Mobile Robot Design for Metal Objects Detection

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Abstract: - A particular importance will be given to how the principle ideas were managed to achieve an optimal mechatronic product if certain conditions imposed. Schemes in principle on the whole mechatronic product was designed, conducted and completed in detail. The present study attempted to design a robot for the detection of metal objects, being the preferred transportation system with tracks. This system has a high stability and provides a backup speed high enough for such applications. As a result, the mobile robot those covered by this paper will adopt this system.

Key-Words: - Bio-mechanism, Mobile Robot, Geometrical Analysis, Simulation, Metal Detection**.**

1 Introduction

Mechatronics is defined simply as "science of intelligent machines." This is the subtitle of international journal "Mechatronics", since the first issue of 1998 [1], [10].

The etymology has given human being the faculty of association. Being smart, in a prime purpose, is therefore, to repeat or create freely some links between objects. This is a more synthetic vision of intelligence.

By extension, today there are other connotations to that word: speed, adaptability, faculty of analysis, ability to learn and perfect itself.

So talking about intelligence for non-human beings or machines, explicitly or not, is made only by human’s reference. Turing understand very well when he developed the follow: "a machine is intelligent if its behavior is like the man who can replace."

Intelligence machinery has been set long time ago in literature and before the appearance of computers, has aroused the interest of scientists. Thus first name was "electronic brain" and the "neurons" to describe circuits [6], [9], [12].

What today is called artificial intelligence (AI) is, in fact, far from being perfectly clear. It is developed around two poles: mechatronics and computer science as a branch of cognitive science, while sources of convergence and divergence. Curiously, the most difficult problems to be solved by machines are simple problems for humans - have a discussion, going, or drive a car.

A generally valid definition of artificial intelligence is difficult to develop because of different views corresponding followers "light" artificial intelligence – in which the machine helps to understand - or "strong" artificial intelligence - when the car is those who understand.

Education tool is a process by which a computer learns to solve new problems. Within certain limits, the machines can learn just like people, through examples of what is right and what is wrong, by comparing them. One of the limitations is the fact that machines do not know what concepts might be relevant to a particular problem, so that those who’s in charge for computer education must take care that the machine may focus attention on specific elements that make a distinction between good and one bad example [10].

To define the basic functions of an intelligent machine is taken into account the above, are shown in Figure 1 basic functions of an intelligent machine:

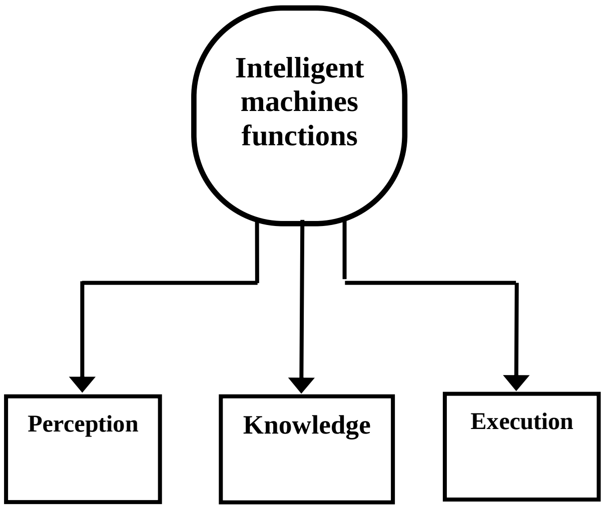

Fig. 1. Basis function of an intelligent machine

There is no general method to determine the boundaries between perception, knowledge and execution. These distinct functions of an intelligent machine are not necessarily implemented as physical components or different parts [12].

2 The technical characteristics of mobile robot and mechatronic design of the product

The purpose of this theme is to realize a mobile robot for metal object detection buried in leveled soils.
The technical characteristics of the robot:

a. the maximum depth of detection:

H_{max} = 150 mm;

b. the maximum speed:

v_{max} = 0.08 m/s

The movement system:
- two technical assemblies tracked type;
- guidance by regulating the lead revolution wheels;
- two DC groups gear-motor.

c. perception system:
- sensor for the detection of metal objects;

d. decision system:
- external computer for application management;

e. communication system:
- through radio waves:

f. three command channels for the movement of mobile platform: ↑,↓,←,→;

g. one reaction signal channel: detection of metallic objects;

h. the minimal radius of curvature of trajectory:

R_{min} = 1 m.

3 Mobile Robot for Metal Detection

The metal detector, used by mobile robot is an electronic device that allows notification and location of metallic objects under various layers of non-metal materials, like earth, wall, snow, water, wood etc [9].
One such device is useful for finding of some buried electrical circuits, for tracking of sewer pipes, for finding of buried metal objects, or to find lost objects. There are several known methods that allow this kind of determination such as, for example, the method of pulse reflection, the magnetic permeability method, density method, and others. Of these, the most widely used and most economical method at the same time is the magnetic permeability. The schemes of those detectors can be realized with transistors, integrated circuit or in combination. For that, herein is presented a scheme operating on the principle of permeability, performed by a single integrated circuit, designed to discover and pipelines, electrical paths, buried objects etc. With a simple mechanical performance, the detector is powered by a voltage of 4.5 ... 6 V at a current of about 4 mA.
In principle, the scheme comprises two oscillators, a mixing stage, a listening device and a power source.
One oscillator has a frequency f1 which can be adjusted manually using a potentiometer and the other oscillator has a frequency f2, the frequency is changed under the influence of a metal object.
Those two frequencies - using the oscillator control element f1 - can be brought to the same value.
The principle scheme of the metal seeker proposed for building is given in figure 2. For performance, it was used a single CMOS integrated circuit, namely circuit type MMC 4011, manufactured in industry.
It comprises four gates type SI-NU each with two entries. Connection of the gates to the capsule is shown, even, in Figure 2. Using gates I and II was performed the f1 oscillator, who is working as a commutation diagram. On exit four are obtained rectangular pulses whose duration depends on the values of C1 and R1 + P1 [6], [9], [12].

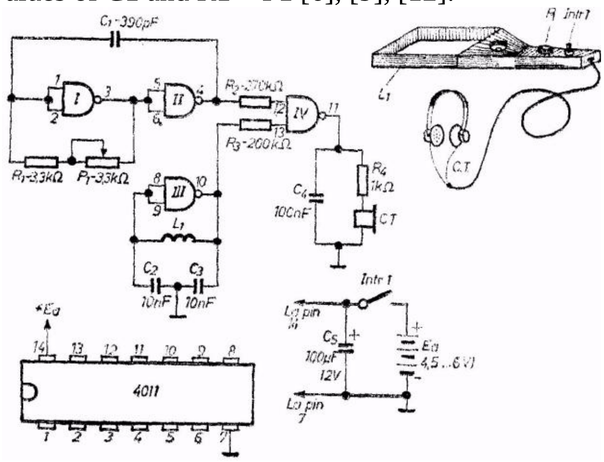

Fig. 2. Schematic diagram of metal detector

3.1 Mechanical Calculus

To obtain good performance in robot exploitation it must study all the mechanical behavior of mobile robot assembly. Below, one tries to present some mechanical calculus necessary for a good functioning of the mechanism.

3.1.1 Velocity distribution study in a technical system for track type

Many mobile robots include traction systems engines based on the tracked system. In the present

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study will determine the speed of an engine with two tracks using theoretical conditions, taking into account the case of a single track as will be shown below. Track system speed, becomes, also, the speed of the mobile robot platform.

Description of operating principle

Assembly track determines the movement of their own direction of rolling, shifting the direction of motion to a mobile robot, too, as a whole, as it is integrated. This direction is, in fact, the support of speed vector of track assembly. To change the direction of motion is necessary to introduce a second parameter, namely the angle theta. This angle is an absolute one, measured as having a part one of the application reference axes of robotic system [9], [12].

The trajectory generation requires varying these two parameters of the robot, respectively, the speed of propulsion v of the track system and theta angle that defines the direction of vector v.

Presentation of the track system type

The track system type from the figure below is composed by:

- Driving wheel;
- Auxiliary wheels;
- Gear-motor group.

The track profile is matched by the driving wheel profile and, also, by auxiliary engines.

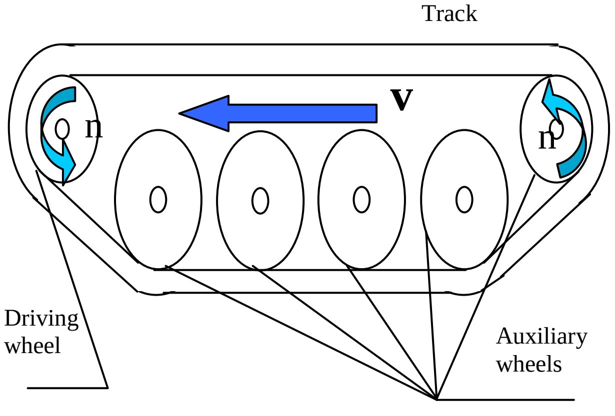


Fig. 3. The track type transmission system

The conditions were considered in the analytical calculation of speed type track system:

- There is no slippage between the tracks and wheels;
- There is no slippage between the track and ground [9], [12].

The calculus of speed track type of technical system:

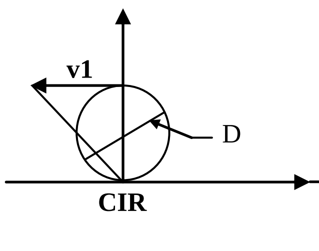
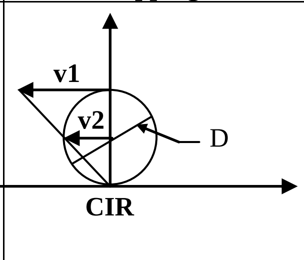
Rolling without slipping	**Rolling without slipping**
	
a	b

Fig. 4. Rolling without slipping of a disc in a horizontal plane

In figure 4a is shown, schematically, the rolling without slipping of a disc having diameter D, the reference of this kind of movement being instant center of rotation with CIR abbreviation inside the drawing [1], [10].

Peripheral speed v1 is given by:

$$v1 = \omega \cdot \frac{D}{2},$$

where:

$$\omega = \frac{\pi \cdot n}{30}$$, n – being the driving wheel speed.

The driving wheel speed n may be written according with de motor speed drive engine, taking into account the gear ratio $i_{transmission}$:

$$n = n_{engine} \cdot n_{transmission}$$

In figure 4b is shown the distribution of velocities for a disc that rolls without slipping, the interest speed is the instantaneous speed v2 of the center of the disc, which will be assigned to the speed type track system.

In Figure 5 it is shown the driving wheel schema:

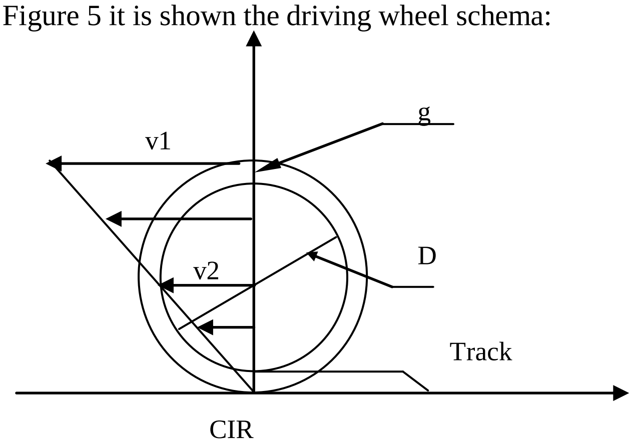


Fig. 5. Distribution of velocities into a type track system

It will introduce a dimensionless factor ψ, which is underscored by the ratio of track thickness g and diameter D of driving wheel.

$$\psi = \frac{g}{D};$$

The following equation describes the analytical value v2 of the mono-track system, which includes all sizes relationship previously described in the previous relations:

$$v2 = \omega \cdot \frac{D}{2} \cdot \frac{\psi^2 + 3\psi + 2}{3\psi + 4};$$

This is a theoretical formula for calculating the speed of a track system and can be experimental corrected in concrete types of tracks from some study case. From this formula can be deduced the formula of the necessary speed measured at the motor shaft for a given engine speed. This formula is the base command function of the engine control system of a mobile robot [12].

3.1.2. The energetic calculus of the necessary moment operation of the driving wheel

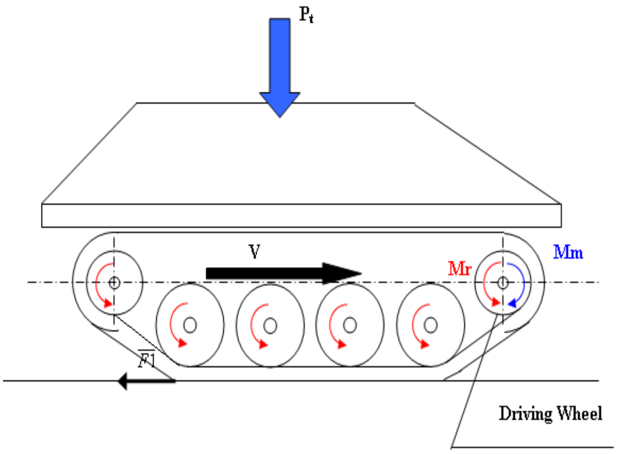


Fig. 6. Model of energetic calculus

As can be seen from Figure 6, the robot is made up of 12 wheels, including two driving wheels and the rest are for support, or idler.

One has the initial data:

- The robot mass: m_{robot} = 850 g = 0.85 kg;
- The battery mass: m_{batery} = 560 g = 0.56 kg;
- The available mass: m_u = 20g = 0.02 kg;
- The driving wheel mass: m_r = 10 g = 0.01 kg.

Also, one considers the next data:

- The whole robot weight is:

Pt = m_R · g = (0.85 + 0.56 + 0.02) · 9.81 = 1.43 · 9.81 = 14.028 [N]

- The driving wheel radius is: r = 0.01 m;
- The driving wheel weight is: p = m_r · g = 0.01 · 9.81 = 0.0981 [N]
- One neglect the auxiliary wheel weight and inertia;
- Air resistance is taken into account by the next:

$$R = k \cdot v^2;$$

- Rolling resistance is neglected.

Given these entire issues one applies in the first stage the differential equation of mobile robot motion:

$$dE = dL_{ext} + dL_{\text{int}}$$

Kinetic equation of the robot is equal to the kinetic energy of robot body and wheels. Given the weight of Pt and that:

$v_c = \omega \cdot r$ and i_c - radius of inertia of the drive wheel, one get:

$$E = \frac{1}{2} \cdot \frac{P}{g} \cdot v_c^2 + 2\left(\frac{1}{2} \cdot y_c \cdot \omega^2\right) = \frac{1}{2g} \cdot \left(P + 2p \cdot \frac{i_c^2}{r^2}\right) v_c^2$$

so:

$$dL = \frac{1}{g} \cdot \left(P + 2p \cdot \frac{i_c^2}{r^2}\right) \cdot v_c \cdot dv_c$$

Among the external forces, only the external force of air resistance performed a mechanical work, if neglect rolling resistance, mechanical work of friction forces $\overline{F_1}$ between the tracks and soil is invalid in this case (because the point of contact between the track and the ground is the instantaneous center rotation).

Therefore:

$$dL = -K \cdot v_c^2 \cdot ds_c$$

where:

ds_c - amount of displacement.

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The mechanical work of external forces (torque and friction of the bearings) is:

$$dL_{ext}=(M_m-4M_r)\cdot d\varphi=(M_m-4M_r)\cdot\frac{ds_c}{r}$$

Substituting expressions of terms dE and dL is dL_{int} in the differential equation of mobile robot motion and dividing those two members by determination, one get:

$$\frac{1}{g}(P+2p\frac{i_c^2}{r^2})\cdot v_c\cdot\frac{dv_c}{dt}=\frac{1}{r}\cdot(M_m-4M_r-r\cdot K\cdot v_c^2)\cdot\frac{ds_c}{\Delta t}$$

where, by simplifying

$v_c=\dfrac{\Delta S_c}{\Delta t}$ **,** obtain the next equation:

$$(P+2p\cdot\frac{i_c^2}{r^2})\cdot a_c=\frac{g}{r}\cdot(M_m-4M_r-4M_r-r\cdot K\cdot v_c^{2)}$$

From this last relation follows:

$$M_m-4M_r-rKv_c^2=0$$
$$M_m=4M_r+rKv_c^2$$

Calculation of resistant moment M_r

Present robot case involves sliding bearings, respectively the case for a radial bearing.
According to the literature:

$$M_r=(\mu+\frac{s}{r})r\cdot P\cdot Fid$$

where (see Figure 7) :

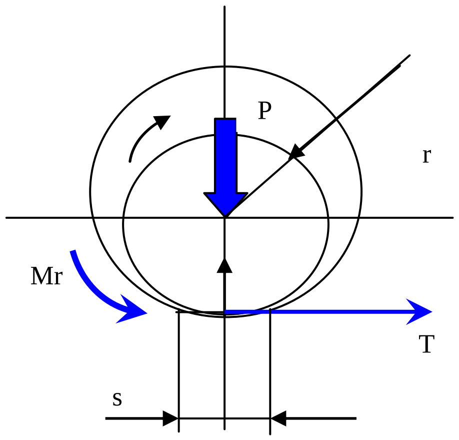

Fig. 7 Sliding bearing

Fid distributed tensile strength value increases the resistant moment by 5%.

μ - friction coefficient steel – plastic = 0,05.

s – rolling friction coefficient steel – plastic = 0,008.

r - shaft drive wheel radius = 0.01 (mm).

p – distributed weight on the wheel = $\dfrac{p_t}{8}$ (8 wheels support).

So:

$$M_r=(0.05+\frac{0.008}{0.01})\cdot 0.01\cdot\frac{1.43\cdot 9.8}{8}\cdot 1.05 = 0.0156 \quad \text{[Nm]}$$

To develop such a speed:

$$v_c=v_{\max},$$

for a coefficient k = 1 (rolling resistance) one obtains next value of engine moment:

$$M_m=12\cdot 0{,}0156+0.01\cdot 1\cdot 0{,}08^2=0.1872 \quad \text{[Nm]}$$

$$M_m=0.1872 \quad \text{[Nm]}$$

Such value can be utilizing to choose the driving engine.

$$M_{motor}^{catalog}\geq M_m$$

The engine choice is a necessary condition. So, one chose the next DC motor by 0.4 W.

4 Conclusion

Following the study, according to tests conducted on several types of locomotion (skeletal system), it was found that for applications intended for mobile robots detections - monitoring, track-type locomotion system is preferred.
This system has a high stability and provides a backup speed high enough for such applications. As a result, the mobile robot used in application in this research will adopt this system.
In future, other improvements of application can be made on electrical and software parts, where one can obtain better results regarding the reliability of the mobile robot.

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