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AN ON-BOARD AI-AIDED GNC FOR SAFE LUNAR LANDING VIA PARTICLE SWARM AND GPU-OPTIMIZED CONVOLUTIONAL NEURAL NETWORKS

Abstract

This paper deals with the hardware-in-the-loop (HIL) testing of a GPU board implementing a hazard detection and avoidance module for lunar landing. The GPU is representative of suitable on-board hardware accelerators enabling future autonomous exploration missions to the Moon. An experimental facility MONSTER (Moon Optical Navigation robotic facility on Simulated TERrain), 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 offline and deployed on a Nvidia GPU Jetson TX2 to ensure real-time inference to prove that the landing position resides outside the craters. The CNN was trained using optical images of the Moon annotated on basis of open-access crater catalogues, and transfer learning has been used to generalize over the simulation facility. In the current HIL setup, the GPU-based crater detection module is connected to the remaining GNC modules running on the external computational unit (ECU) of the experimental facility. In further details, the trajectory planning running on ECU efficiently generates fuel-efficient trajectories by means of the metaheuristic Particle Swarm Optimization (PSO). A new trajectory is computed each time the GPU-optimized CNN algorithm returns 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. Preliminary results of the HIL system have shown CNN accuracy of 98% and the feasibility of using different artificial intelligence techniques to achieve real-time optimal trajectory planning and online hazard detection. 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 PSO trajectory is generally lower than 50 milliseconds, while the mean CNN inference time on the GPU is 8 milliseconds on a single image. In the future work, we plan to deploy the whole system on the GPU board to demonstrate the feasibility of a fully AI-based GNC.