Motion Planning & Control of Skid-Steered Mobile Robot

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***Abstract*— This paper reports the design; development and evaluation of a prototype four wheeled Skid-Steered Mobile Robot to execute in two different motion schemes. First, different types of locomotion systems used for mobile robots are compared and their pros and cons are presented. Then the mechanism designed for the prototype wheeled SSMR is described with the aid of a CAD model. To validate the designed algorithm, extensive simulation results for trajectory tracking and set-point cases are discussed. Finally, the results of field testing of the actual robot are presented and the behavior of wheeled Skid-Steered Mobile Robots in presence of slippage is discussed.**

***Keywords*- Locomotion System, Mobile Robots, Skid-Steering, Slippage**

I. Introduction

In recent years a growing interest in the mobile robotics area is perceived. Tons of research concentrates on the description of kinematic models of mobile robots and designing feedback control laws for non-holonomic systems.

Researchers typically consider wheeled platforms with non-holonomic constraints while assuming perfect rolling. Modern and specialized uses of mobile robots are constantly picking up in significance, specifically under contemplations of dependability (continuous and dependable execution of repetitive assignments, for example, surveillance), openness (review of locales that are blocked off to people, e.g. tight spaces, perilous situations alternately remote locales) or expense (transportation frameworks in view of self-sufficient mobile robots can be less expensive than standard track-bound frameworks). It is clear that a scope of key skills should be accessible for a mobile robot to be helpful. The robot must work securely, i.e. it must stay away from risks, for example, snags or working conditions perilous to the robot itself (e.g. plummeting stairs), and it must represent no danger to people in the region of the Robot.

There are three fundamental configurations of locomotion system for a mobile robot, i.e. rolling, ambulatory and articulated body. Locomotion system based on the endless rotation of wheels or crawlers, corresponds to the rolling configuration, while legged locomotion systems corresponds to the ambulatory configuration. Similarly, slithering or snake-type locomotion system corresponds to the articulated body configuration. In addition, there may be a combination of these three configurations, which is commonly termed as hybrid locomotion system [1].

Each locomotion system in mobile robots has its own advantages and disadvantages. For example, mobile robots, based on wheeled locomotion system provide high speed maneuverability and high payload capacity. These are relatively simple to construct, energy efficient and easy to control but they have poor terrain adaptability [2]. Furthermore, wheeled mobile robots cannot go through obstacles with height larger than the radius of the wheel and therefore only suitable for flat or smooth terrains [3].

Tracked mobile robots have demonstrated favorable circumstances to wheel construct ones when moving in light of low contact weight grounds (free soil, profound mud, and snow) and unpleasant surfaces. The increment in the portability is possible by changing so as to protract the chains or their shape. This is accomplished through including one or more passive tensioning wheels and adjusting the type of the suspension or trough lifting of the drive wheels hub.

Legged vehicles display a prevalent mobility in asymmetrical landscapes, subsequent to these vehicles may utilize discrete dependable balance for every foot, contrary to wheeled vehicles, that need a constant bolster surface. In this manner, these vehicles may move in variable territories, by fluctuating their legs plan in solicitation to conform to surface sporadic ties, however, the feet may set up contact with the ground in selected centers according to the passage conditions. Thus, legs are characteristically satisfactory systems for movement in irregular ground. Additionally, the utilization of various degrees of freedom (DOF) in the leg joints, allows legged vehicles to change their path without slippage [4].

Skid Steered Mobile Robots (SSMR) are extensively used because of their user friendly mechanism and high reliability. Understanding the kinematics and dynamics of such a robotic platform is, however, challenging due to the difficult wheel/ground interactions and kinematic restraints. [5].

The steering of a SSMR is accomplished by differentially driving wheel pairs on each side of the robot. In spite of the fact that the guiding plan yields some mechanical benefits, the control of a SSMR is a stimulating assignment on the grounds since the wheels slide and skid laterally to follow a curved way.

In this work, a prototype skid-steered mobile robot is designed and developed for the terminal goal to complete a 3X3 meter square predefined trajectory by implementing autonomous trajectory tracking control. The designed mechanism is described with the help of a CAD model. Finally, the performance of the robot is evaluated and the overall behavior of the SSMR is discussed.

II. RELATED WORK

Skid-steered mobile robots provide better traction than differential drive mobile robots. Due to this, they are suitable for both indoor and outdoor applications.

An improvement in real-time motion control and dead-reckoning of wheeled skid-steer vehicles by considering slippage effect is made by [6]. The traction scheme is successfully applied to a popular robotic platform, Pioneer P3-AT, with different kinds of tires and terrain types.

The Pioneer P3-AT has a 4-wheel drive skid-steer platform. It measures approximately 0.5m in length and is 0.25m tall. Tread length (i.e. the distance between the front and rear wheels) is 0.27m. The robot weighs 23.6kg and can carry a 35kg payload. P3-AT receives commands from a PC and sends operational information under a built-in-client-server architecture. Auriga-ß, a dual-track mobile robot, developed for fire extinction task, weights 286 kg and equipped with self-stabilized landing platform for mini-helicopters [7]. Amoeba-II developed for urban search and rescue applications, consists of two modular tracks connected through a yaw joint, and is capable of changing its posture according to the environment [8]. HELIOS-VIII, a tracked vehicle equipped with a manipulator is presented by [9].

III. DESIGN DESCRIPTION

The mechanical framework is constructed on the basis of skid steering locomotion system. Two wheels on the left half of the convenient robot were joined together through belt pulley frameworks which make them pivot at the same rate. On the right side the same design was connected. The mobile robot in this way can be control by controlling the pace of the wheels on the left and right side as shown in Fig. 1. In the event that the left wheel is turning clockwise and the right wheel is turning hostile to clockwise then the mobile robot will turn clockwise. On the off chance that it is the inverse then the mobile robot will turn hostile to clockwise. Accelerating the mobile robot forward or reverse can be performed by turning both the left and the right wheels clockwise or anti- clockwise. The platform is composed in a manner that not a piece of the build outstrips the body surface. The benefit of this framework is that if an accident occurs of impact the body parts and exceptionally the delicate devices, for example, sensitive hardware and sensors not specifically crashes into the hindrances, and is kept from being harmed.

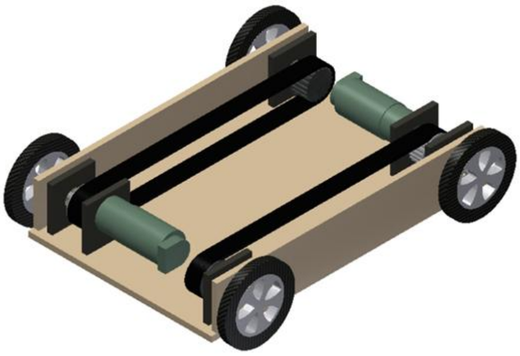

Fig.1. CAD model of the prototype design

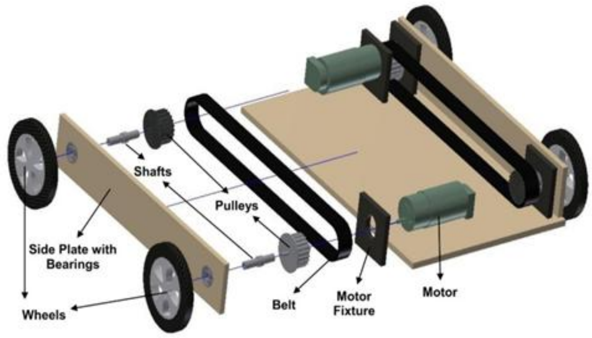

Fig.2. Detonated view of the platform CAD model of the prototype design

Fig. 3: Chassis Assembly

The detonated view of the SSMR is demonstrated in Fig. 2. Despite single body, the structure is assembled by joining differing parts to each other. There is an another purpose of preference in light of the way that if in future there is a need to change the design to consolidate included components or sections, for instance, a manipulator arm, then as opposed to overhauling the entire assembly a certain part can be attuned that is elementary and economically smart.

A DC geared motor from Pittman motor was joined with the pulley belt gear framework on each side of the convenient juncture as shown in Fig.3. The motor is couple with a planetary rigging head with 19:7:1 gear proportion. The DC motor operates on 30.3V power supply and the most extreme accessible torque when consolidate with the planetary rigging is 0.76 N/m. The greatest pace of the motor after gear reduction is around 207 rpm and this mean pretty nearly 0.13 m/s direct speed of the mobile platform. The DC gear motor is additionally outfitted with an optical encoder which takes into account position and speed sensing.

IV. PERFORMANCE EVALUATION AND DISCUSSION

The designed prototype performed considerably well as completed the square path of 3m x 3m by moving forward along the straight path and then rotate 90 degree clockwise about the center point. The speed is detected in the range of 0.2m/s to 1 m/s for the SSMR to complete the square path in autonomous motion scheme. The detailed specifications and performance parameters are summarized in Table I.

Table I: Specifications & Parameters of the Actual Robot

Chassis Length	520 mm
Width	340 mm
Height	153 mm
Total Mass	18.5 kg
PayloadCapacity	>20kg
MaximumVelocity	3.6 Km/hr
Trackbelts	8mmHTD Belts
Drive Motors: Pittman DC Motors with Planetary gear head and encoders	02 Motors

The experimental outcomes demonstrates that the prototype wheeled SSMR's performance is quite satisfactory. The platform exhibits stability while completing the predefined trajectory as shown in Fig. 4. No loss of traction was observed during the operation of SSMR in autonomous and semi-autonomous operation. The autonomous and semi-autonomous operations are illustrated in Fig. 5.

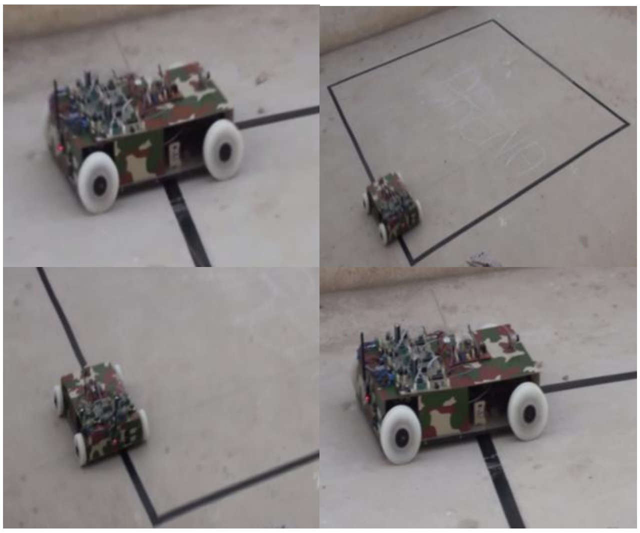

Fig. 4. SSMR Completing Predefined Trajectory

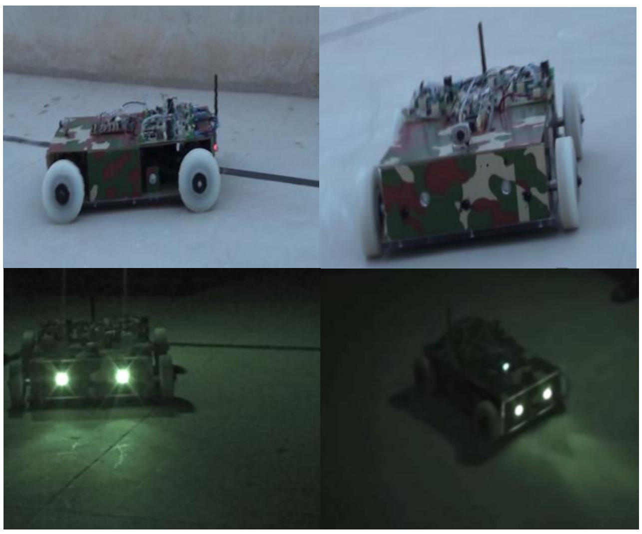

Fig. 5. SSMR Semi/Autonomous Control

First, it provides simplicity and robustness in mechanical terms; second, it only utilizes components required for straight line motion.

Wheel-track locomotion system is implemented in the SSMR. Skid-steering method is widely used in circumstances where the controlling of relative velocities is concerned. Skid-steered locomotion system provides two advantages of utmost importance over other wheel configurations.

Furthermore it allows better maneuverability including zero-radius turning. Certain velocity constraints of SSMRs are quite different from other mobile platforms where, there is an absence of lateral skidding phenomenon.

Due to different unlike ground surface conditions and track-terrain interactions, it is difficult to determine kinematic and dynamic models for the SSMRs. Control inputs are not enough to facilitate in the prediction of the exact motion of the vehicle. This means that the control methods of differential drive mobile robots are not applicable on vehicles, based on the skid-steered locomotion system.

The counterpart research on the control of skid-steered mobile robots is less frequently reported as compared to different locomotion mechanisms. Hence, the motion control of skid-steered tracked mobile robots in skid-slip conditions still remains a challenge.

The future work includes a number of general problems to be solved in order to advance the described SSMR. Gyroscopes and accelerometers can be used for measuring and maintaining orientations and proper acceleration of the SSMR. Trajectory tracking control of the SSMR for curvilinear trajectories in autonomous operation will be a great deal of effort to enhance the trajectory tracking control. GPS (Global Positioning System) and a manipulator arm can be incorporated in order to perform several tasks and locate the position of the SSMR.

V. EXPERIMENTAL RESULTS

Several tests have been carried out in order to analyze the proper functionality of the SSMR presented in this work. MATLAB is used to simulate and display the experimental results. A proportional controller is used for trajectory tracking and the outcomes in Fig. 6(a, b, c, d) demonstrate that the described SSMR is capable to complete the planned trajectory within some displacement errors.

The comparison of simulated and real-time results can be seen in figure 6 that compares the simulated and actual responses of both DC motors. The errors are originated from some resources such as misalignment in wheels and friction effects. The result presents the general odo-metric precision of the SSMR. The experimental tests of the SSMR are taken with different speeds. Additionally the simulated results also compare the real world and simulated responses at different speeds of SSMR.

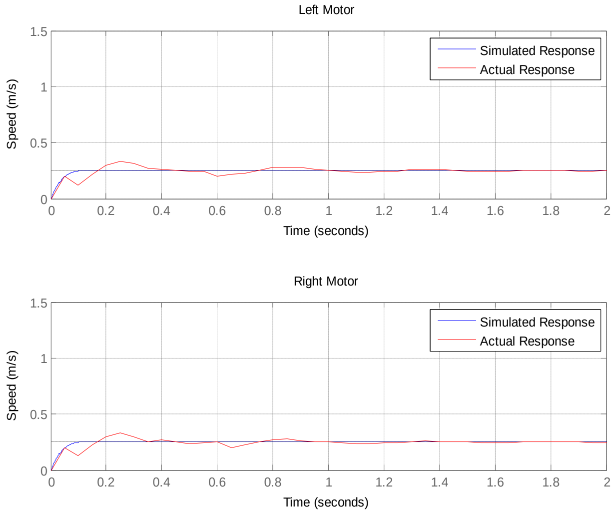

Fig.6(a) Step Response for Speed = 0.25 m/s

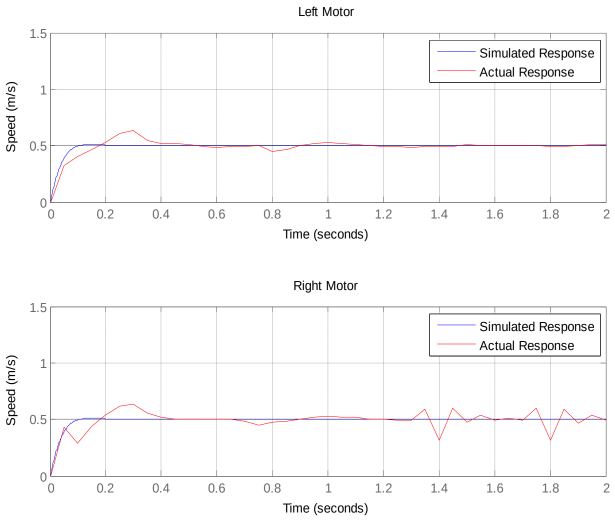

Fig. 6(b) Step Response for Speed = 0.5 m/s

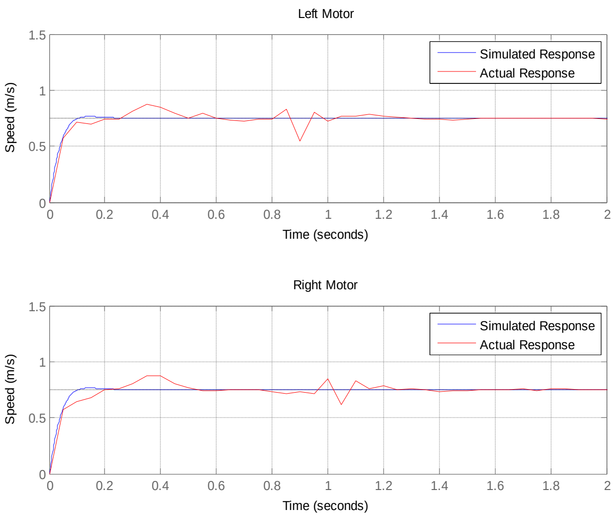

Fig. 6(c) Step Response for Speed = 0.75 m/s

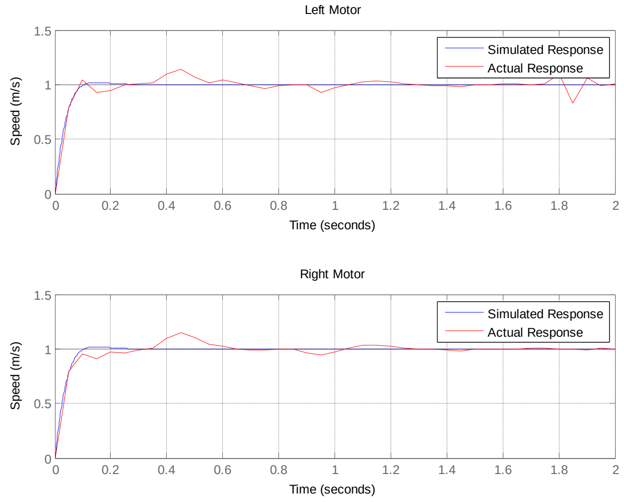

Figure 6(c) Step Response for Speed = 1.0 m/s

Additionally, the analysis of SSMR in autonomous motion scheme involves certain simulated results for linear and rotational motion. Fig. 7(a) and 7(b) shows the responses of trajectory tracking along the square path.

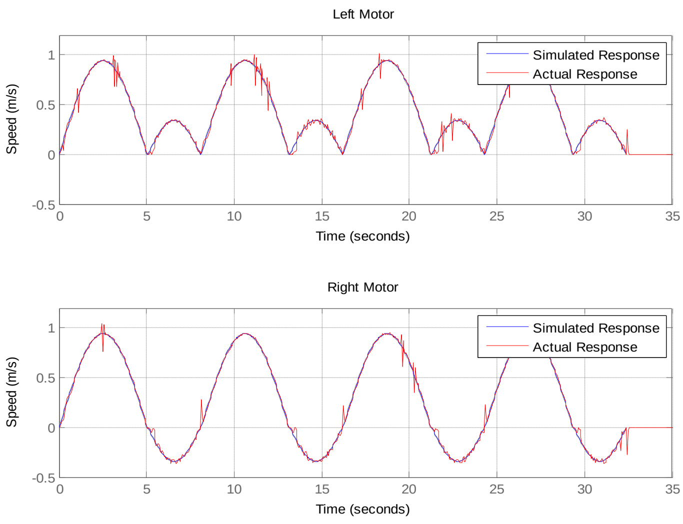

Fig. 7(a) Trajectory Tracking Response along Square Path

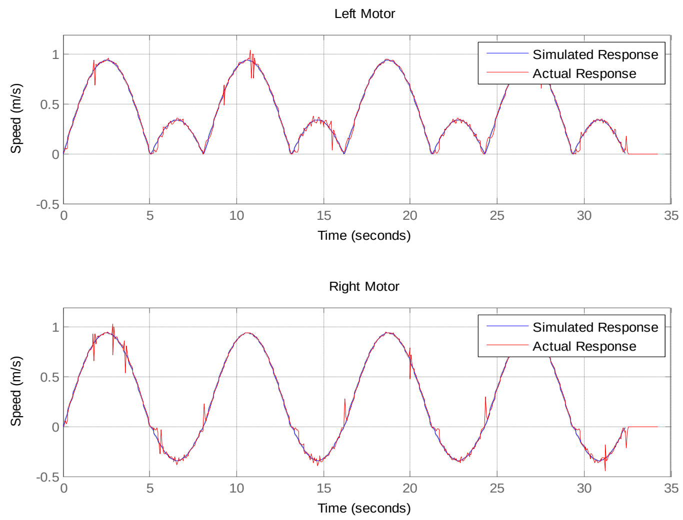

Fig. 7(b) Trajectory Tracking Response along Square Path

VI. CONCLUSION

In this paper a prototype of a four wheeled Skid-Steered Mobile Robot that can execute in two different motion schemes is presented. To validate the designed algorithm, extensive simulation results for trajectory tracking and set-point cases are performed. Finally, the results of field testing of the actual robot are presented and the behavior of wheeled Skid-Steered Mobile Robots in presence of slippage is discussed.

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