Modeling of corridor navigation robot through bond graph

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Abstract

In this research we are trying to find a mobile robot control method for corridor navigation and wall following in a partially known environment, when obstacles trajectory is unknown or information about it is incomplete, and the environment consists of stationary obstacles. Gathering information of the robot travelling is based on IR sensors. The aim of the robot is to select avoidance maneuvers to avoid collision with obstacles.

Introduction

Mobile robots are increasingly being used to perform tasks in unknown environments. The potential of robots to undertake such tasks lies in their ability to intelligently and efficiently locate and interact with objects in their environment.

Various methods for controlling mobile robot systems have been developed which are generally classified into two categories: global planning and local control. Many works, based on the complete knowledge of the robot and the environment, use a global planning method such as artificial potential fields, connectivity graph, cell decomposition, etc. These methods build some paths (set of sub-goals) which are free of obstacles. The local methods are mainly used in an unknown environment. They could be called reactive strategies and are completely based on sensory information.

The environments where robots are used can be categorized as dynamic or time varying or static. In these environments, there are several stationary or moving objects. Common examples of these environments will be manufacturing industry with machinery parts as the moving objects, an office or a museum where the moving objects will be humans or a road-system where the moving objects will be the vehicles. The robot has to negotiate and avoid these obstacles while moving towards its destination. If mobile robots are to be used to solve various problems, it is necessary that they be able to autonomously compute a safe trajectory. Mobile robots have been used as museum guides and office assistants. They have also been used for search and rescue operations and for exploration of hazardous environments. For these systems it becomes important that the robot finds an autonomous path with least chance of collision with any objects and humans. While navigating in a crowded environment, a dynamic obstacle can block the path of the robot. The robot must stop its motion until the obstacle moves away. So, for three decades, many algorithms have been developed to solve the mobile robot navigations with specific conditions.

Modeling through the bond graph

There exist different methods to obtain the equations of motion of physical systems. One way for deriving a mathematical model of systems is the usage of bond graphs [1-9]. The aim of this section is to give a general view of bond graphs. Bond graphs that provide a systematic way of describing physical systems and their corresponding dynamics are introduced by Karnopp [1], and extensions appear in [10-19].

The main idea, introduced in [1, 2], is that the representation of geometric considerations by bond graph transformers leads to conservation of energy. This enables bond graphs to be created from geometric transformation without concerning about the power conservation since it automatically implies the forces corresponding to the velocities.

Graphical representation of physical systems that explain the dynamic behavior of the system is called bond graph. Bond graphs are independent of the domain. It means that they explain physical systems in different energy domains in the same manner. The main concept of bond graphs based on energy and energy exchange.

Bond graph splits complicated systems into simple subsystems. These subsystems can be in different domains of energy. Analyzing these subsystems, the bond graph provides the system model. This model can be used for simulation and study the dynamic behavior of the system.

In general, subsystems are connected by means of engineering links (mechanical shafts, electrical wires, etc.). Through these links' energy transfers between subsystems. Utilizing energy as the exchange variable for a model yields to the use of two co-variables in each energy domain which are commonly called effort (e) and flow (f), where energy . These variables are also called power variables. They have a different meaning in different physical domains (mechanical, electrical, hydraulic, thermal, chemical systems). The power is a product of these two variables.

Modeling assumptions

Mass, rigidity, and linearity of components, and so forth. The result of these assumptions can sometimes lead to mathematical formulation problems. In this system 8 energy storage elements end up in derivative causality.

Angular velocity of center of mass of the robot assumes to be positive in clock wise mode otherwise it is negative.

Linear velocities of tires must be positive relative to center of mass.

Description of Robot

This mobile robot contains two wheels with radius R1 which run by two D.C. motors independently. Also, there exist two power sources which obtain the power of the robot. Meanwhile to reduce angular velocity which each D.C. motor give a set of gears used.

Fig. 1 gives a scheme of the robot, components and variables which used in this report.

a=10cm w V a=10cm

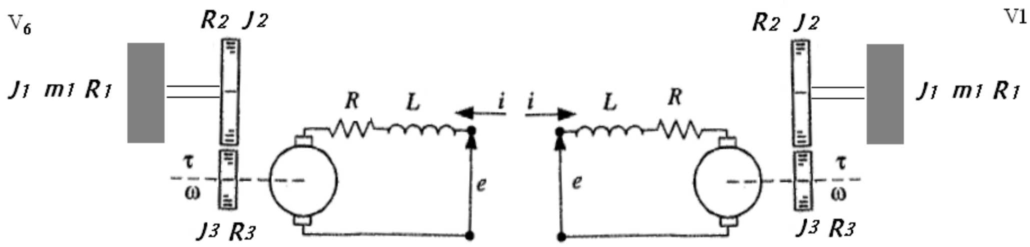

Fig. 1 Scheme of the robot

Mobile robots are mechanical devices capable of moving in an environment with a certain degree of autonomy. Autonomous navigation is associated to the availability of external sensors that capture information of the environment through visual images or distance or proximity measurements. In this robot there are eight sensors that do distance measurements, which set in the structure of robot as shown in Fig. 2. To control this robot, to find its way through the corridor and avoid collision with obstacles, the algorithm which used in this project is finding the linear and angular velocities of center of mass of the robot then finding necessary inputs corresponding to these velocities, in addition required data for modulated transformer are stored in two 16 by 16 matrices (Table 1& 2) and also state space equations found by using bond graph.

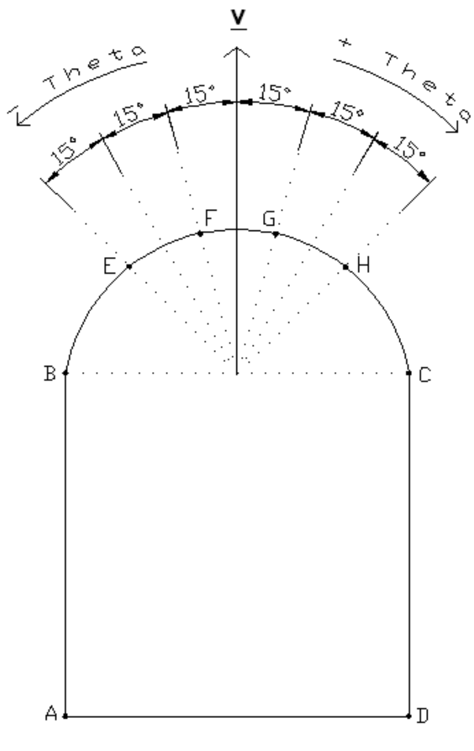

Fig.2 Position of the Sensors

Table 1

ABCD	0000	0001	0010	0011	0100	0101	0110	0111	1000	1001	1010	1011	1100	1101	1110	1111
0000	A1	A2	A2	A2	A2	A2		A2	A3	A6	A3	A2	A3	A4	A4	
0001	A1	A2	A2	A2	A2	A2	A2	A5	A6	A6	A2	A2	A5	A5	A5	A8
0010	A2	A5	A5	A5	A2	A2	A2	A2	A2	A2	A2	A2	A2	A2	A5	A8
0011	A6	A2	A2	A2	A2	A2	A2	A5	A2	A2	A2	A5	A2	A2	A5	A8
0100	A3	A3	A3	A3	A3	A3	A3	A4	A3	A3	A3	A4	A3	A4	A4	A7
0101	A2	A2	A2	A3	A3	A3	A3	A3	A3	A3	A3	A3	A3	A3	A4	A7
0110	A1	A2	A2	A2	A2	A2		A2	A3	A6	A3	A2	A3	A4	A4	
0111	A2	A2	A2	A2	A3	A3	A3	A2	A3	A2	A9	A9	A3	A9	A9	A9
1000	A1	A3	A2	A5	A2	A2	A2	A5	A2	A6	A2	A5	A2	A2	A5	A8
1001	A1	A2	A2	A2	A3	A2		A2	A3	A6	A3	A2	A3	A3	A3	
1010	A2	A3	A3	A2	A2	A2	A2	A2	A2	A2	A2	A2	A2	A2	A5	A8
1011	A2	A2	A2	A2	A3	A2	A2	A2	A3	A6	A2	A2	A2	A9	A9	A9
1100	A6	A3	A3	A3	A3	A3	A3	A4	A3	A3	A3	A3	A3	A4	A4	A8
1101	A3	A2	A2	A3	A3	A3	A3	A9	A3	A6	A3	A9	A3	A3	A3	A9
1110	A3	A2	A2	A2	A3	A9	A2	A9	A3	A3	A2	A9	A3	A9	A3	A9
1111	A1	A2	A2	A2	A2	A2		A3	A3	A6	A3	A9	A3	A9	A9	A9

Table 2 Modulate of transformers for each state

State	Angle(Deg)	Velocity of mass center (rpm)	m_1	m_2
A1	0	30	0.5	0.5

A2	-15	10	0.0512	0.282
A3	15	10	0.2821	0.0512
A4	30	10	0.33	0.0034
A5	-30	10	0.0034	0.33
A6	0	10	0.167	0.167
A7	90	18	0.5828	0.0172
A8	-90	18	0.0172	0.5828
A9	0	0	0	0

Source: Fictitious data, for illustration purposes only setting R(radius of tire)=2.5cm, a=10cm

To derive the state equations the bond graph method used. The distinct velocities are found from dynamic equation of motion of the mobile robot (which explain in appendix) and using these relations and applying a power sign convention to construct the bond graph of the system which shown in Fig.3. By doing the sequential causal assignment procedure to above bond graph and propagate it the result is a completely augment bond graph which shown in Fig.4

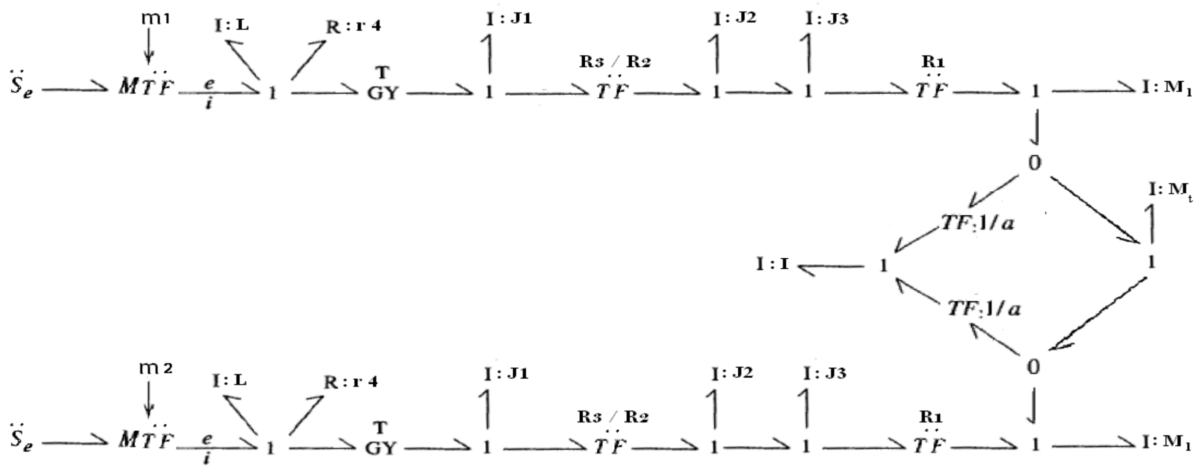

Fig. 3 bond graph model of the system

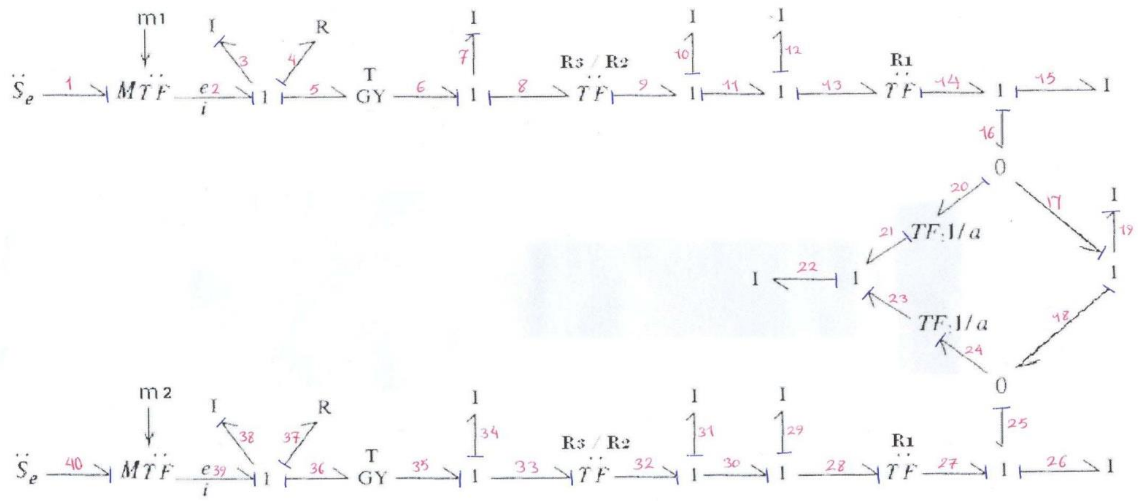

Fig. 4 bond graph model of the system - causality

According to the causal bond graph, the order of the system is 4 because of 4 integer able elements, so states of system become (P3, P7, P19, and P38), and also e1 and e2 are two source of effort act as inputs. Linear and angular velocities are the output if the system. The formulation always starts by writing the rate of change of a state variable equals an effort and flow. We then use causality to track the efforts and flow through the bond graph. The formulation procedures are attached in appendix the result is shown in Matrix form (state space realization). The definitions of the variables are attached in appendix.

$$\begin{bmatrix} \overset{\circ}{P}_3 \\ \overset{\circ}{P}_7 \\ \overset{\circ}{P}_{19} \\ \overset{\circ}{P}_{38} \end{bmatrix} = \begin{bmatrix} \frac{-r_4}{I_3} & \frac{-T}{I_7} & 0 & 0 \\ \frac{\alpha_2}{\beta} & 0 & 0 & \frac{\alpha_3-\alpha_1}{\beta} \\ \frac{\alpha_5}{\beta} & 0 & 0 & \frac{\alpha_4+\alpha_6}{\beta} \\ 0 & \frac{TR_1^2R_3^2}{R_2^2I_7} & \frac{-2TR_1R_3}{R_2I_7} & \frac{-r_4}{I_3} \end{bmatrix} \begin{bmatrix} P_3 \\ P_7 \\ P_{19} \\ P_{38} \end{bmatrix} + \begin{bmatrix} 1 & 0 \\ 0 & 0 \\ 0 & 0 \\ 0 & 1 \end{bmatrix} \begin{bmatrix} e_1 m_1 \\ e_{40}/m_2 \end{bmatrix}$$

$$\begin{bmatrix} y_1 \\ y_2 \end{bmatrix} = \begin{bmatrix} 0 & 0 & \frac{1}{I_{19}} & 0 \\ 0 & \frac{R_1R_3}{aR_2I_7} & \frac{1}{-aI_{19}} & 0 \end{bmatrix} \begin{bmatrix} P_3 \\ P_7 \\ P_{19} \\ P_{38} \end{bmatrix}$$

Simulation results by 20SIM

For simulation of the system instead of real parameter m1 and m2 we use any arbitrary signal for inputs and by attaching observer to the outputs elements we can find the response of system to any arbitrary inputs. Therefore, using the redundancy of the system, both the translational and rotational motion of the object are controlled by the modulate transformers. These results shown in Fig. 5 and Fig. 6 and also the Continuous-time equations demonstrated by 20SIM are attached in appendix.

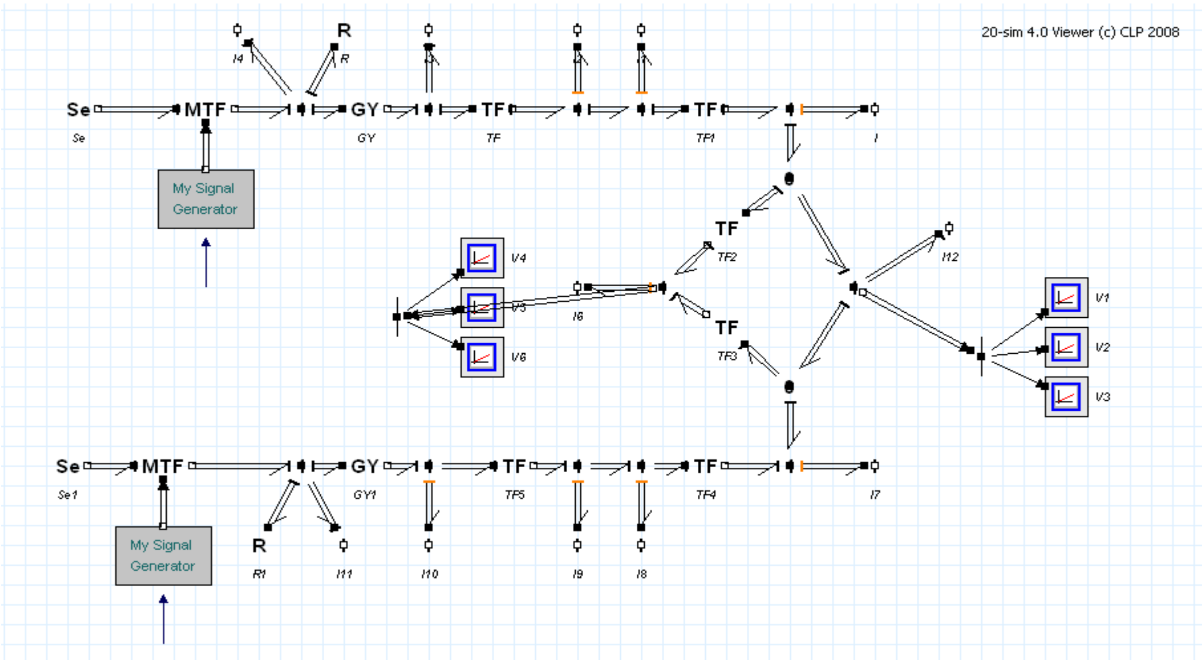

Fig. 5 bond graph model of the system in 20SIM

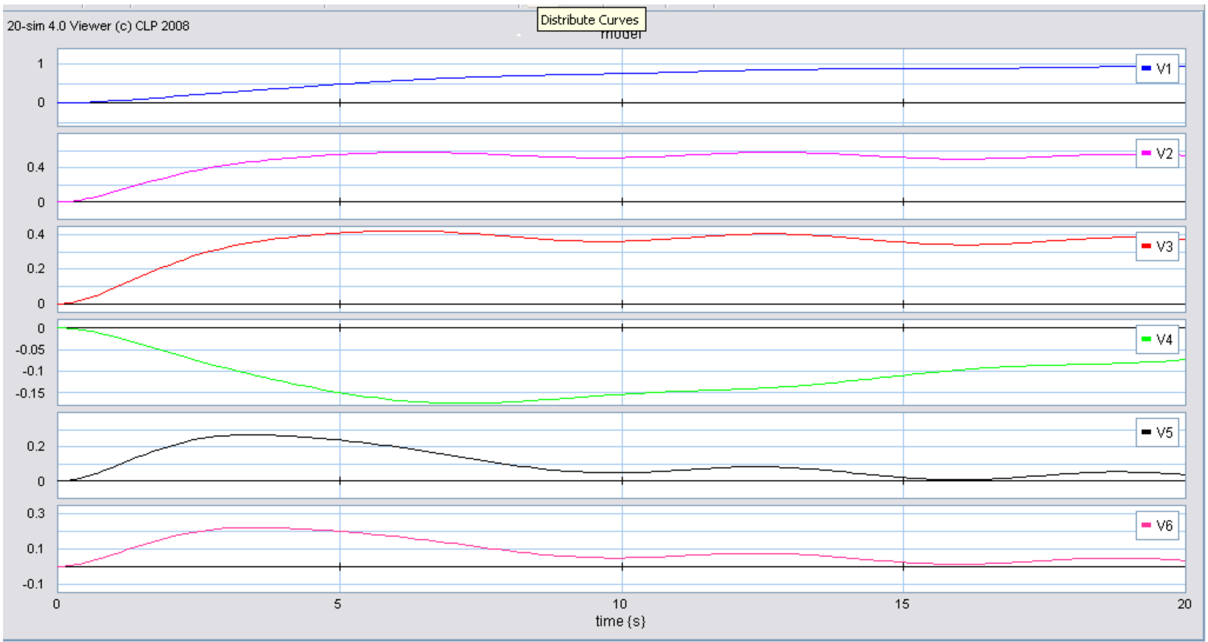

Fig.6 results of modeling through bond graph by 20SIM.

Conclusion

The results shows that we can control the translational and rotational velocities of center of mass of mobile robot by using bond graph model, and applying proper inputs corresponded to each state that robot will face. With regard to state space equations, system is LTI so we can control it by PID controller.

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