Paper ID: 64365
student

IAF SPACE EXPLORATION SYMPOSIUM (A3)
Interactive Presentations - IAF SPACE EXPLORATION SYMPOSIUM (IP)

Author: Mr. Andrea D'Ambrosio
Sapienza University of Rome, Italy

Mr. Andrea Carbone
Sapienza University of Rome, Italy
Dr. Francesco Latorre
University of Rome "La Sapienza", Italy
Dr. Dario Spiller
Sapienza University of Rome, Italy
Prof. Fabio Curti
Sapienza University of Rome, Italy

# ROBOTIC SIMULATION OF A SAFE LUNAR LANDING VIA PARTICLE SWARM OPTIMIZATION AND CONVOLUTIONAL NEURAL NETWORKS

**Abstract**

This paper proposes an approach of guidance, including hazard detection and avoidance, for a lunar landing trajectory, considering also an experimental application. In particular, an experimental facility, made up of a cartesian robot able to move along the three directions and a high-fidelity reproduction of the lunar equatorial zone located at the Mare Serenitatis, is employed. The lunar soil simulant is made by sifted basalt powder, while the craters are made by calk. Moreover, the robot is equipped with a camera thanks to which hazards can be identified. To detect the hazards from images, a Convolutional Neural Network (CNN) is trained and employed online and in real-time to ensure that the landing position resides outside the craters. For what concerns the trajectory planning, fuel-efficient trajectories are rapidly generated by means of the metaheuristic Particle Swarm Optimization (PSO). A new optimal trajectory is computed each time the camera detects the final landing position lying within a crater. To speed up the computation and enable all the framework for a real-time application, the inverse dynamics approach is pursued and the trajectory is approximated using 5th degree polynomials for each component of the position vector. In addition, control constraints are also taken into account considering an augmented cost function, which penalizes those solutions that do not fulfil the imposed constraints. The combination of the PSO, the inverse dynamics and the polynomial approximation of the trajectory allows to obtain high accuracy and low computational times, which are necessary for a real-time use. The whole software is currently implemented on an Intel Core i7-3160 CPU PC with a frequency of 2.30 GHz and 4 GB of RAM. Preliminary results have shown good accuracy and the feasibility of different artificial intelligence techniques (PSO and CNN) to achieve real-time optimal trajectory planning and online hazard detection for an experimental simulation of a soft lunar landing. In particular, robotic simulations have shown a final error in position and velocity lower than 2 m and 1 m/s, respectively. Moreover, the computational time required to generate a new optimal trajectory is generally lower than 50 milliseconds. In the future work, we will also investigate the possibility to test the software on a flight-proven electronic board, such as the Intel Myriad X board, by using a Hardware-in-the-loop simulation, making the system suitable for an actual real-time application.