rate and δ the rudder angle.

To describe the vehicle motion the notations in Fig. 2 are introduced

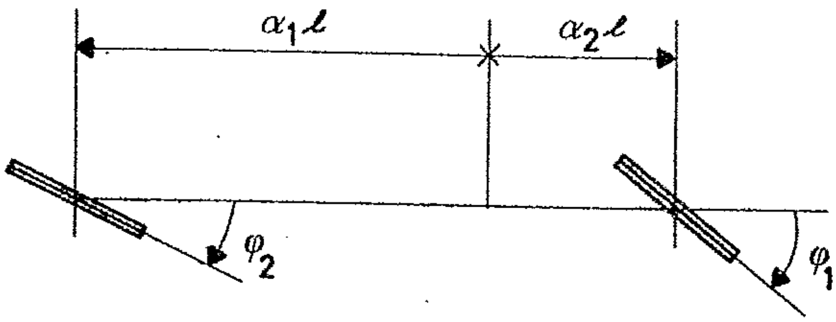

Fig. 2.

The following kinematic relations are obtained

$$v = (\alpha_1\varphi_1 + \alpha_2\varphi_2)V$$

$$r = \frac{V}{\ell}(\varphi_1 - \varphi_2) \qquad (2)$$

where v is the velocity component orthogonal to the vehicle length direction , r the angular rate, V the velocity and ℓ the distance between the wheels.

If the vehicle whose kinematics is described by (2) should follow the equations (1) describing ship dynamics, we get the following identity

$$\frac{dv}{dr} = V(\alpha_1\dot{\varphi}_1 + \alpha_2\dot{\varphi}_2) = a_{11}v + a_{12}r + b_1\delta$$

(3)

$$\frac{dr}{dr} = \frac{V}{\ell}(\dot{\varphi}_1 - \dot{\varphi}_2) = a_{21}v + a_{22}r + b_2\delta$$

These equations give the control law for rotating the wheels, hence

$$\begin{bmatrix}\dot{\varphi}_1 \\ \dot{\varphi}_2\end{bmatrix} = \begin{bmatrix}1 & \alpha_2 \\ 1 & -\alpha_1\end{bmatrix} \begin{bmatrix}(a_{11}v + a_{12}r + b_1\delta)/V \\ (a_{21}v + a_{22}r + b_2\delta)\ell/V\end{bmatrix}$$

where

$$\begin{bmatrix}v \\ r\end{bmatrix} = \begin{bmatrix}\alpha_1 V & \alpha_2 V \\ V/\ell & -V/\ell\end{bmatrix} \begin{bmatrix}\varphi_1 \\ \varphi_2\end{bmatrix}$$

Hence

$$\begin{bmatrix}\dot{\varphi}_1 \\ \dot{\varphi}_2\end{bmatrix} = \begin{bmatrix}\alpha_{11} & \alpha_{12} \\ \alpha_{21} & \alpha_{22}\end{bmatrix}\begin{bmatrix}\varphi_1 \\ \varphi_2\end{bmatrix} + \begin{bmatrix}\beta_1 \\ \beta_2\end{bmatrix}\delta \qquad (4)$$

To mechanize a ship simulator it is thus necessary to provide the steering sheels with motors and to connect them to the signal representing rudder angle according to (4). A block diagram of the connection is shown in Fig 3.

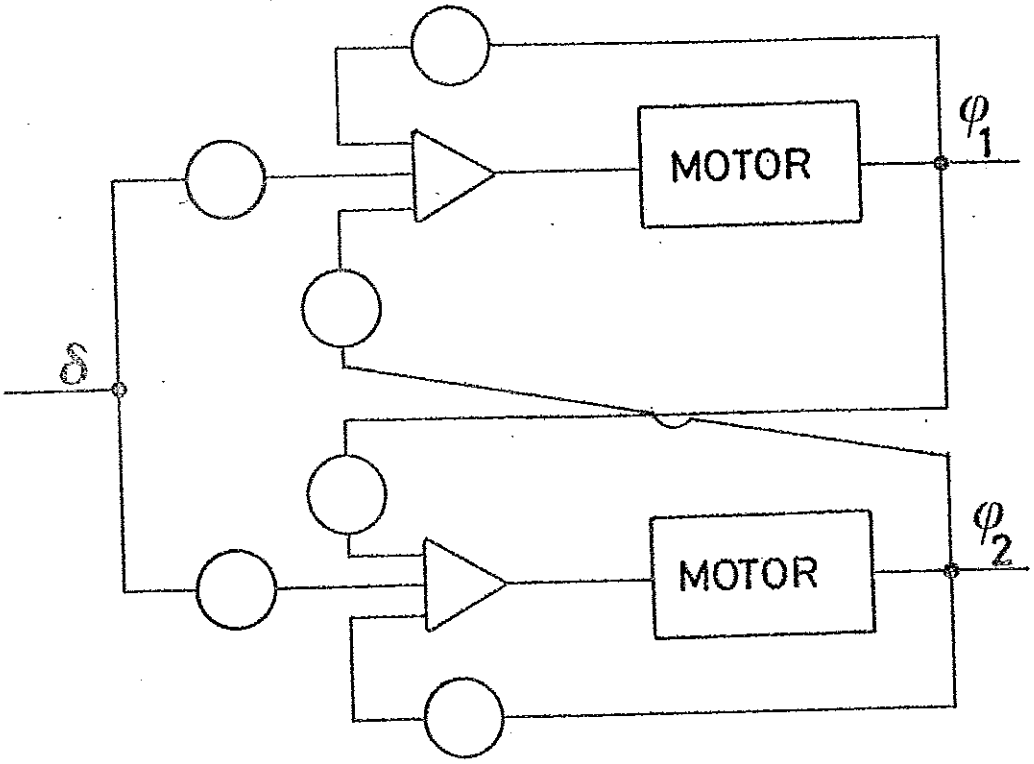

Fig. 3.

3. KEY PRACTICAL PROBLEMS

There are several practical problems to be resolved. The basic vehicle can be designed with two wheels and support wheels as indicated in Fig. 1, with two pairs of wheels or with three wheels. It must be decided if the vehicle should be provided with batteries and high frequency transmission of signals or if flexible wires should be used. To be able to control the vehicle in a meaningful way it is also necessary to provide position and orientation sensors. The position can be determined by measuring the angles to a light on the vehicle from fixed positions. There are various possibilities to measure orientation. The angle to a fixed light can e.g. be measured from the vehicle, etc. With regards to dimension, consider a supertanker 300 m long and 10 m/s. A suitable scale model is then 0.3 m and 0.1 m/s or 0.6 m and 0.2 m/s.