CURRICULAR STAGE OR THESIS PROPOSAL AT ALTEC S.P.A.

Thesis proposal on realistic optical sensor simulation for robotic space exploration missions

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1 INTRODUCTION

1.1 Background and Motivation

Future of space exploration will increasingly rely on robotics as a key technology to perform safe human missions, long-term planetary colonization, deep space exploration and exploration of hostile environments [1], [2].

Robotics has revolutionized space exploration enabling the exploration of extreme environments, reduce human risks and mission costs. Rigorous testing and validation in simulated environments are key for the success of these missions allowing to validate flight software early and frequently and support the development of mission operations. Highly realistic rendering and accurate sensors data simulation of the target environment plays a key role in validation of autonomy algorithms or operations and in operators training and certification. For example, in the lunar south-pole, the absence of an atmospheric scattering, the sun elevation being very close to the horizon and the presence of permanently shadowed regions (so called PSR), create very challenging scenarios for on-board navigation software or for operator guided teleoperation activities. Moreover, deep learning or reinforcement learning based techniques could also benefit from large highly realistic datasets of sensor data from planetary scenarios.

This research will build upon previous work including a simple lunar scenario with a sample robot.

1.2 Problem Statement

The latest versions of the Gazebo simulator support physically based rendering but advanced real-time or faster than real-time rendering techniques are not currently the main focus. Additionally, PBR (Physically Based Rendering) techniques require careful design and preparation of the materials assigned to each element of the scene. Finally, sensors data may be affected by different artifacts which are peculiar to the environment or the hardware to be used for a specific mission.

1.3 Objectives

The project objectives are the following:

- Introduce the candidate to typical space engineering software development approaches
- Perform a state of the art research to assess the requirements for the rendering system to produce realistic optical sensor data. This may not only include cameras but also LiDARs or time of flight cameras.

- Enhance the existing Gazebo-based robotics simulator to produce more realistic sensor data, Depending on the initial assessment this may require the integration of other rendering back-ends to support more advanced rendering capabilities available.
- Implement realistic reproduction of typical artifacts which may occur in these scenarios such as camera optics straylight, sensor noise, optics distortions, optics dust deposition, black sun effect, bleeding, arbitrary noise distributions (to simulate thermal, readout, cosmic hits or similar phenomena), motion blur etc…
- Develop realistic lunar scenarios for operational use cases studying the lunar south-pole environment. This will be performed importing real Moon south pole DEM and/or randomly generating plausible terrains. Additionally, carefully selected PBR materials or available assets will have to be designed or selected to produce realistic sensor data.
- Provide means to generate high volumes of sensor data offline (to support DL models training) or provide headless, software in the loop, faster than real-time (to support RL techniques or real time simulation scenarios for operations simulations). Particular attention to appropriate multi-node parallelization of the rendering task should be taken into account.
- Develop a demonstrator showcasing the functionalities developed.

1.4 Expected Outcomes

The student, with his / her thesis work, will be contributing to the production of the following items:

Software :

- An enhanced robotics simulator using Gazebo, capable to support realistic sensors data generation for Moon south pole exploration scenarios.
- Software tests suite for all developed software including, at least, integration and system level tests.
- Demonstrator showcasing a realistic lunar scenario supporting operational use cases and ideally datasets generation or headless simulation.

Documentation:

- Design document of the additional software components developed.
- Software user manual.

Exact scope and details of the activity may be discussed and adapted depending on university and student needs.

This work is intended to be performed as a curricular internship on which the student may write his final thesis.

1.5 Project organization

While the ideal candidate is expected to be proactive and autonomous, ALTEC takes very seriously the educational aspects of interns and the student will be closely followed with a SCRUM-like structured

approach where a sprint meeting will be held every two weeks to review the status of the student work, provide feedback and guidance, plan the upcoming sprint tasks.

2 REFERENCES

[1] ISECG, "The Global Exploration Roadmap - Supplement October 2022 - Lunar Surface Exploration Scenario Update" 2022. [Online]. https://www.globalspaceexploration.org/wp-content/isecg/GER_Supplement_Update_2022.pdf.

[2] Y. a. S. C. Gao, "Review on space robotics: Toward top-level science through space exploration.," in *Science Robotics 2.7*, 2017.