# University of Glasgow

# James Watt School of Engineering

# Simulation of Engineering Systems 3

## Assignment: Turning Control System for a Wheeled Rover

## Part 2: Model & Simulation Based Design

### Aim

Part 2 of the Simulation of Engineering Systems 3 Assignment involves the model based design of the control system for the Turning Control System for a Wheeled Rover simulation that you developed in Part 1 of the assignment. This part of the assignment involves improving the controller design for this system using the Matlab version of your simulation. Once your control system is making your simulated system perform better, you should study the effects of changing a key system parameter through the interpolation of data. For the Wheeled Rover Turning Control System the key parameter is the resultant forward velocity, $V_T$. This document provides an overview of the control system used in this simulation followed by the Assignment Specifications for this final part of the assignment.

### Introduction

The initial design of the Wheeled Rover Turning System, which was developed in Part 1 of this assignment, was not very good i.e. very oscillatory. The reason it was not very good was that the design of the controller was not suitable for this system. Therefore, Part 2 of the assignment involves the redesign of the control system so that the performance of the overall system is much improved.

The second stage of Part 2 of the assignment is to test the redesigned control system by varying a key parameter that has been constant in the earlier stages of this assignment. In the case of the Wheeled Rover Turning Control System the key parameter is the resultant forward velocity $V_T$. This represents the longitudinal velocity of the rover and the variation of this value represents approximate changes in the longitudinal dynamics. In this assignment the variation in values is achieved by interpolating data points that represent the velocity at specific time points.

### Problem Specification

The Assignment Specification Document for Part 1 indicated that the turning control system produces the required wheel speeds to generate a coordinated turning manoeuvre that changes the rover's heading or yaw angle. It achieves this by comparing the actual yaw angle, $\psi$ (radians), with the reference heading, $\psi_{ref}$ (radians). A diagram of the total system is shown in Figure 5.

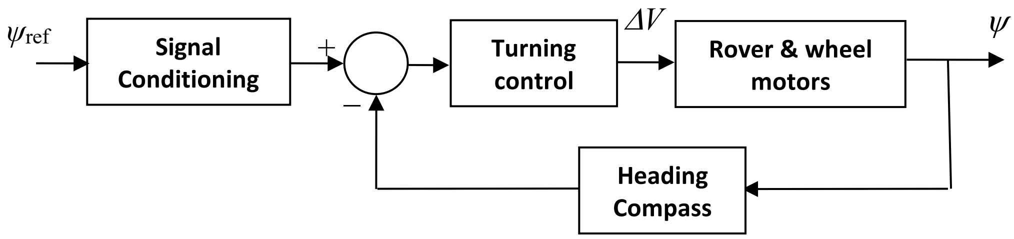


Figure 1: Rover Turning Control System

From Figure 1 it can be seen that the Turning Control System uses the error difference between the reference yaw angle, $\psi_{ref}$, and the rover's actual yaw angle, $\psi$. In this case the value for $\psi_{ref}$ (the reference heading) is taken to be 55°, which passes through the Signal Conditioning system (represented by a simple gain $K_C$). The yaw angle, $\psi$, is measured using the Heading Compass which is represented by a simple gain $K_H$. The comparison of these values is performed by a turning control system. The first control system design, used in Part 1 and at the beginning of Part 2 is a proportional control system i.e.

$$\Delta V = G_C \Delta \psi \tag{1}$$

Here $G_C$ is the controller's proportional gain. The performance of this control system can be improved by changing the gain value for $G_C$. Another way to improve performance is to add an integral term into the control system i.e. it then becomes a PI controller of the following form:

$$\Delta V = G_C \left(1 + \frac{K_I}{s}\right) \Delta \psi \tag{2}$$

Here $K_I$ is the integral gain, and $s$ is the Laplace operator. The resulting commanded heading angle $\psi_c$ is then fed into the lateral autopilot to generate an appropriate heading for the rover to follow ($\psi$).

**Assignment Specifications**

The main purpose of this second and final part of the assignment for this course is to redesign and test the control system so that the Rover Turning System performs better. This involves completing the following steps:

*Control System Design & Implementation*

1. Using your Matlab script based simulation and the parameter values in Appendix A, investigate the effect of varying the Turning Controller gain $G_c$ on the performance of the Rover Turning System.
2. In order to improve the performance of the Turning Controller further it is normal practice to include an integral term within the controller of such a Rover Turning System. Use your Matlab simulation and the best value for $G_c$ (found in step 1 above) to investigate the effect of introducing the integral term into your coupler and varying the associated gain $K_I$. Is the performance of this system improved? **Do not** use any of the in-built MATLAB functions to introduce the integral term i.e. write your own code.

*Interpolation*

3. So far the longitudinal dynamics of the Rover have been considered to be constant. One way to incorporate these dynamics is to vary the resultant forward speed of the Rover, $V_T$. Within your Matlab simulation use the data presented in Table 1 (Appendix B) to represent the change in the speed of the rover as time progresses as time progresses by using Newton's Divided Difference interpolation method. Firstly, use this method to calculate by hand the interpolating polynomial that represents the speed values that connect the data points in Table 1.
4. Implement the resulting interpolating polynomial within your Matlab simulation code and analyse the effect of forward motion on the Rover Turning System. **Do not** use the in-built Matlab interpolation functions i.e. write your own code.

**Report Part 2 Specifications**

Once you have finished this part of the assignment, complete the report form for the second part of the assignment. This report form should outline the redesign of your control system for your model, the interpolation of the range in your simulation and your analysis of this system in each case. The Part 2 report form template can be found on the moodle page for this course. Your completed report for this final part of the assignment must not exceed 5 pages in length and it should be submitted through the moodle submission portal for part 2 of the assignment before 4:30pm on **5th December 2025**.

**Appendix A: Parameter Values**

The following parameters are typical for the Rover and its Turning Control System:

$B_S$ = 0.02Nm/rad/s
$G_c$ = 11.6
$J_M$ = 0.003 kgm$^2$
$J_W$ = 0.001 kgm$^2$
$K_C$ = 1.2
$K_D$ = 18.14
$K_E$ = 0.35 V/rad/s
$K_H$ = 1.2
$K_S$ = 9.81
$K_T$ = 0.35 Nm/A
$K_V$ = 0.486
$K_Y$ = 29.94
$L$ = 0.16 H
$R$ = 5.4 Ω
$R_M$ = 0.124m
$R_W$ = 0.064m
$V_D$ = 3.0 V
$V_T$ = 0.75 m/s

Typical initial conditions are:

$\psi_o$ = -12°
$r_o$ = 1 rad/s
$v_o$ = 0 m/s

**Appendix B: Velocity Variation**

The following table contains data points that describe how the resultant forward velocity of the rover changes with time:

Table 1: Velocity Data

| Time (s) | 0 | 1.2 | 3.2 | 6 | 9 | 10 |
|---|---|---|---|---|---|---|
| $V_T$ (m/s) | 0.72 | 0.8 | 1.5 | 0.6 | 0.4 | 0.2 |

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