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Engineering

THE STUDY OF GRAZING ROBOTS

Stroe Ioan Transilvania" University of Brasov, B-dule Eroilor, No. 29, 500036 Brasov, Romania

ABSTRACT The mobile robots have offered the support of impressive results in almost all areas. The foot's number is an important element and affects mostly the next proprieties: stability and energetic efficiency. The paper presents the study of a stepping robot with six foots. The actuating is realized through a motor, and the free transmission uses mechanisms with gear wheel. A controller realizes the actuation and the control. There are presented: the constructive shape, the stepping diagram and the 3D-ensemble design of the six-foot stepping motor.

KEYWORDS : Robots, Stepping Robot, Orthogonal, Locomotion Function

INTRODUCTION

The researches, in the area of mobile robots, have begun in the 50's, but the fascination of this area have appeal long time before even though the technological support of that time haven't permitted spectacular results.

The current researches are clearly oriented to the implementation of the performing robotic structures, using the new technologies, which facilitates both the mechanical part structure and the force or the intelligence.

An analysis of the researches in this area shows a clear increase of the approached subjects numbers and a clearly orientation, a research direction concentration to the most prestigious universities and research institutes.

The complexity of the animal world offers the best field for an authentic scientific research. Starting from the new obtaining composite technologies of new materials and until the control with genetic algorithm (based on the evolutionary principles), the mobile robots had offered the support of great results in almost all domains.

The area of animal world offers by it's diversity the best and the perfect solutions for the implementation of a robotic structure. We just have to imitate it, appealing to the technological support that we have and to the qualitative solutions which bring us near to the animal world [5], [7].

ORTHOGONAL STEPPING ROBOTS

The stepping robots presents interest for the quality that they can appear in rough ground.

In comparison with the industrial robot, that, in general are skilful arms capable to ensure the precise position of an object, the stepping robots have as principal part the stepping vehicle (SV) composed by a body and foots with more than 3 liberty degrees that ensure the body support and the locomotion function.

The locomotion through stepping ensures the foots displacement on the ground, the avoiding of the unsuitable (for stepping) places, the stability optimization, the displacement of the body independent from the ground configuration. In rough ground, the stepping strategies must ensure the static stability, what means, that in every situation, the stepping robot can interrupt its movement and remain stabile.

The body movement, at the orthogonal stepping vehicles, is executed in a plane, with a engines group, and the vertical movement with an other engines group [7].

The maintenance elements are orthogonal to the plane that contains the elements meant to propulsion. The foots are linkages having motor couple RTT or RRT, with translation elements; the kinematic element which come in contact with the ground is always on the stepping shade vertical.

The static stability conditions had imposed stepping vehicles with six foots.

Three configurations of orthogonal stepping vehicles are standing out:

- Stepping vehicle with weaving walker;
- Stepping vehicle with circular walker;
- Stepping vehicle with follow-the-leader walker.

ELEMENTS COUCERNING THE STEPPING ROBOTS DRIVING

The stepping robots driving impose the knowledge of the vehicle possibilities for the trajectory determination of the body and foots in the stepping phase.

The driving of this robots maybe accomplished on two levels. At the superior level, the robot is managed, in its working universe, by a remote controller or following a clearly road, defined given to an initial point in this universe. At local level, the locomotion function is being realized.

It is convenient that at superior level, the positions and the orientations, of the robot, to be established by the planned trajectories (by decomposition in line segments and in circular arcs).

The trajectory generator supplies the robot positions and orientations corresponding to an elementary displacement at a sampling period τ.

When this segments are covered there will be generated parametrical the intermediary current points that are necessary in the engendering of the position references for the actuating elements. The elementary displacement can correspond to a stepping cycle.

The fixed reference and the elementary displacements are presented in figure 1

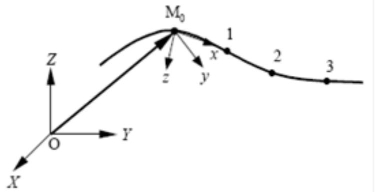

Figure 1: the fixed reference and the elementary displacement

The homogenous matrix H characterizes the position and the orientation in point M(x,y,z).

$$H = \begin{bmatrix} \cos\varphi & -\sin\varphi & 0 & X \\ -\sin\varphi & -\cos\varphi & 0 & Y \\ 0 & 0 & -1 & Z \\ 0 & 0 & 0 & 1 \end{bmatrix} \tag{1}$$

An elementary displacement carries the vehicle mass point (considered characteristic point and the origin of a Cartesian reference attached) from a point M0 in a destination point crossing a trajectory segment. If the displacement is approximated with a line segment, the destination is the point M1 and if is approximated with a circular arc the destination point will be the point M2 passing through point M1. Let us consider an elementary displacement corresponding to a step on the segment M0M1. If the matrix T0 determines the placement in M0 and T1 determines the placement in M1, figure 2, the transformation P determines the placement in M0 seen from M0.

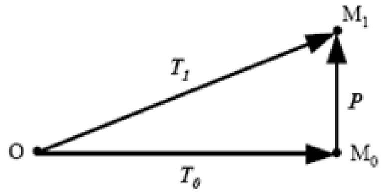

Figure 2: the graph of the homogenous transformation for an elementary displacement on a line segment

If matrix P is, like:

$$P = \begin{bmatrix} \xi_{1x} & \xi_{2x} & \xi_{3x} & P_x \\ \xi_{1y} & \xi_{2y} & \xi_{3y} & P_y \\ \xi_{1z} & \xi_{2z} & \xi_{3z} & P_y \\ 0 & 0 & 0 & 1 \end{bmatrix} \tag{2}$$

in which px and py are the coordinates of point M_1 in the plane M(0xy); the orientation variation $\beta = \Delta\varphi = \varphi_1 - \varphi_0$, if exists, is given by the next

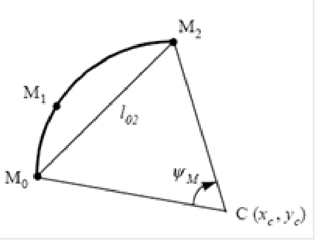

Figure 3: elementary displacement on a circular arc

bearing:

$$\beta = tg^{-1}\frac{\xi_{1y}}{\xi_{1x}} \tag{3}$$

For an elementary displacement on a circular arc, there are considered, a circle C(xc,yc) in the reference M0 (figure3) and two points, M1 – intermediate and M2 – the arc's extremity.

$$\begin{aligned} & x_c^2 + y_c^l = R^2 \\ & (x_1 - x_c)^2 + (y_1 - y_c)^2 = R^2 \\ & (x_2 - x_c)^2 + (y_2 - y_c)^2 = R^2 \end{aligned} \tag{4}$$

The system's solution

$$\begin{aligned} & 2x_1x_c + 2y_1x_c = x_1^2 + y_1^2 \\ & 2x_2x_c + 2y_2x_c = x_2^2 + y_2^2 \end{aligned} \tag{5}$$

leads to the discovery of the central circle coordinates (x_c,y_c) and of its radius R.

For the circle's arc engendering with the parameter Ψ, in the space [0,Ψ_M] the parameter Ψ_M must be determined. Solving the triangle CM_0M_2, figure 3 we will obtain the span l_{02} and the central angle Ψ_M:

$$l_{02} = \sqrt{x_2^2 + y_2^2} \tag{6}$$

$$\psi = 2tg^{-1}\frac{l_{02}}{\sqrt{4R^2 - l_{02}^2}} \tag{7}$$

Being given the tangential velocity $v_t = \frac{ds}{dt}$ and using the finite difference it is obtained:

$$\Delta\Psi = v_t\frac{T}{R} \tag{8}$$

where: $\Delta\Psi$ is the step of the parameter Ψ, for the circle's arc engendering at a sample period T.

The position references can be engendered through the equations:

$$\begin{aligned} & x = \pm R(l - \cos\Psi) \\ & y = R\sin\Psi \end{aligned} \tag{9}$$

where the sign "±" depends on the way in which the arc circle is crossed. When the extremities of the segments M1 and M2 are reached, this will become M0 for the next segment. The position references for the locomotion function will be determined, while the segment (with a current point M) is being crossed, by sampling with a period T<<τ.

In figure 4 highlighted: the reference placed in M0 fixed on a segment, the mobile reference attached to the robot's body – in M(x,y); β – the change angle of the direction in M0; fA – the angle between the axis Mx and the position vector's direction ρA of the foot's shade A, in rapport with M the current reference.

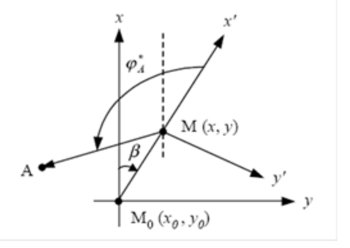

Figure 4: the reference systems

For certain types of robots, it is necessary for the normal stepping that the propulsion mechanism of the robots body be constituted only by two symmetrical foots [5], [7].

THE DESIGN OF THE STEPPNG ROBOT WITH SIX FOOTS

A basis conditions, imposed as early as the design phases, is the robot stability.

The stability of the stepping robots must be studied differently:

- walking – dynamic stability;
- stationary – static stability.

The adaptability isn't always necessary, in the case of the stepping robots, which walk on harsh surfaces, these needs certain sensor types and actuating: the measurement of the foot's angles and torques, the realization of the contact foot-ground force etc. [7]

The geometrical functions of the foot ensure two movements: up-down and forward-back. From the mathematical point of view, the simplest foot architectures are: the Cartesian architectures and the polar architectures. The structure's diversity is very big. The most usual structures are the 2D structures.

The mechanical structures of the animals are adjusted to there necessities. The foot's number is an important element because it affects many proprieties of the stepping robot.

In figure 5 is presented the scheme of the stepping robot with six foots presented by the authors. The actuating is realized through two engines, and the transmission is using mechanisms with gear wheels. A controller realizes the command and the control.

The robot's foot is a quadrangular mechanism of type 4R. The robot's foots are driven by the gear wheels and these are working three-by-three. The foot pairs 1, 3 and 5 respectively 2, 4 and 6 are moving simultaneous realizing the robot stepping. In figure 6 there is presented the stepping diagram of the robot. The stepping is realized in the periods $t_1 \ldots t_4$ corresponding the foot actuating.

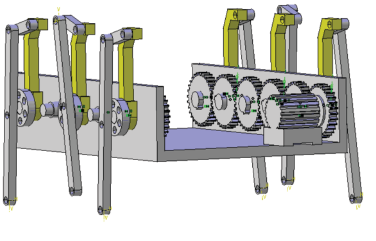

Figure 5: the scheme of the stepping robot with six foots

The stepping diagram allows the visualization of the two support phases. By the diagram study it can be determined the support foots in each moment of the stepping. The stepping matrix allows the description of the stepping regime through the highlighted of the support step succession and balancing step succession. For the same robot's displacement, the configuration, from figure 6, can be made.

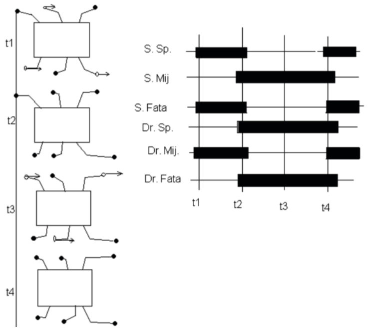

Figure 6: the stepping diagram

$$\begin{bmatrix} 1 & 1 & 0 & 1 \\ 0 & 1 & 1 & 1 \\ 1 & 1 & 0 & 1 \\ 0 & 1 & 1 & 1 \\ 1 & 1 & 0 & 1 \\ 0 & 1 & 1 & 1 \end{bmatrix} \tag{10}$$

CONCLUSIONS

The assembling mode of stepping robot's foots has an important role concerning the stepping. Using different reduction ratio in the actuating systems, an optimal variant for the robot's stability can be obtained. As the robot stepping is slower, the robot's stability is better. The execution errors and the assembly errors lead to the robot's instability.

The use of the quadrangular mechanism, in the foot structure, allows the description of the tiller curves when the stability function is chosen. Thus a pull, without the body control position, had been realized.

Using the 2D structures and the actuating with rotary engines, the working space is in acceptable limits.

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