Multi Robot Sensor Fusion and 3D Modelling for Subsurface Lunar Exploration

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Introduction

Caves and lava tubes are the next great frontier in planetary exploration. Recently discovered skylights on Moon and Mars provide access to these subterranean voids. These hold the prospect for geological discoveries, human safe havens, and signs of prior life.

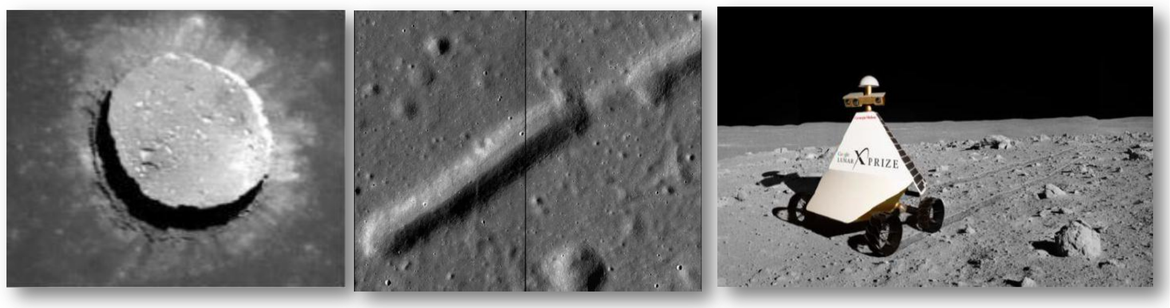

Fig.1 (a) Skylight and (b) Lava Tube on the surface of moon (c) Red Rover on simulated moon surface.

However, current modelling methodology using direct sensing produces poor returns on the cost of robotic deployment. Multi robot frameworks are thus being explored to match to abilities like range accuracy, reconstruction and scene understanding using Multi-sensor fusion. The Goal of our research was to solve the problem of fusing disparate sources of spatially and temporally distributed data and develop a framework to ensure fast, efficient and robust modelling of such terrains.

Sensor Fusion

Stereo Vision

SIFT feature based matching is chosen for their robustness under scaling and light condition changes. RANSAC and epipolar constraint are applied to further remove outliers.

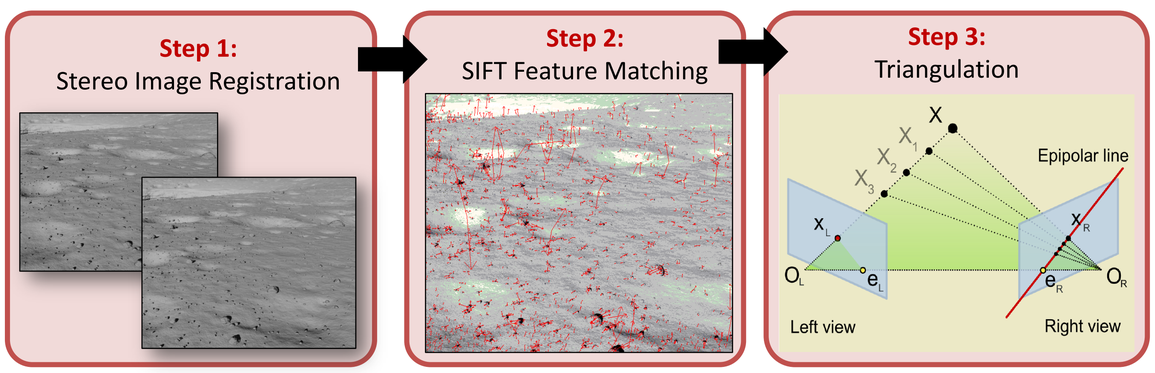

Fig.2. Stereo Vision Pipeline

Super Resolution Range Sensing

Sparse LIDAR range readings and high resolution intensity images can be fused to create super-resolution models with a Markov Random Field.

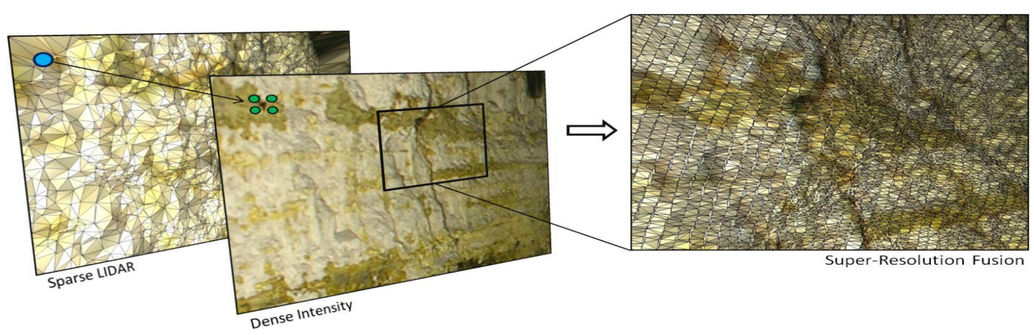

Fig.3. Super Resolution Modelling (Image courtesy: Uland Wong, “Lumenhancement: Exploiting Appearance for Planetary Modelling”, PhD thesis)

Field Tests and Results

Robots with heterogeneous sensing capabilities were used for field tests at Robot City test site for exploration, mapping and modelling. The Robots used were:

- Pioneer
- LAGR’s
- Ice Breaker
- Cave Crawler

Fig.4 Robots used for Field Test

The Ground truth model was generated using Faro Scans to evaluate the model by robots:

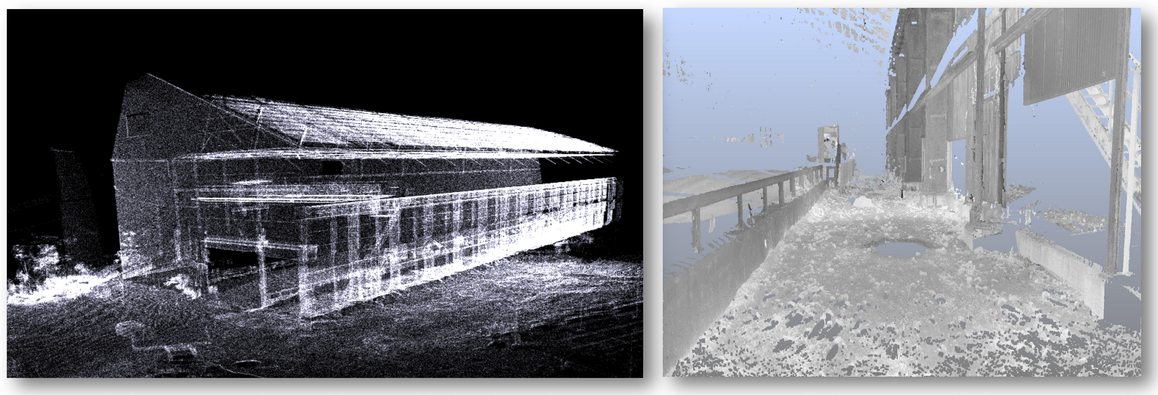

Fig.5 (a) Ground Truth model of Robot City Test site (b) View of the Tunnel replicating the environment that of a Lunar tube

Maps and Models generated from the Multi-Robot Experiments have been shown and its quality has been evaluated in comparison to the ground truth model.

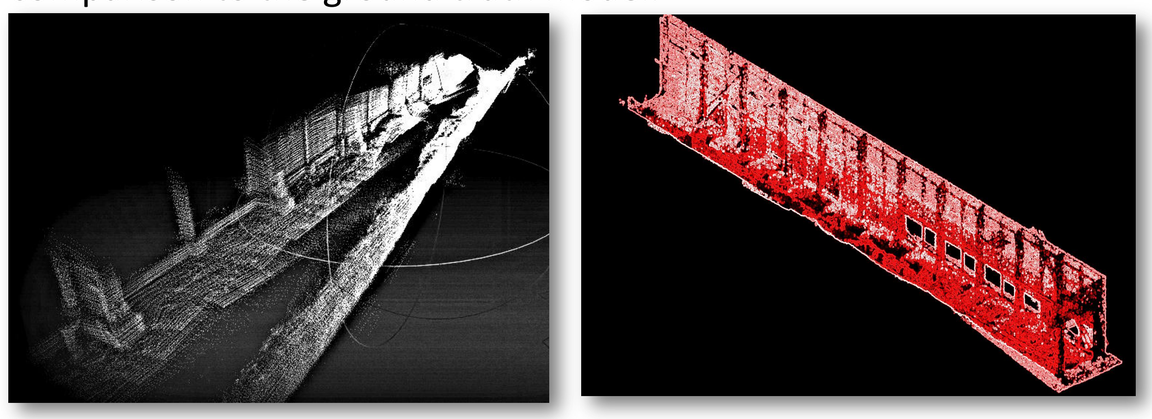

Fig.6 (a) Model of a part of the tunnel generated from cave crawler (b) Model of the tunnel color coded based on RMS error from ground truth with error increasing from red to black

References

- Wong et all, “Camera and LIDAR Fusion for Mapping of Actively Illuminated Subterranean Voids”, In Proc. Field and Service Robotics (FSR), 2009.
- Thrun et all, “6D SLAM with an Application in Autonomous Mine Mapping”, In Proc. ICRA, 2004.
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