Space Exploration Technology Cluster (ARC-SET) Presentation in Joint Research Forum 2025

Research Title: Research of 3D geological map construction method using the related space exploration technologies

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Abstract

For upcoming rover-based lunar and planetary exploration, ARC-SET (Space Exploration Technology) aims to establish a method for 3D geological mapping using the rover data acquired through communication, operations and environment expected in actual explorations. Each related technology is being researched within subgroups, and some preliminary results have been obtained from experiments conducted in the simulated lunar crater area.

Background and Research targets

In recent years, explorations of lunar and planetary surfaces using rovers (ground vehicles) has become a prominent topic. In rover-based exploration, a 3D map that reconstructs the surrounding terrain with geological information can be crucial resource for environment recognition, rover localization and navigation toward scientifically valuable targets.

Primary target of this cluster is to establish a method for the 3D geological mapping using data acquired by onboard sensors (3D LIDAR, visible and spectroscopic cameras) of the rover.

In actual explorations, the sensor data for the map construction can be affected by running condition and operation status of the rover, and remote control and data transmission by space communication from the Earth can be important factors.

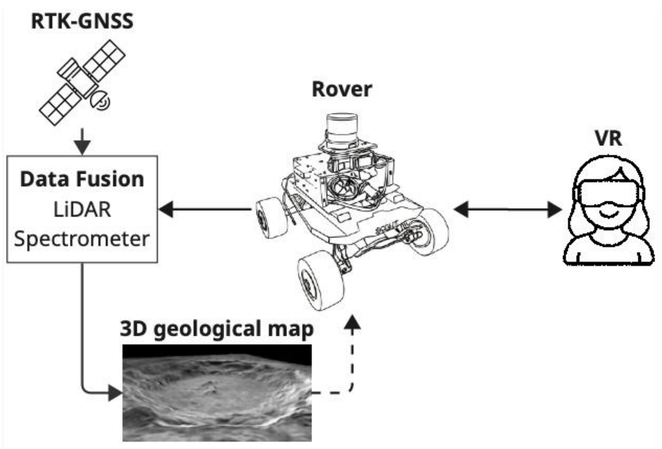

Fig.1. Overview of research framework

We also aim to construct end-to-end experimental system to simulate realistic exploration scenario by integration of each research component; 3D Mapping, Data analysis, Operation, Communication and Facility (Fig.1).

Crucial Technology for future space explorations!

Research Contents (Methodology)

We advance the cluster research through four subgroups and integrate their outcomes to construct the end-to-end system and the resulting 3D geological map.

[3D mapping and Localization group]

Research a method for constructing the 3D geological map through onboard sensor data fusion and develop new rover localization methods on the map using satellite and gravity data

[Spectral Data Analysis group]

Research a method to derive geological information from multiband images captured by a spectroscopic camera onboard the rover, based on the techniques applied to 2D satellite imagery

[VR Data Monitoring group]

Research a VR-based visualization method that uses onboard sensor data and is applicable to rover operation from remote sites

[Space Communication group]

Develop a remote communication system to simulate delay and data compression in transmission between Earth and other bodies

Experiments and Current results

We have already constructed a simulated lunar crater (Fig. 2) in the Fukushima Robot Test Filed to replicate lunar terrain and surface and developed a four-wheel rover equipped with the sensors (3D LIDAR and visible and spectroscopic cameras) (Fig. 3) through, previous activities of the related projects (Hakoniwa concept and ARC-SDU).

Fig.2. The simulated lunar crater

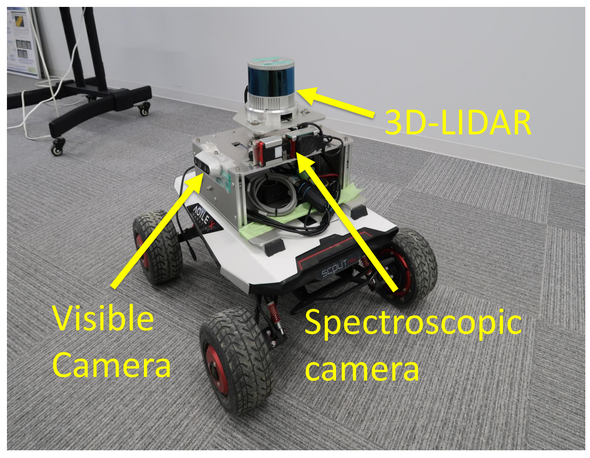

Fig.3. The four-wheel rover for the cluster

Preliminary experiments on 3D mapping and remote communication have been conducted in the crater area through prior activities. We have constructed an initial data fusion map (Fig.4) based on LIDAR-SLAM [1], and we were able to control the rover under simulated communication latency. In addition, a geological classification method using machine learning has already been developed for 2D lunar satellite images (Fig. 5) [2].

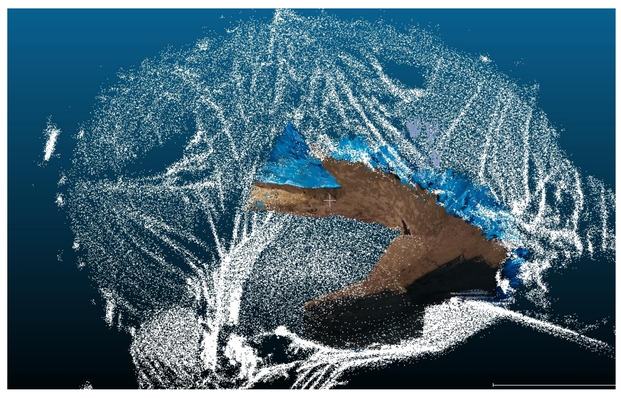

Fig.4. The 3D data fusion map of the crater using LIDAR and camera point cloud

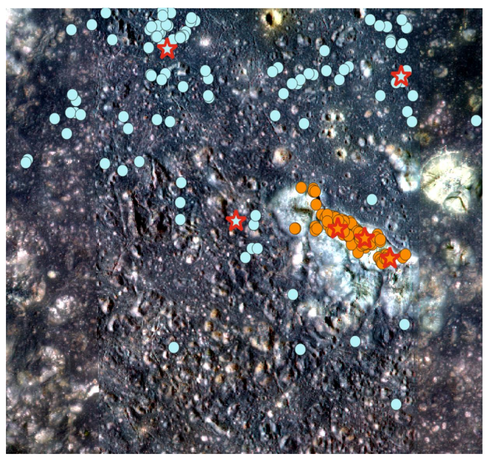

Fig.5. The result of geological classification on the lunar map

We also progress the development of a VR-based visualization system and data-compression method using actual rover onboard sensor data. The first experiment dataset will be obtained this November.

Conclusions and Future Works

We started research and development as ARC-SET (Space Exploration Technologies) for 3D geological map construction through the related technologies of rover operation, communication and data analysis.

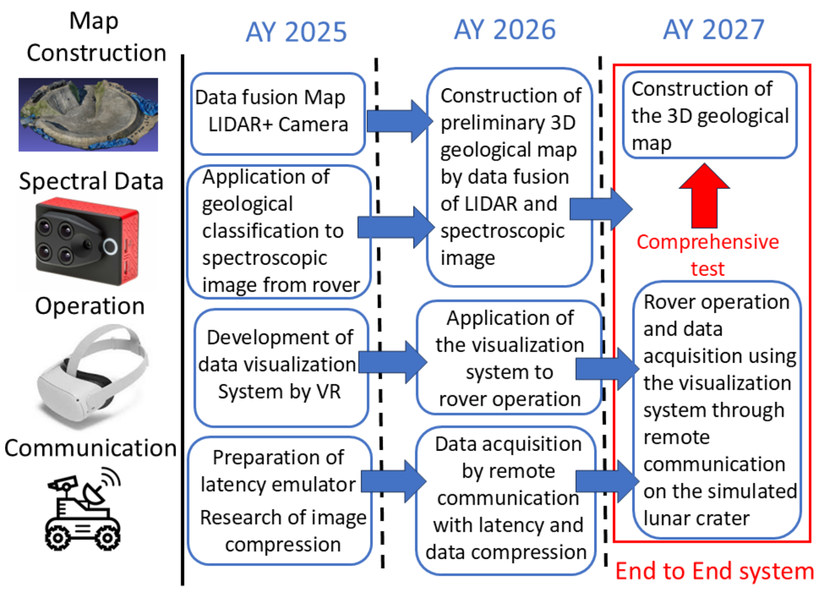

Fig.6. Diagram of research flow in three years

We aim to construct preliminary end-to-end system within first three years (Fig.6) and the system can be valuable tool to achieve successful rover-based lunar and planetary explorations.

References

[1]T. Shan, B. Englot, D. Meyers, W. Wang, C. Ratti, D. Rus, "LIO-SAM: Tightly-coupled Lidar inertial odometry via smoothing and mapping, IEEE IROS 2020.

[2] P. Veena, R. U. Kiran, Y. Ogawa, M. Ohtake, "rasterMiner: an Open-Source Python Library to Discover Knowledge from Raster Imagery Data, Space, Aerospace and defence conference, 2024.