Phase 4: Damped Harmonic Oscillator

MEEN 357-505, Team 07:
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"An Aggie does not lie, cheat or steal or tolerate those who do."

"None of the members of the team communicated in any way with other teams with regards to specific coding issues with this project."

Introduction

A Mars rover is to be optimized so that its cost and mission time is minimized while not compromising its strength. The rover is delivered to the surface of Mars using an Entry, Descent, and Landing system (EDL). While many of the variables are fixed, other variables can be changed by the user: ex. motor type, battery modules, and material of chassis. The maximum budget of the rover should not be exceeded.

Formulating Design Problem

The changeable variables are tested with different values to determine which solution causes the rover to complete the mission the fastest. For qualitative variables, a random search method was used to individually test each method to determine the optimal solution. For quantitative variables, either an optimizer function, coding loop, or numerical method was used.

Selecting Final Design

When designing the rover specifications, the rover should complete the mission in the least amount of time and be under the maximum budget. Cost is not a primary criterion since in most cases, it is difficult to exceed the maximum budget.

First, using a random search method, the ideal qualitative variables were determined to minimize the mission time. Some experimented variables include battery type, chassis material, and motor type. The energy density for batteries was calculated by hand as shown by the following:

Table 1: Battery types.

Identifier String	Description	J/kg	J/$	
`LiFePO4`	36V module made of Lithium-Iron-Phosphate cells	26024.1	0.4032	13012.3
`NiMH`	36V module made of Nickel-Metal-Hydride cells	29958.4	0.5184	14979.5
`NiCD`	36V module made of Nickel-Cadmium cells	13542.6	0.3624	6771.48
`PbAcid-1`	36V module made of Lead-Acid cells, variant 1	14600	2.92	7301.46
`PbAcid-2`	36V module made of Lead-Acid cells, variant 2	14600	41.7143	7320.86
`PbAcid-3`	36V module made of Lead-Acid cells, variant 3	14600	3.86471	7301.93

Since the cost was not an issue at this point in the optimization, the most energy-dense battery was chosen. Similar hand calculations were completed to find the energy-to-cost ratio from the batteries.

"For loops" were implemented to search for the smallest diameter parachute that would not cause the rover to crash. Another Loop was used to select the least amount of required battery cells to provide just enough energy to complete the mission.

Design Solutions Considered

Depending on the terrain characteristics, some rovers may be faster than others. For example, having a high torque and large wheel size may be faster for off-road terrain while having a lower torque and smaller wheel size may be faster for flatter terrains. Below is a list of possible design combinations considered:

- High torque - high weight
- High speed - low speed
- Medium speed - medium torque
- Low cost - low success rate
- High cost- high success rate
- Medium cost - medium success rate

Our group found that a high cost - high success and high speed - low weight rover yielded the fastest mission time without crashing or exceeding the maximum budget. This may be different if the terrain was changed.

Numerical Methods Used

The Bisection numerical method was used to select the ideal chassis weight. This was done by first taking the minimum weight as the lower bound and the maximum weight as the upper bound. Then, the weights were iterated to find the optimized weight to yield the fastest mission time without the rover collapsing.

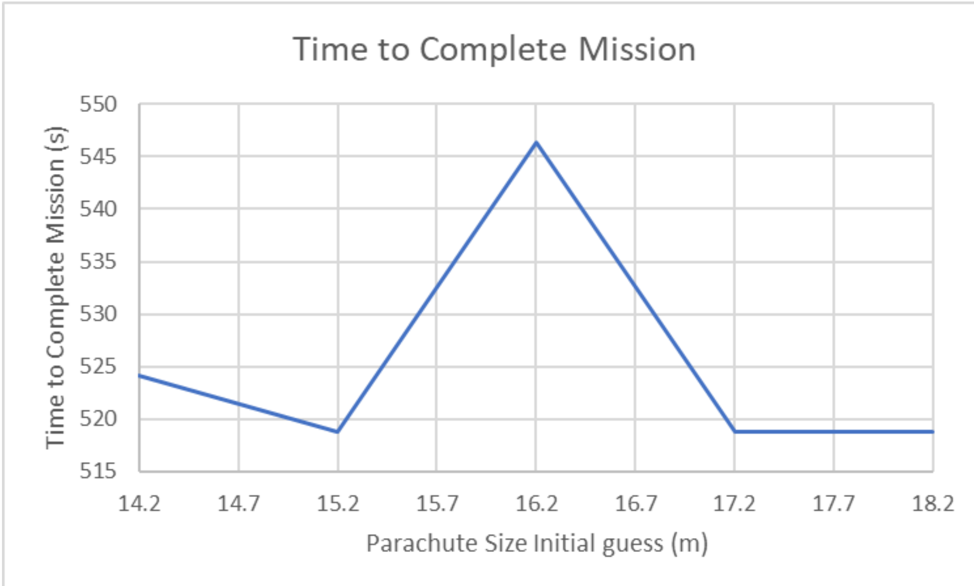
The COBYLA optimizer was used to find optimal solutions for a set of variables. Some of the input variables for this function were the objective function, maximum iterations, and initial guesses. Initial guesses were values made for examples such as parachute diameter, fuel mass, wheel radius, speed reducer gear size, etc.

Final Design

As mentioned earlier, our group chose the high cost - high success, and high speed - low weight rover design. The speed motor was selected with the NiMH batteries due to their high power efficiency and little requirement for power. An additional battery was equipped in case the unknown terrain required unforeseen power from the rover. However, the lightweight and minimalist rover design is still susceptible to steep terrains and may not have enough power to finish all terrains. Ideally, the unknown terrains will be relatively flat and not have dramatic changes in elevation. The following table shows the specifications of our rover.

Parachute Diameter	16.492 [m]
Rocket Fuel Mass	268.161 [kg]

Time to Complete EDL Mission	136.582 [s]
Rover Velocity at Landing	-0.000181 [m/s]
Wheel Radius	0.700 [m]
d2	0.0500 [m]
Chassis Mass	441.620 [kg]
Time to Complete Rover Mission	382.844 [s]
Time to Complete Mission	519.426 [s]
Average Velocity	2.512 [m/s]
Distance Traveled	1000 [m]
Battery Energy per Meter	552.915 [J/m]
Total Cost	4167503.43 [$]
Chosen Motor	Speed
Battery	NiMH
Number of Battery Modules	9



The plot above shows how the total time to complete the mission changes as the initial guess of the optimal parachute size changes. Since the goal is to minimize the time to complete the mission, we chose 17.2 m as the initial parachute size guess. The optimizer finds a local solution so the optimizer must be run for multiple iterations to find the global max/min.