2012 IACSIT Coimbatore Conferences
IPCSIT vol. 28 (2012) © (2012) IACSIT Press, Singapore

Sliding Mode Control of Wheeled Mobile Robots

Tisha Jose [1 +] and Annu Abraham [2]

Department of Electronics Engineering
K.J Somaiya College Of Engineering, Vidyavihar, Mumbai
[1]tishajose1@yahoo.co.in and [2]annu_abraham@yahoo.com

Abstract. In this paper Sliding mode control of wheeled mobile robots using powerbot robot is presented. PowerBot is a mobile platform with two differential driving wheels and two balancing caster wheels. It is an automated guided vehicle specially designed and equipped for autonomous, intelligent delivery and handling of large payloads. PowerBot is a member of Mobile Robots Pioneer family of mobile robots, which are research and development platforms that share a common architecture, foundation software and employ intelligence-based client-server robotics controls.The PowerBot is a high-payload differential- drive robot for research and rapid prototyping. The programming for this Powerbot robot has been done in mobilesim and aria using c++. The results presented, shows the effectiveness of the proposed controller.

Keywords: Trajectory tracking, Sliding mode control, Kinematic model.

1. Introduction

Variable structure control (VSC) proved to be a robust approach in various applications, since it has begun its development in the 1950s, and can be used for the control problem of wheeled mobile robots. One particular type of variable structure control is the sliding mode control (SMC) methodology. Mobile robots control has been a very active research field for many years, motivated by the multitude of applications suitable for autonomous vehicles.

Out of all mobile robots the most important are the wheeled mobile robots, due to their simplicity and robustness. Such robots can be used in applications that include delivering components between assembly stations in factories, delivering food and medication in hospitals, cleaning rooms, mowing lawns or agricultural tasks. Some applications may take place in dangerous environments, for example nuclear waste facilities. All these applications require precise control.

Figure 1.Powerbot robot.

+ Corresponding author. *E-mail address*: tishajose1@yahoo.co.in.

The Figure 1.shows a PowerBot Robot which is a high- payload differential-drive robot for research and rapid prototyping. Featuring the same intelligence and maneuverability of our smaller platforms, PowerBot moves up to 1.6 m/s with a payload of up to 100 kg.It is an ideal platform for laboratory and research tasks involving delivery, navigation, and manipulation.The base PowerBot platform arrives fully assembled and ready for years of classroom and laboratory use. The steel frame and aluminum body support a wide range of accessories, including a 6-DOF arm, and the 2160 watt-hr batteries provide 4.5 hours of continuous runtime, including a full-size embedded computer.

In control theory, sliding mode control, or SMC, is a nonlinear control method that alters the dynamics of a nonlinear system by application of a discontinuous control signal that forces the system to "slide" along a cross-section of the system's normal behavior.The state-feedback control law is not a continuous function of time. Instead it can switch from one continuous structure to another based on the current position in the state space. Hence, sliding mode control is a variable structure control method.

To control the PowerBot, an advanced interface for applications called ARIA is used. ARIA is released under GNU Public License and complete with fully documented C++ libraries and source code. ARIA is the ideal platform for integration of robot-control software, since it neatly handles the lowest-level details of client-server interactions, including serial communications, command and server- information packet processing, cycle timing and multithreading.

In this we will be coming across Mobilesim and Aria software. Aria is basically an Activ Media Robotics Interface For Applications (ARIA).This is designed to get people up and running with ARIA in the fastest possible time.

2. Mobile Robot Kinematic Model

The model of a wheeled mobile robot is presented in Fig. 2. The model takes into account the two diametrically opposed drive wheels of radius R, the distance between the wheels (2L), the angular speeds of the drive wheels (ω_L ,ω_R) ,the center point (CP) of the robot. The pose of the robot is considered P=(x_R ,y_R ,θ_R)where x_R represents the position on the x axis, y_R the position on the y axis and θ_R the heading of the robot, v_R represents the linear velocity while ω_R represents the angular velocity of the robot.

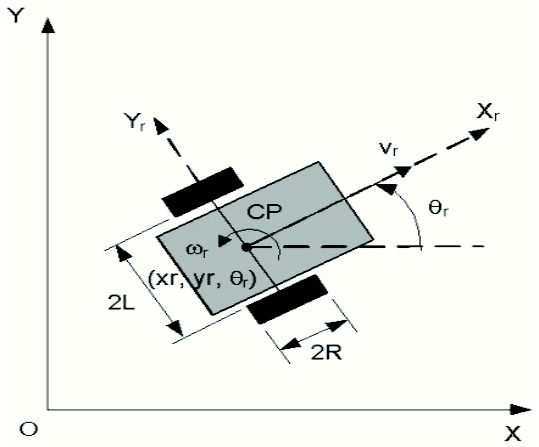

Figure 2.Kinematic model of mobile robot

$$\begin{bmatrix} x'_r \\ y'_r \\ \theta'_r \end{bmatrix} = \begin{bmatrix} \cos\theta_r & 0 \\ \sin\theta_r & 0 \\ 0 & 1 \end{bmatrix} \begin{bmatrix} v_r \\ \omega_r \end{bmatrix} \quad (1)$$

representing the nonlinear system.

Another form of the kinematic model is:

$$\begin{cases} x'_r = v_r \cos\theta_r \\ y'_r = v_r \sin\theta_r \\ \theta'_r = \omega_r \end{cases} \quad (2)$$

Considering a sample interval Ts and a zero-order hold, (2) changes in discrete-time to

$$\begin{cases} x_r[k+1] = x_r[k] + v_r[k] \cos\theta_r[k] T_s \\ y_r[k+1] = y_r[k] + v_r[k] \sin\theta_r[k] T_s \\ \theta_r[k+1] = \theta_r[k] + \omega_r[k] T_s \end{cases} \quad (3)$$

The trajectory tracking problem is how to design a controller capable of tracking a desired trajectory. For this purpose a virtual robot, with the desired trajectory $q_d(t)=[x_d(t)\ y_d(t)\ \theta_d(t)]^T$,is considered resulting the following kinematic model of the virtual robot:

$$\begin{bmatrix} x'_d \\ y'_d \\ \theta'_d \end{bmatrix} = \begin{bmatrix} \cos\theta_d & 0 \\ \sin\theta_d & 0 \\ 0 & 1 \end{bmatrix} \begin{bmatrix} v_d \\ \omega_d \end{bmatrix} \quad (4)$$

where $P_d=(x_d\ ,y_d\ ,\theta_d)$ represents the desired pose, v_d the desired linear velocity, ω_d the desired angular velocity. From (3) we obtain the following:

$$\begin{cases} x'_d = v_d \cos\theta_d \\ y'_d = v_d \sin\theta_d \\ \theta'_d = \omega_d \end{cases} \quad (5)$$

Equation (4) can be written in discrete-time as:

$$\begin{cases} x_d[k+1] = x_d[k] + v_d[k] \cos\theta_d[k] T_s \\ y_d[k+1] = y_d[k] + v_d[k] \sin\theta_d[k] T_s \\ \theta_d[k+1] = \theta_d[k] + \omega_d[k] T_s \end{cases} \quad (6)$$

The tracking errors of the robot shown below in Fig. 3 are expressed as:

$$\begin{bmatrix} x_e \\ y_e \\ \theta_e \end{bmatrix} = \begin{bmatrix} \cos\theta_d & \sin\theta_d & 0 \\ -\sin\theta_d & \cos\theta_d & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x_r - x_d \\ y_r - y_d \\ \omega_r - \omega_d \end{bmatrix} \quad (7)$$

In discrete-time domain (7) becomes:

$$\begin{cases} x_e[k] = x_{rd}[k].\cos\theta_d[k] + y_{rd}[k] \sin\theta_d[k] \\ y_e[k] = -x_{rd}[k].\sin\theta_d[k] + y_{rd}[k] \cos\theta_d[k] \\ \theta_d[k] = \theta_r[k] - \theta_d[k] \end{cases} \quad (8)$$

$$x_{rd}[k]=x_r[k] - x_d[k] \quad (9)$$

$$y_{rd}[k] = y_r[k] - y_d[k] \quad (10)$$

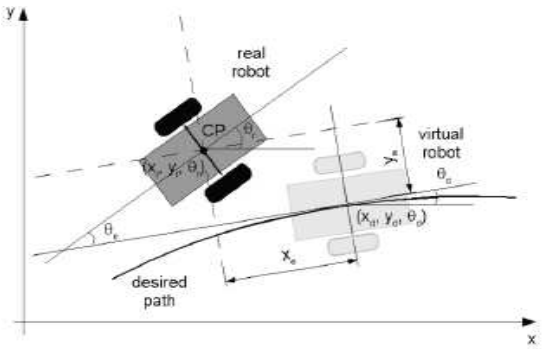

Figure 3:Trajectory Tracking Errors

The error dynamics for trajectory tracking is defined as:

$$\begin{cases} \dot{x}_e = -v_d + v_r \cos\theta_e + \omega_d y_e \\ \dot{y}_e = v_r \sin\theta_e - \omega_d x_e \\ \dot{\theta}_e = \dot{\theta}_r - \dot{\theta}_d \end{cases} \tag{11}$$

In discrete-time (11) changes to:

$$\begin{cases} x_e[k+1] = x_e[k] + (v1 - v_d[k] + y_r[k].\omega_d[k]).T_s \\ y_e[k+1] = y_e[k] + (v2 - x_e[k].\omega_d[k]).T_s \\ \theta_e[k+1] = \theta_e[k] + (\omega_r[k] - \omega_d[k]).T_s \end{cases} \tag{12}$$

Where

$$v1 = v_r[k].\cos\theta_e[k] \tag{13}$$

$$v2 = v_r[k].\cos\theta_e[k] \tag{14}$$

Wheeled mobile robots are increasingly present in industrial and service robotics, particularly when autonomous motion capabilities are required over reasonably smooth grounds and surfaces. Several mobility configurations (wheel number and type, their location and actuation, single- or multibody vehicle structure) can be found in the applications. The most common configuration for singlebody robots are differential drive and synchro drive (both kinematically equivalent to a unicycle), tricycle or car-like drive, and omnidirectional steering.

The kinematics model is a simplified representation that does not capture the rich dynamics of a moving robot, for example with unknown timevarying mass and frictions. The controller design using the WMR dynamics model allows to explicitly take into account robot physical parameters. The dynamics of WMRs has been investigated by three approaches: Newton method, Lagrange's equations, and Kane method.

Control of WMRs has also been studied from several points of view, including set point stabilization, trajectory tracking, path-following, etc. A topic still deserving research efforts is trajectory-tracking control for WMRs and other robotic mechanisms.The path has an associated velocity profile, with each point of the trajectory embedding spatiotemporal information that is to be satisfied by the WMR along the path. By other words, trajectory-tracking is formulated as having the WMR following a virtual target WMR which is assumed to move exactly along the path with specified velocity profile.

3. Use of Mobilesim and Aria in Project:

All the simulations are done on mobilesim. It is a software which is designed to simulate the behaviour of Mobile Robots/Active media platforms produced by Mobile Robots Inc.and their environments,for debugging and experimentation with ARIA. Mobilesim is software mobile robots and their environments for debugging and experimentation with ARIA .It converts a MobileRobots to a stage environments, and places a simulated robot model in that environment.It then provides a simulated pioneer control connection accessible via a TCP port. ARIA is able to connect to TCP ports instead of serial ports.

A window will appear ,displaying your map environment and robots.The robot will start at a home position in your map, if present or at the center of the map.The robots body is drawn based on the approximate length and width—including wheels—of the model selected.You can pan in the window by holding down the right mouse button and dragging towards or away from the center of the circle that appears.

4. Working In Mobilesim:

To simulate a robot you need a map file containing lines for walls. Mobilesim can be launched from the start menu. Load the Mobilesim and select the required map as shown in the Figure 4 .

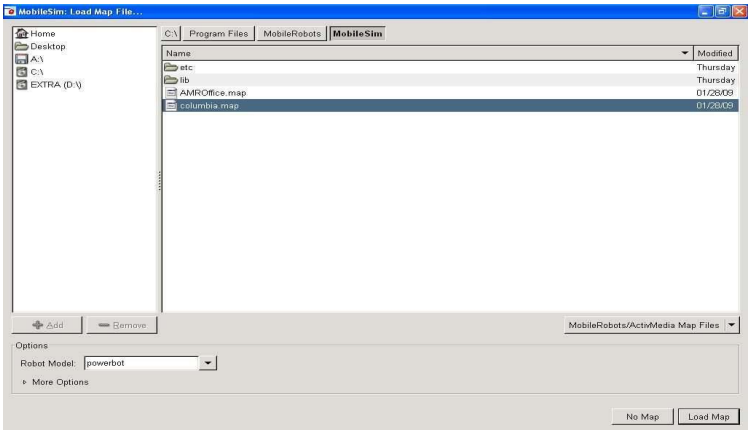

Figure 4 Loading of required map

The map file can be created using Mapper3 or can be loaded through Mobilesim software. Select any map out of the two Columbia or AMRoffice.map distributed with Mobilesim as shown in Figure 4.

From the robot model we can select any required robot model. In this case we have selected Powerbot robot.

Now go to the options window and start the ARIA software. You will come across a window in Aria.The robot will move on its own without any collision according to your instruction in ARIA. This mode is observed in Figure 5.

.

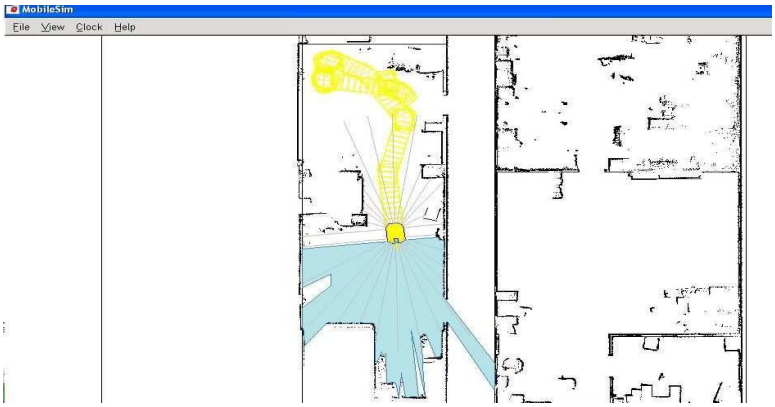

Figure 5.Movement of robot without any collision

Based on our requirement we can move the robot. The required instructions have to be put on the command window of ARIA.

5. Programming in C++

The programming of the sliding mode control of mobile robots is done in Microsoft Visual Studio or in C++.The required programming code for the Powerbot robot has been written and coded in Microsoft Visual Studio as shown in Figure 6.

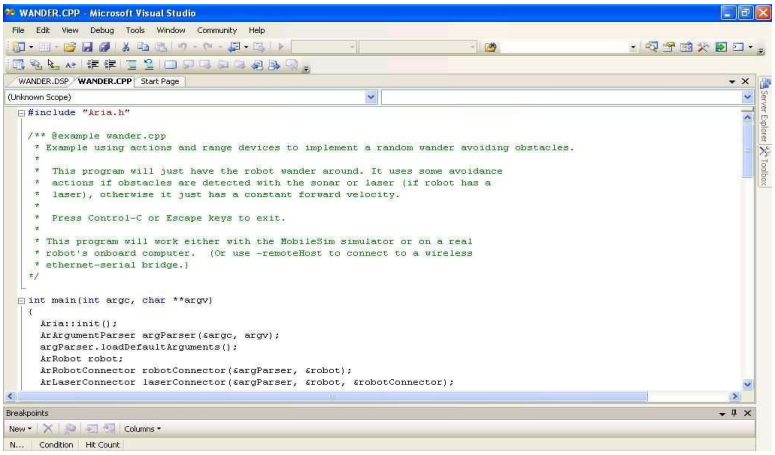

Figure 6.Coding

The code is successfully working. Thus showing the sliding mode control of mobile robots.

6. Conclusion:

The effectiveness of the proposed sliding-mode controller is proven using the required code. The desired performances for this controller is achieved. The controller is simple and easy to use. The PowerBot mobile platform controlled by the proposed sliding mode controller can be used in many practical implementations.

7. References:

[1] "Discrete-Time Sliding Mode Control Of Wheeled Mobile Robots" B. Dumitrascu, A. Filipescu, A. Radaschin, A.Filipescu Jr. E. Minca Departament of Automation, Computer Science and Electrical Engineering.

[2] "Trajectory-Tracking and Discrete-Time Sliding-Mode Control of Wheeled Mobile Robots". Adrian Filipescu, Viorel Minzu, Bogdan Dumitrascu and Adriana Filipescu.

[3] C.Chu-quing,G. Lian-zheng, and L. Rui-feng, "Mobile robots target tracking using finite-time convergence sliding mode controller controller," 8th IEEE International Conference.