Sensory System for Controlling Robot`s Motion

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***Abstract*-The article shows the concept of organizing the control of a educational robot in terms of its functional characteristics, allowing it to come into contact with the serviced person completely safely. The idea of using the functional characteristics of Collaborative robots, which are mainly used in industry, is considered. In this paper authors is making an attempt in building a simulation model of a differential drive robot in order to achieve various movement patterns. A methodology for calculating the travel distance as well as a methodology for implementation of the dead reckoning algoithm are being proposed.**

Keywords: Robot sensor, encoder, dead reckoning algorithm

I. Introduction

A differential wheeled robot is a mobile robot whose movement is achieved by the use of two separately driven wheels placed on either side of the robot body. The first task that needed to be accomplished was moving the robot on a prescribed distance. That kind of processes where the current position of a robot is calculated by the distance travelled is called a Dead Reckoning. In general this falls under the problem of knowing where the robot is and this is called a localization.

One possible way to do this is to use what are called encoder sensors to compute the number of rotations of the wheel and to determine the distance travelled. Other popular ways to achieve localization are to use other sensors such as GPS, an IMU, a camera or LIDAR. The choice of the authors was to use encoder sensors to implement the Dead Reckoning algorithm. The final goal of the experiment was to move the robot in a straight line.

II. ORGANIZATION OF CONTROL STRUCTURE OF THE ROBOT

Assume that the used wheel has 9 teeth and is shaped as shown on Fig. 1. An encoder is a device that is connected to the wheel motor shaft. If the wheel is rotated for 1 full revolution, that is to be 360° the encoder counts discrete number of pulses corresponding to the rotation. In this case the encoder sensor will count 9 pulses.

The number of points N we want to measure per revolution is given by:

$$\mathbf{N = 360 / I} \qquad (1),$$

where:

I is the smallest increment I that needs to be monitored for the application.

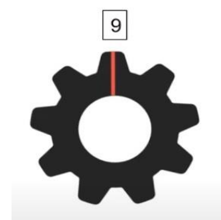

Fig. 1. Example of encoder wheel.

Reference for the encoder parameters can be found in the manufacturer`s datasheet. A device used to measure the distance travelled is called an odometer. Such odometrical device can be build using encoders. If we were to rotate the wheel given in Fig. 1 by one full revolution its center would have travelled a distance equal to the circumference of the wheel.

1 rotation=D= 2* π* R (2), where:

D is the wheel circumference;

R is the wheel radius.

For the organization of the control of the service robot, the controller performing the functions of management needs to have a multilevel structure with hierarchical connections between the different structural levels. At the heart of the management organization at each level is a single principle, which consists in minimizing some functionalities representing the mismatch between commands, generation from the top level and the magnitude characterizing the current state of the robot and the environment, called “Vector of the situation”.

Within this principle, the given commands represent the elements $\boldsymbol{x\ y}$ in the general case subsets $\boldsymbol{X^{*}_{y}}$ of the set $\boldsymbol{X \in M_{\alpha}}$ – metric space. This set can be called "Situation Space" and

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it characterizes the state of the robot and the environment [4], [7].

The situation vector x_c represents the value of the operator P in this situation space: $x_c = P(\upsilon, \lambda)$, where $\upsilon \in \theta \in R_n$ characterizes the state of work and represents a set of coordinates of the degrees of mobility of the working module, where n is the number of degrees of mobility of the working module, and $\lambda \in \Lambda \in M_\lambda$ characterizes the state of the environment. M_λ – metric space. In a constant medium, obviously

$$x_c = P_0(\upsilon) \quad (2)$$

According with equation (2) the values of the situation vector are obtained on the basis of the processing of the information by the sensor – measuring system of the robot.
The mismatch function of the robot position and the situation vector is assumed to be expressed as the distance $\rho(X^*_y, x_c)$ between the subset X^*_y and the vector x_c, where:

$$\rho(X^*_y, x_c) = \inf_{x_y \in X^*_y} \rho(x_y, x_c) \quad (3)$$

According with equation (3) if X^*_y remains unchanged during the execution of the command, then obviously:

$$\rho(X^*_y, x_0) = N(x_0) = L(\upsilon, \lambda), \text{ where } L = NP \quad (4)$$

As a special case under constant, we have

$$\rho(X^*_y, x_c) = L_0(\upsilon) \quad (5)$$

According with equation (4) and (5) the control of each of the levels of the hierarchical structure is realized by generating commands, influencing at the lower level, ultimately providing such a change in the external environment and the state of the robot, which leads to reaching the set goal. In this way, the management task can For the purpose of building the system model following block from the library will be needed: Ramp block, from Sources category; Gain, from Math operations category. Scope block, found under Sinks library.

Ramp block is used to simulate the encoder sensors themselves. Its output is a rising signal with a constant slope. This is representative of an encoder behavior when the robot Gain block is used to convert the encoder pulses into distance travelled since the output distance travelled is a constant multiplication factor of the input encoder pulse count. Finally for the purpose of visualization of system output Scope block is used. is moving with constant velocity in a straight line.

be described as follows:
The existing functionality is:

$$\rho(X^*_y, x_c) = L(\upsilon, \lambda) \quad (6)$$

According with equation (6) in the general case may not be given, but be known by the realization:

$$(x_c, X^*_y) \in X,\ x_c = P(\upsilon, \lambda) \quad (7)$$

$$\upsilon \in \Theta,\ \lambda \in \Lambda$$

where X, Θ and Λ are bounded sets of some metric spaces.
It is necessary to build such a control algorithm that provides minimization of the functional and to clarify the conditions that must be satisfied by $L(\upsilon, \lambda)$ to ensure the convergence of the minimization process to $\inf L(\upsilon, \eta)$. It is characteristic that all constraints of the sets X, Θ and Λ can be unknown in advance and it is necessary to specify in the process of solving the problem [11].

III. ODOMETER IMPLEMENTATION IN SIMULINK

This experiment was done in the Matlab Simulink software. A system model was built whose output is the distance travelled.
It is important to know that the output pulse count from the encoder as well as the wheel circumference are fixed values for most robots and need to be determined only once. The output pulse count for any given rotary encoder is constant as stated in manufacturer`s datasheet. Thus the only variable in the system is the total number of encoder ticks. That variable is assumed to be the input of the system. Hence the proposed structure (Fig. 2)

Fig. 2. System simulation structure.

First step is calling the Simulink software from the Home tab of Matlab. This will open Simulink start page, containing a set of model templates. Selecting a template will create a new Simulink model based on that template. Simulink model window is where the block diagram of the system is visualized and simulated. The blank model template is required for the task.

Adding blocks to the model is done by selecting the library browser icon. Simulink library browser displays libraries in a list on the left hand side. (Fig. 3).

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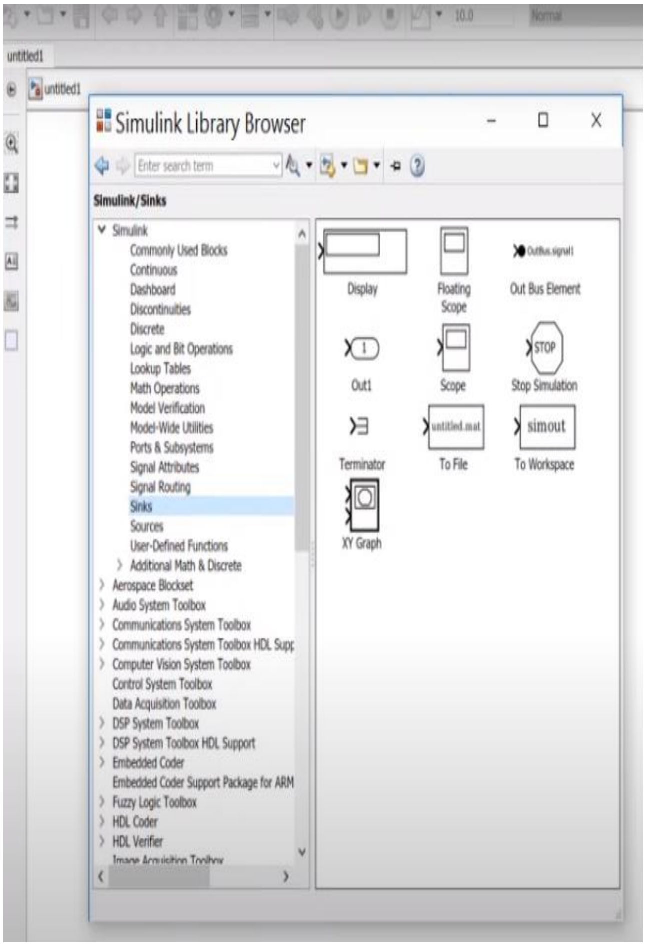

Fig. 3 Simulink library browser.

Block and signals names are changed in order to enhance diagram readability (Fig. 4)

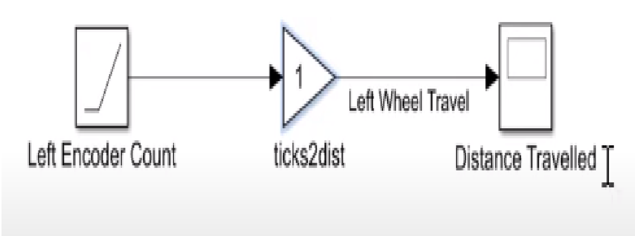

Fig. 4. Odometer structure.

By double clicking on a block parameters that describe the system have to be set. Ramp parameters are left at default value. For ticks2dist block the following is specified:

$$(2*pi*wheelR)/ticksPerRot) \tag{3}$$

By adding additional Scope block encoder pulses can also be visualized. On Fig. 5 is the final structure.

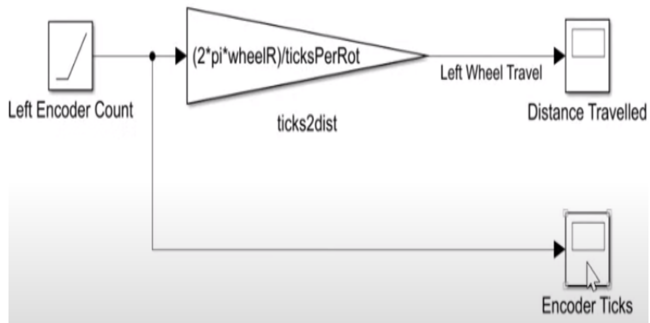

Fig. 5. Enhanced Odometer structure.

IV. EXPERIMENTAL RESULTS

Results from simulation show the encoder outputs 10 pulses (Encoder Ticks block). (Fig. 6) Result from the Distance travelled block shows number close to 10^{-2} m. The way the Ramp block is set up outputs one pulse per second. Thus simulation time must be set to 360 seconds. Expectation is encoder will produce 360 pulses which is equal to one wheel rotation.

These results are regarding a single wheel. When a robot travels in a curved trajectory boths wheels cover different distances. However we are interested in the distance covered by the centre point of the robot Dc:

$$Dc=\frac{D\ Left+D\ Right}{2} \tag{8}$$

An expanded structural design for both of the wheels is proposed (Fig.6)

In order to obtain distance data for the root`s center point an average quantity from both sensors needs to be calculated. By connecting the Left Wheel Travel and Right wheel travel and adding them up via Add block and then dividing by 2 that average value is easily obtained. Setting the gain parameter to 0.5 is equivalent division by two.

In the areas where the use of robotic mechanisms and manipulators is applied, the question arises with their correct control in the workspace, given the peculiarities of manipulators and their complex kinematic structure, as well as the fact that some of them are nonlinear dynamic systems. This is sometimes an ambitious task - manipulators are used mainly in tasks that are characterized by uniformity of movements.

Hence one of the challenges associated with this management, namely the realization of a certain accuracy in positioning and repeatability of the movement in the workspace. Studies have shown that an open control system based on a single-board computer, such as the Raspberry PI, can be created by solving forward and reverse kinematic tasks. The most commonly offered manipulator has three degrees of freedom, built with four servo motors [9].

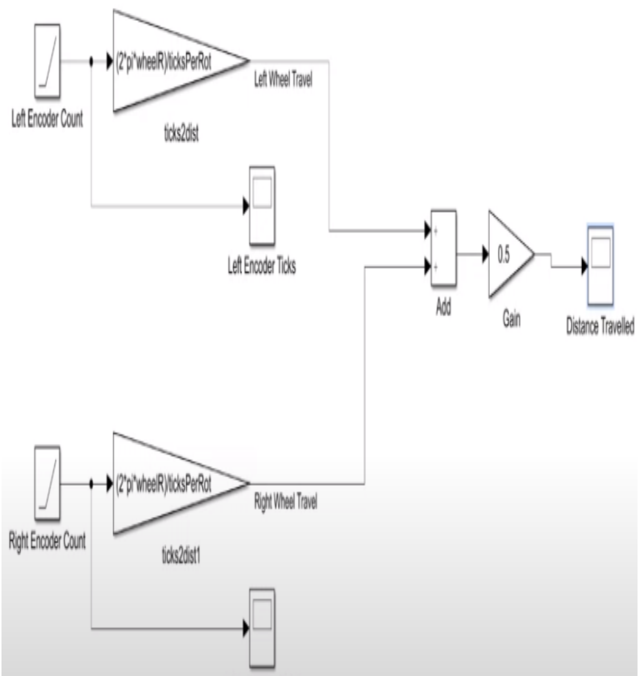

Fig. 6. Skeme of Simulation structure, 2 wheels.

The created training robot is an experiment to construct on the one hand a manipulator with the help of a 3D printer, as well as to establish the controllability in the workspace and the accuracy of repeatability with the use of servo motors. In essence, this robot is an open kinematic system.

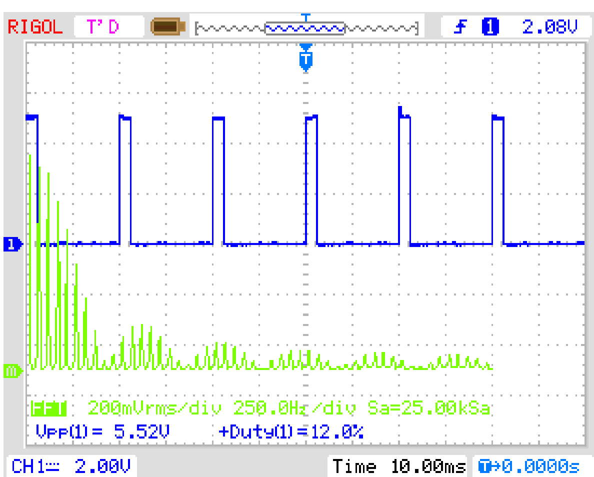

Fig. 7. Oscillogram of control signal of potentiometer P1 at position: 0%, basic servo.An

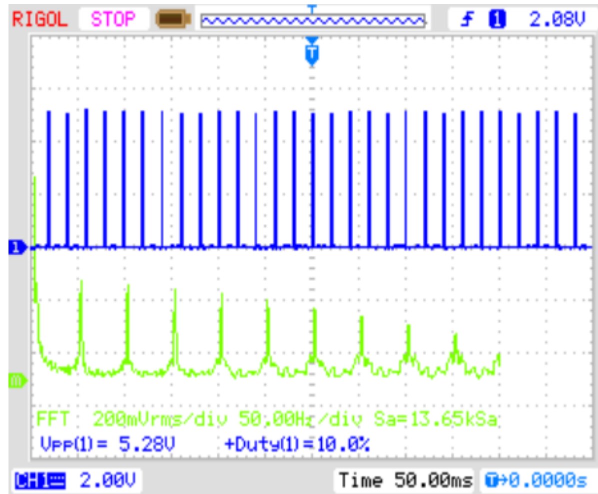

Fig. 8. Oscillogram of control signal of potentiometer P1 at position.

As a result, servomotors can be controlled very precisely. In particular, a command can be sent to the motor so that the servo drive shaft rotates to a certain position. The disadvantage of these servo drives is that the range of rotation is limited (for example between 0° and 180° degrees). However, servo motors are very convenient if a project requires a motor with precise control and reading of its current position. The SG90 used is a servo motor that can rotate up to 180 °. It is also very compact, small in size and light in weight (weight: 9g; size: 22.2 x 11.8 x 31 mm).

The so-called module, a rotation angle sensor, is used to control the engine. This module is a simple potentiometer combined with a circuit breaker. Therefore, it can simply be replaced with almost any type of potentiometric sensor.
Characteristics of the servomotor:
Rotation range: 0 ° - 180 °; Power supply: 4.8V - 6V; Torque: 1.8 N.cm at 4.8 V; Rotation speed: 60 ° in 0.12 sec. at 4.8 V; Response time: 7 ms; Internal interface: analog; Operating temperature: -30 to + 60; Direction: CCW (counterclockwise); Gear material: plastic; Housing material: plastic; Cable length: 25 cm; Dimensions: 23 × 12.2 × 29 mm; Weight: 9 g.

By using this methodology, an innovative effect is achieved in the education of children, which is very close in nature to the way information is transmitted between people. The results of the laboratory tests were very encouraging. Young people with normally developed abilities were placed in the role of trainees. The dialogue between the robot and the learner was observed, which ended with a reported number.

On the basis of the studied nessesary robots behavioral models, the hardware part should be further developed, which can provide the necessary basis for further development of the program platform in order to better meet the service needs of the same users. In this respect, advances in modern technologies are developing and increasing the capabilities of the used equipment for robots control in “real time" mode. Here, not only the rapid development of digital technology has led to an unprecedented rise in communication tools in society [10].

There is already a new technical revolution with the possibilities for developing analog technology. In this way, extremely fast processes for collection of analogue information from the environment are obtained, without having to transfer it in digital form in order to process it properly and then to decide on the implementation of a given task.That is why these two processes of development of the hardware and the software part of the robot should go in parallel and iteratively, with the development of one part implying a jump in the development of the other part, which in turn puts its own possibilities and requirements that catalyze the development of the other part.

Conclusion

The management organization in this case of educational robots is designed to serve people with problems. The control in the service process is carried out by recognizing voice commands, which is very important from the point of view of user convenience. In addition, the created service robots have the ability to transmit information to trainees not only verbally but also with gestures and actions implemented with the help of service robots

To make personal robots affordable to people is the main challenge of the project which is to be achieved by implementing innovations in all aspects of functioning of the robotic device – materials, sensors, cognitive, communication, actuators, energy consumption, etc. Also an essential point is the definition of clear street of work and tactical goals in the extremely complicated process of education with the help of The Educational Robots. The hardware and software Robots Control Systems should be further developed on the basis of the studied in spetial conditions Robots behavioral models. This can provide the necessary basis for further development of the Service Robots in order to better meet the spatial needs of the people with disabilities and elderly. Advances in modern technologies in this connection, are developing and increasing the capabilities of the used equipment for Robots control in "real time" mode. It is known, that not only the rapid development of digital technology has led to an unprecedented rise in communication tools in society. New technical revolution there already exists with the possibilities for developing analog technology. In this meaning extremely fast processes for collection of analogue information from the environment are obtained, without having to transfer it in digital form in order to process it properly and then to decide on the implementation of a given task.

The mechanical design of the Service Robots is very important step also. The ability of the robot to move in the stochastic changing environment is very important to realize in the process of development of mobile robots systems. The Robots behavior has to be stable and to be easily controlled. It has to determine the desired number of degrees of freedom in order to be assured the adequate movement of the robot along any direction.

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