Obstacle Surmounting and Manipulator Arm Simulation of a Tracked Mobile Robot

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Abstract

This presentation focuses on the use of virtual prototyping process for an existing tracked mobile robot using MSC Adams along with MSC Adams Tracked Vehicle (ATV) Toolkit. The virtual robot was created and tested on different terrains in order to study the robot’s ability to negotiate these terrains and to complement physical testing. Dynamic simulations related to the robot manipulator arm were also performed. The validated process can now be used for new robot designs while still in their conceptual design stage.
Introduction

- The mobile robot can be used for tasks like surveillance and search/rescue operations.
- The robot is required to surmount and move over different types of terrains and hence extensive testing is required in order to study the robot’s performance on different terrains.

Motivation

- To facilitate the conceptual design of mobile robots by using the virtual prototyping process to help the designer visualize the functionality and study the performance of the robot even before building the physical prototype.
Model Building

- Template based module of ATV toolkit used for creating the virtual prototype
- Different terrains like flat road, stairs, longitudinal and lateral slopes, obstacles, ditches, logs, etc. were created to test the virtual robot on these terrains

Model Statistics:

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of rigid parts</td>
<td>169</td>
</tr>
<tr>
<td>No. of joints and joint motions</td>
<td>33</td>
</tr>
<tr>
<td>No. of force and contact elements</td>
<td>655</td>
</tr>
<tr>
<td>Total no. of degrees of freedom</td>
<td>870</td>
</tr>
</tbody>
</table>

Model with all icons

Track segments
Validation

The following are some of the parameters that were found from tests conducted on the physical prototype and were used to validate the virtual prototype

- Longitudinal pulling force required for the robot to overcome the resistance and start rolling on a flat ground (the wheels were kept free in this case). This was used to calculate the resisting torque. The track system parameters like friction and damping in Adams model were fine tuned so as to have the same resisting torque.

- Longitudinal pulling force required for the robot to overcome the ground friction and start sliding on a flat ground (The wheels were kept locked in this case). This was used to calculate the friction coefficient between track and ground.

- Motor current value recorded while the robot moved on flat ground and over obstacles.
Simulation: Stair Climbing

- The maximum stair height (with 45° stair inclination) that the robot with arm and payload can safely climb was found to be 224 mm.

- The motor current requirements were calculated using the motor torque results.

- Battery life required for an operation can then be predicted using the current value.
Simulation: Obstacle climbing

- For obstacle climbing, the maximum obstacle height that the robot with arm and payload can climb was found to be 282 mm.
- In the case of obstacles, the robot can scale higher heights than in the case of stairs.
- The optimum orientation angle of the robot with arm and payload was found to be 52°.

**Obstacle climbing simulation stages**

**Optimum robot orientation angle**
Simulation: Ditch Crossing

Stages of a Ditch Crossing Simulation

- The robot with the help of its flipper mechanism was able to cross a ditch with width almost equal to the distance between the front and back platform wheels.
Simulation: Manipulator Arm

Inverse dynamic simulation

- Displacement functions applied at the end effector as general point motion
- Motor torque required at joints to achieve this motion found using GCON statements
Simulation: Manipulator Arm

Singularity Simulation

- Joint velocity increases rapidly when approaching the singular position
Discussion

- The simulations presented were for a robot which already exists and hence it helped in validating the simulation process.
- The simulation results were helpful in many ways including:
  - Visualization of the robot’s motion on different terrains and to determine the best strategy to be used while negotiating different obstacles.
  - Finding torque, current and battery requirements.
  - Determining the limiting dimensions of obstacles, stairs, etc., that the robot can safely negotiate.
- Customization was done in order to speedup the model assembly and simulation process.
- The availability of real time simulation capability would have been helpful for controlling the robot while negotiating different terrains.
Conclusion

• Successfully used Adams along with ATV toolkit to create a complete dynamic model of the track system of a small mobile robot with variable track configuration

• Developed a procedure for performing mobility and manipulator arm simulation of a tracked mobile robot

• The described validated process is now being used for new robot designs, while still in their conceptual design stage

• The various terrain models that were created can be used to test the performance of new robot designs

Future work

• Soft soil simulation

• Cosimulation with Matlab for auto navigation of the robot while surmounting obstacles
Thank You