An overview on real-time control schemes for wheeled mobile robot

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Abstract. The purpose of this paper is to review real-time control motion algorithms for wheeled mobile robot (WMR) when navigating in environment such as road. Its need a good controller to avoid collision with any disturbance and maintain a track error at zero level. The controllers are used with other aiding sensors to measure the WMR’s velocities, posture, and interference to estimate the required torque to be applied on the wheels of mobile robot. Four main categories for wheeled mobile robot control systems have been found in literature which are namely: Kinematic based controller, Dynamic based controllers, artificial intelligence based control system, and Active Force control. A MATLAB/Simulink software is the main software to simulate and implement the control system. The real-time toolbox in MATLAB/SIMULINK are used to receive/send data from sensors/to actuator with presence of disturbances, however others software such C, C++ and visual basic are rare to be used.

1. Introduction
Nowadays, mobile robots are a common use in many applications that represent a hazardous, complex, high accurate or hard tasks in worldwide fields, like aerospace, under-water, military, medicine. Usually the robot is supposed to navigate autonomously in restricted environments; which need high robust control to determine its path within terrain and avoiding obstacles. In some conditions such as road environments, it is indeed required to control robustly the robot in the planned path; otherwise it will crash cars or people.

The wheeled mobile robot usually move using the wheels like two, three and four wheel mobile robot. Two wheel robot or other name is Segway, this type is requires Gyro Sensor to keep it balance in order to remain stable. There are two types of three-wheeled robot. The first one is two differential drive wheel to move the robot plus caster wheel for balancing, others type is a synchronous 3 wheels robot which are both rotating by certain velocity at same time or 3 mecanum Wheels, which have a small cylinder rollers inside and allowing the mobile robot to move in all directions. Lastly, Four Wheeled Mobile Robot or Ackerman driving can be used for driving mobile robot which have two rear wheels that can move continuously, and the front wheel used as ordinary wheels.

A wheeled mobile robot’s navigation system controls a task in real-time such as control of motion, planning of the path, and self-localization. The control of motion is the important task to make sure the robot is operating well in restricted environment. The path planning is the process of finding a path for the moving of robot from the start destination to the end destination while avoiding obstacles and
disturbances. The self-localization is the robot’s skill to specify its position within restricted environment.

In this research, the wheeled mobile robots explores in restricted environment such as factories and road to find the location and then perform any kinds of work. The robot is using laser simulator for navigation system and controlled by active force control. The navigation system is important for generating road path in the whole of the environment and to find the robot position in the restricted environment. It is also to identify all obstacles and disturbance to the path that corresponds to the desired destination in real time. Laser simulator is important to carry out discovery tasks involving the use of sensors.

2. Kinematic Based Controllers

The kinematic based controller have been used to solve obstacle avoidance and tracking problem of wheel mobile robot with nonholonomic [1] and formation control of wheel mobile robot with virtual robot [2]. It is used also for tracking control problem when skipping and slipping for wheeled mobile robot [3], control a wheeled mobile robot using autonomous control in obstacles environment [4] and trajectory tracking for wheeled mobile robot in unknown longitudinal [5, 6] moving in cylindrical environment. It was used for round pipe [7], problem for estimate the slip ratio control of WMR and longitudinal velocity [8]. The PD controller [1] have been resulted big tracking error without PD controller (4.5m – 10m), with PD controller (4.9m-8.5m), then nonlinear control algorithm and cascade system theorem [2] have been resulted error 5 to 10 second to perform the desired formation. GPS-based tracking control and Real-Time Kinematic (RTK) [3] shown the error 0 to -1 and 0 to 4 degree then it stable after 20 second, then lagrange-D’alembert and backstepping-based control law [4], Unscented Kalman Filter and tracking control law [5] the error are close to zero with error 0.2 second. However, the control law and biaxial clinometer method [6] have been resulted much bigger error but remain stable after swinging several times and kinematic controller and Lyapunov stability theory [7] shown the error between actual and desired trajectory tend to zero in a short time. The adaptive unscented Kalman filter [8] have been resulted the big error for wheel angular velocity between measured and AUKF method. The slip ratio error of wheel mobile robot using AUKF is stable from time 2 second until finish and for measured slip ratio of wheel mobile robot, the signal error is oscillate from 0 to -0.2.

3. Artificial Intelligence Based Control System

The artificial intelligence based control system have been used to solve trajectory tracking problem of wheeled mobile robot [9, 10], to control of wheeled mobile robot to reach the target without crash with object and obstacles avoidance [11], the problem unknown disturbance, uncertain parameter and trajectory tracking control of wheeled mobile robot [12], formation control problem of nonholonomic for wheeled mobile robot [13], the basic nonholonomic navigation problem [14], problem to control the movement of outdoor mobile robot [15], the consensus problem for leader-following of wheeled mobile robot [16]. The D-type iterative learning control (ILC) [17] and control law method [18] have been resulted the value of tracking error decreases clearly and is close to zero in tenth iteration in 10 second, then fuzzy logic controller and lagrange’s equation [11,13] show the small error for mobile robot to avoid the obstacles and the error between leader robot follower robot 1, follower robot 2 and follower robot 3 has been resulted with big tracking error (0.1 meter, 0.4 meter, 1 meter) respectively. A adaptive-neural control law and Lyapunov-based stability analysis [12] shown the error between error 1 and error 2 is small error (0.2 meter). A neural network-based adaptive control [14, 18] have been resulted the tracking errors of velocities and posture in graph by using adaptive neural network controller is converge to minimum error and near to zero even if there are external disturbance. The adaptive control method and control law [16] show the result of trajectory tracking error is big error in 2 second and after 2 second the error maintain to zero.
3. Dynamic Based Controllers

The dynamic controllers have been used to solve dynamic design of omni-wheeled robot [19], control the path and motion of wheeled mobile robot [20, 21], control the external disturbance of WMR [22, 23], trajectory tracking control for two-wheeled mobile robot [24]. The Computed Torque Control (Vishal A. 2016) [19] and nonlinear model predictive control (NMPC) [20] have been resulted with big tracking errors (0 - 0.5m), (-0.5 - 0.2) respectively, however disturbance observer and dynamic controller [22], Sliding mode dynamic controller (SMDC) [23] and Lyapunov theory and nonlinear controller [21] are tended to be zero in a short time. The sliding mode control [24] have been resulted the small error between actual trajectory and reference trajectory. The time response error of simulation 1 and simulation 2 is become stable after 5 second.

4. Active Force Controller

The AFC has generally two loops; first loop is used for kinematic parameters control and another loop for dynamics control of mobile robot. The active force control have been used to solve reject the unwanted disturbance of frictional force in pike [25], tracking the wheeled mobile robot in pre-planning path in difficult environment [26], the problem to remove the effect of disturbance in the system and any disturbance in the dynamic system [27], problem to reject the disturbance and noise [28, 29, 30]. The Proportional-integral-derivative (PID), Active Force Control and sliding mode controller (SMC) [25] have been resulted the PID without AFC is the signal error oscillate from 1 second to 10 second and after 10 second the signal become stable at zero level. Resolved Acceleration Control (RAC) with Active force control (AFC) [26] have been resulted no difference between reference path and actual path when there is no disturbance for RACAFC. With constant disturbance, the tracking error has significant difference between reference path and actual path which is small error in power 10^-2. A feedforward active force control control (AFC) with Robust controller [27] and active force control (AFC) with computed torque control [28] show the result tracking error is AFC is perform to oscillate between -0.01 to 0.02 rad. only compare to compute torque that oscillate from -0.04 to 0.03 rad. AFC is perform more better than much lower than compute torque.

5. Conclusion

This review paper shows how to solve the control problem for wheeled mobile robot in many environments using different controller. Most of the controllers that have been used are in the form PD controller, kinematic and dynamic based controllers, Fuzzy logic controller, active force controller. Most of the mobile robot control show good performance to control the robot but it still has some errors and not accurate 100%; however the active force control can guarantee to reach zero level error.

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