CHAPTER V

MOTION CONTROL

5.1 Introduction

Control structure of the robot is divided into 3 main loops. The largest loop is a robot command position, received input from the operator. The second loop, traction control, received angular velocities from all wheels and compare with the robot velocity and then send a control signal to the lowest level, wheel motion control loop. As shown in the following schematic.

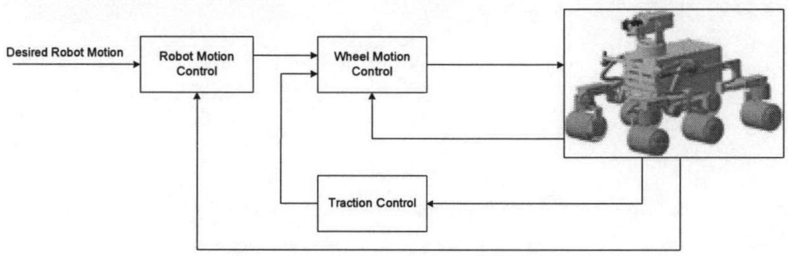

Figure 5.1: Control Structure

5.2 Motion Control

All six wheels and four steering joints are driven by DC servo motors which can be individually controlled using standard PID controller. Each motor is held at the desired position or rotating at desired speed by applying a restoring force to the motor that is proportional to the position error, plus the integral and the derivative of the error. The expression for the PID controller in the continuous domain is

$$H(s) = K_p + \frac{K_i}{s} + \frac{K_d}{s} \tag{5.1}$$

where K_p = proportional coefficient

K_i = integral coefficient

K_d = derivative coefficient

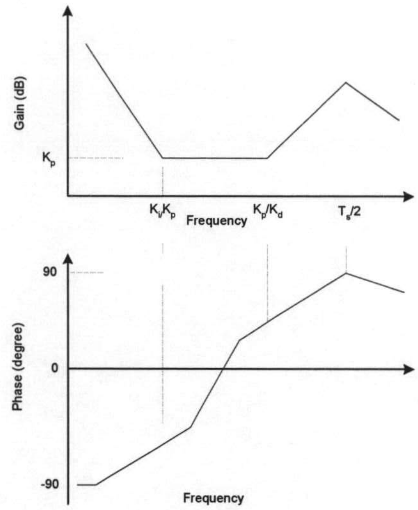

Figure 5.2: Bode Plots of PID Transfer Function

The Bode plots show the effect of the individual terms. K_p provides adjustment of proportional gain. K_d increases the system bandwidth but adds leading phase shift to the control loop at high frequencies. This improves stability by counteract the lagging phase shift by other components such as motor. K_i provides high DC gain to reduce static error but introduces a lagging at low frequencies. The relative magnitude of K_p, K_i and K_d have to be adjusted to optimum performance without introducing instability.

We use K_p = 150, K_i = 5 and K_d = 20 equally in all wheels and steering.

5.3 Velocity Profile (Trajectory) Generation

The trapezoidal velocity profile generator computes the desired position of the motor versus time. There are 2 modes of operation. In the position mode, the processor specifies acceleration, maximum velocity and final position. Profile generator uses this information to affect the move by accelerating as specified until maximum velocity is reached or until deceleration must begin to stop at the specified final position. At any time during the move, the maximum velocity and/or the final position may be changed.

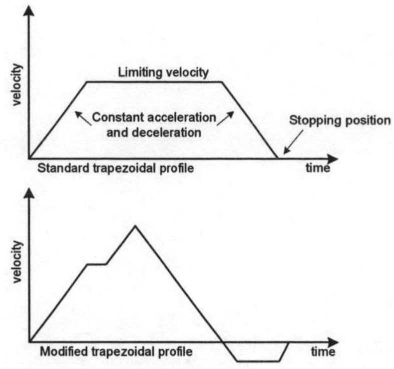

Figure 5.3: Typical Velocity Profiles

In velocity mode, the motor accelerates at specified rate to the specified velocity and maintains the specified velocity until commanded to stop. The velocity is maintained by advancing the desired position at constant rate.

5.4 Slip Ratio

In Chapter 4, in order to derive kinematics modeling, we assume that there is no side slip and rolling slip between wheel and ground. Then slip must be minimizing to guarantee accuracy of the kinematics model.

The slip ratio S of each wheel is defined as follows:

$$S = \begin{cases} (r\dot{\theta}_w - v_w)/r\dot{\theta}_w & (r\dot{\theta}_w > v_w : accelerating) \\ (r\dot{\theta}_w - v_w)/v_w & (r\dot{\theta}_w < v_w : decelerating) \end{cases} \quad (5.2)$$

where r = radius of the wheel

θ_w = rotating angle of the wheel

$r\dot{\theta}_w$ = wheel circumference velocity

v_w = traveling velocity of the wheel

The slip ratio is positive when the robot is accelerating and negative when decelerating.

5.5 Traction Control

From the slip ratio, a robot can travel stably when the slip ratio is around 0 and will be stuck when the ratio is around 1. To gain maximum traction, we must keep the slip ratio as low as possible.

By measuring of the wheel angles conjunction with information from the accelerometer, we can estimate slip and adjust wheels' speed to improve the traction of the robot.

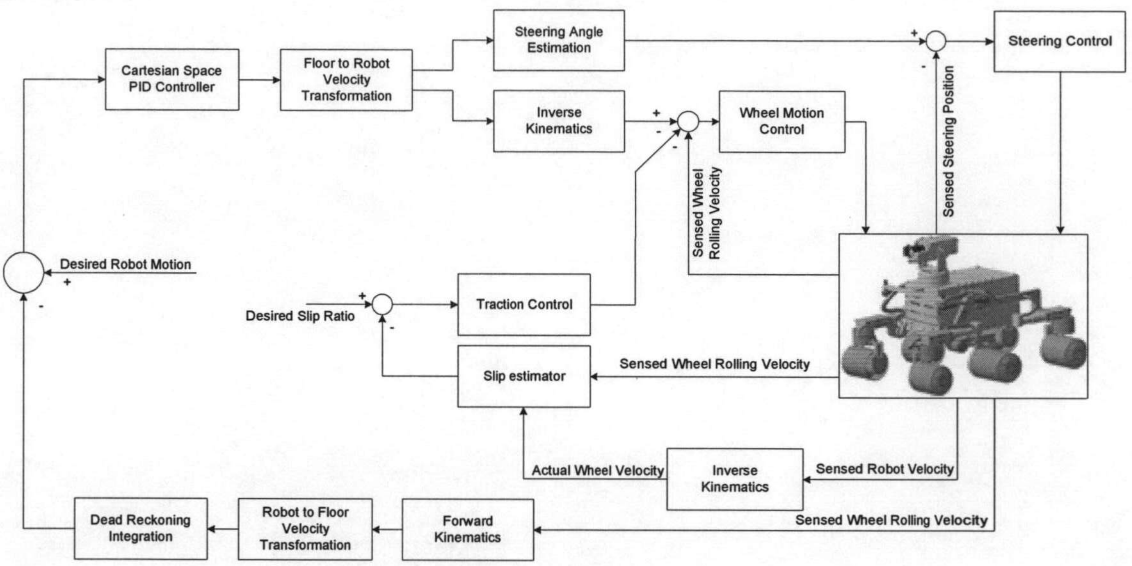

Figure 5.4: Robot Control Schematic

In the traction control loop, a desired slip ratio S_d is given as an input command. The feedback value $\hat{S}$ is computed from a slip estimator. To complete the estimation of the slip, we need the angular velocity and the traveling velocity of the wheels, ω and v_w. Angular velocity of the wheels is easily obtained from encoders which installed in all wheels. Traveling velocity of the wheel can be computed from robot velocity by using data from onboard accelerometer.

The controller goal is to minimize wheel slip while tracking desire wheel rolling velocity. If a wheel is rotating too fast compare to traveling velocity, this means slipping may be occurred. The angular velocity and torque of the wheel must be reduced until the traction force is below maximum shear stress of the ground.

It can be seen that the wheel angular velocity do not exactly converge to the desire angular velocity. This is because the controller primary task is to keep slip ratio at minimal, not only to track the desire angular velocity.