Using UAV Toolbox to Simulate Uneven Martian Terrain

Francesca Afruni, [redacted]
Florida Institute of Technology, Melbourne, FL, 32901, USA

The incorporation of autonomous vehicles throughout the space industry has been a pivotal contribution to expanding humanity's exploration beyond Earth. The UAV Toolbox in MATLAB allows engineers to generate and simulate UAV scenarios to test flight controllers and autonomy algorithms. Using the UAV Toolbox combined with the scenario designer app, several missions will be demonstrated as a quadcopter navigates around obstacles. Separate STL files will be implemented in the model to demonstrate the ability of a drone to navigate through the uneven Martian terrain.

I. Introduction

The UAV Toolbox in MATLAB [1] provides the necessary tools to design, simulate, and test unmanned aerial vehicles (UAVs) and advanced air mobility (AAM) applications. Key features of the toolbox include designing flight controllers, developing autonomy algorithms, and planning UAV missions. The objective of this project is to simulate the uneven Martian terrain to demonstrate the capability of a drone to navigate through an unexplored environment. Prior to the simulation, several free Mars terrain STL files were found by the team (Figures 1 and 2) [2]. These files present perfect scenarios for a drone mission on the Mars surface. Using the UAV Toolbox combined with the scenario designer app, the terrain will be imported into the UAV scenario file, and the quadcopter will navigate through the environment.

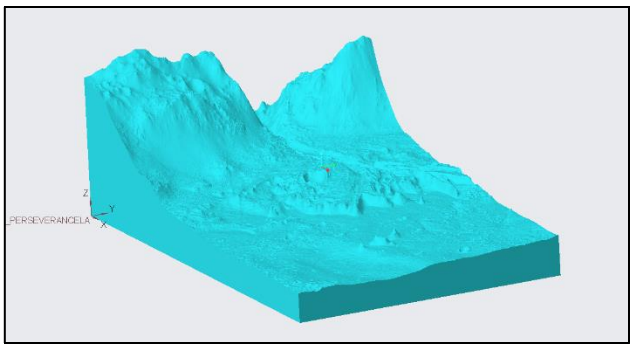

Figure 1: STL File 1 [2]

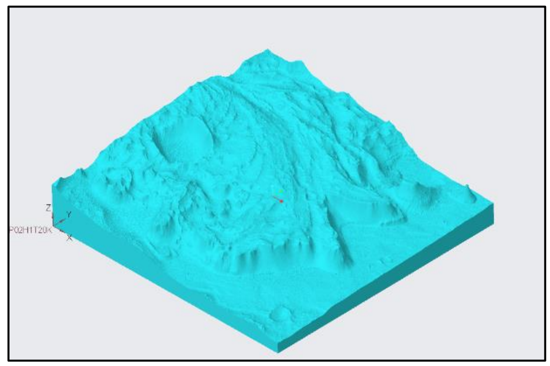

Figure 2: STL File 2 [2]

II. Problem

The success of the NASA Mars Helicopter Ingenuity, the first spacecraft ever to take off and land on the Martian surface, has opened new opportunities for future planetary exploration missions. However, flying on Mars presents numerous challenges: the thin atmosphere, the low gravity, and the extreme environment. The UAV Toolbox Scenario Designer allows engineers to simulate various mission scenarios, including flight paths, and optimize trajectories to develop and test algorithms for obstacle avoidance, ensuring drones can navigate safely despite reduced visibility (due, for example, to sandstorms). By simulating these challenges, engineers can identify potential issues and develop mitigation strategies. The team plans to investigate the creation of a drone mission path for the complex Mars terrain using the MATLAB UAV toolbox. The STL files featured above are converted into a mesh by MATLAB and imported into the UAV Scenario. Then, through a series of waypoints and coordinates, the team can decide the chosen path of the simulated drone.

III. Utilization of the Toolbox

To use the .stl files in this toolbox, the user creates a script in MATLAB and generates a scenario. The scenario name is used as an identifier after opening the UAV Scenario app. Once the name is chosen, the command "Your name = uavScenario" is used to initialize the scenario. Next, the data is imported from the .stl file into the script using the MATLAB function: "stlread." Then, the "addMesh" command given by the toolbox is used to create a custom mesh utilizing the data received from the "stlread" command.

```
fx >> addMesh(scene,"custom",{stltri.Points stltri.ConnectivityList},[1 0 0])
```

The first input is the name of the scenario, the second input is specifying that this is a custom mesh, and the third is the data received from the "stlread" function. The last set of numbers is an RGB color input where the range of each color is 0-1. Finally, after running the script, open the UAV scenario designer app, click on the import scenario button, and select the one with the previously chosen name. After this, platforms can be added, which in this case is a drone, and using the "trajectory" tab, a path can be set using waypoints. Every aspect of the path (including x,y,z coordinates and climb speed) can be varied.

IV. Results

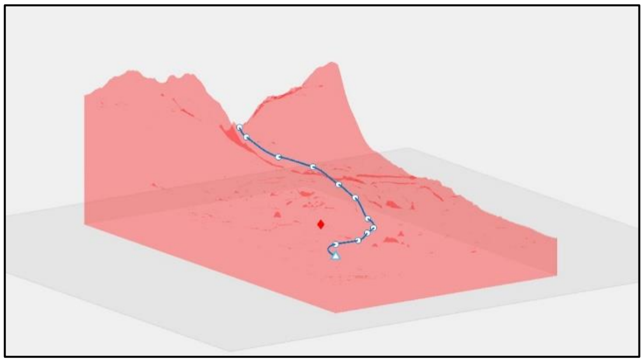

Figure 3: Scenario 1 Drone Path

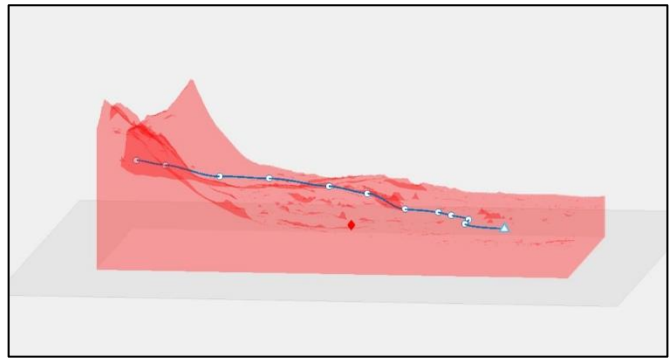

Figure 4: Scenario 1 Drone Path

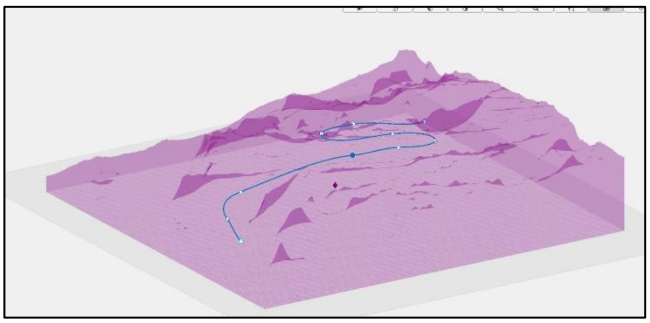

Figure 5: Scenario 2 Drone Path

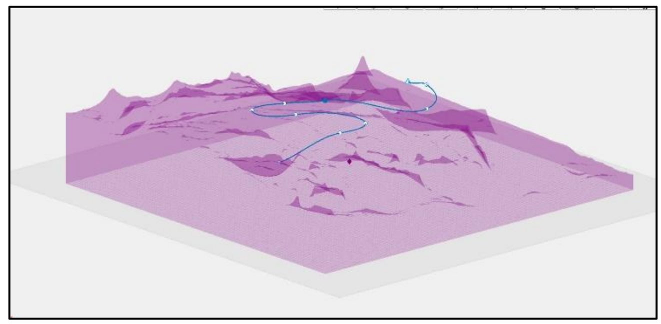

Figure 6: Scenario 2 Drone Path

The UAV Scenario Designer [3] provides the user with an animated simulation alongside the final product of the drone's path to reach each designated waypoint. The paths chosen by this team are provided in the figures above. In Scenario 1 (Figures 3 and 4), the path begins at the relatively flat portion of the Mars surface, identified by the team as a potential landing sight. It then continues its mission up the rocky terrain through the ravine. In Scenario 2 (Figures 5 and 6), the drone climbs up the valley and navigates the high-altitude portion of the terrain while always starting from a flat area of the Mars landscape. The drone is then utilized to explore the large crater present on the Mars surface (This crater is better seen in Figure 2).

V. Conclusions

The UAV Toolbox is an extraordinarily helpful resource as it allows engineers to design and analyze UAV behavior prior to building the product. This paper focuses on applying the UAV Scenario Designer within the UAV Toolbox to simulate a quadcopter's navigation through Martian terrain. Two scenarios were demonstrated in the previous section using two different STL files. In these scenarios, the drone navigated through the difficult terrain to explore the surface. In future applications, the battery of the drone could be specified as a variable to provide insight into its navigational capabilities and flight endurance through this difficult terrain. Additionally, cameras and sensors could be added onto the quadcopter to enable it to map the environment and autonomously navigate through obstacle avoidance, which would eliminate all interactions required with the user by taking out user-defined waypoints. Implementing this toolbox was straightforward and allowed the team to visualize the difficulties in navigating a UAV through Mars.

VI. References

[1] "UAV Scenario Tutorial." UAV Scenario Tutorial - MATLAB & Simulink. Accessed April 7, 2024. https://www.mathworks.com/help/uav/ug/uav-scenario-tutorial.html.

[2] Thingiverse.com. "Mars Perseverance Rover Landing Site Jezero Crater: Mars Lesson Built with the 'Nasa Mars Trek' & Qgis by Growflavor." Thingiverse. Accessed April 12, 2024. https://www.thingiverse.com/thing:4747950#Summary.

[3] "Uavscenario." *Design UAV Scenarios with Terrain, Platforms, and Sensors - MATLAB*, www.mathworks.com/help/uav/ref/uavscenariodesigner-app.html. Accessed 12 Apr. 2024.