Experiments for Autonomous landing of an Underwater Vehicle at Teishi Knoll

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Study of seafloor mineral deposits, such as ferro-manganese crusts and hydrothermal vents is an important topic for seafloor exploration and economic development. However such deposits are often dispersed over vast areas and in order to understand them better, high resolution data needs to be obtained. Underwater systems are typically not capable of performing such wide area surveys while obtaining high resolution data at the same time, and often multiple deployments of different types of vehicles are necessary. In order to achieve more efficient surveys, this work proposes a multi-resolution survey strategy. The strategy involves superimposing high-resolution visual observations of the seafloor, including microscopic imagery of the seafloor, obtained at discrete intervals within a lower resolution, wide area acoustic map of the region taken during a single AUV dive. By utilizing such a strategy, data of various resolutions can be obtained to generate a multi-layered map of a wide area of the seafloor. A three stage strategy has been proposed for an underwater autonomous mobile platform to perform such a survey. First, the AUV cruises between points at high speed while measuring acoustic bathymetry. At intermediate points along its track, the AUV measures higher resolution data using a sheet laser system, while searching for suitable landing sites within the laser scanned area, to land. Once landed, the vehicle remains stationary and performs further higher resolution observations of the seafloor. We are currently developing such a platform, or 'Bottom Skimmer', to perform high-resolution visual, acoustic and chemical analysis of the seafloor from low altitudes.

In order to make high-resolution measurements on the seafloor, it is necessary for the bottom skimmer to land and provide a stable platform so that precision instruments can be used. Since the seafloor can vary abruptly and is not always safe to land, it is necessary to detect and automatically identify suitable landing sites where a stable platform can be provided. This is achieved using a system to accurately generate bathymetry with centimeter order resolution based on light sectioning using a sheet laser. Through two-dimensional frequency analysis of this information and image processing algorithms, it is possible to identify flat areas on which the vehicle can land safely. After landing, the vehicle cannot control its range to the seafloor, which is important for proper functioning of the seafloor observation instruments. As a result a mechanical focusing mechanism, such as a linear stage needs to be used for accurate stable focusing. To test this approach, a microscope sensor was developed to measure sand grain size on the seafloor which has a focusing range of 62mm in water and 0.3mm focusing depth, tolerance, which cannot be implemented on a normal cruising or hovering type vehicle as they cannot provide such stability. A linear stage was developed which makes it possible for the microscope to focus within its tolerance range once the vehicle has landed on the seafloor.

During the KY10-04 cruise of the R/V Kaiyo, the laser profiling system and the underwater microscope with its focusing mechanism were mounted on the AUV/ROV 'Tuna-Sand' as a test platform and experiments were performed to evaluate the landing system. The system was deployed for a total of 5 dives inside the crater of the Teishi knoll over three days. The main objective was to detect autonomous landing sites in real time using the developed algorithm and hardware and also to verify if the vehicle can be stable on the seafloor after landing to obtain high resolution data, in this case microscopic images. Dives were conducted along different regions of the knoll. Steep slopes, rocky outcrops as well as sandy flat central areas were scanned to calibrate the sensors and to evaluate the performance of the landing system. The top region, side slope and central region of the knoll were surveyed and laser profiles were taken at various locations in each region. The landing algorithm was implemented to detect landing sites in this scanned data. Once the algorithm detected suitable landing coordinates, the vehicle was maneuvered to the point and landing was performed. Microscopic images were taken to compare sand grain structures from different parts of the knoll. Landing algorithm was found capable of detecting landing sites in real time along different seafloor terrains. It was also possible to obtain focused microscopic images by the use of linear stage after stable landing even with a very fine focusing tolerance of the microscope. Colored seafloor maps were generated using a pixel mapping technique to represent the area where the experiments were performed. The results obtained during this cruise provided useful engineering feedback for the development of a bottom skimmer vehicle.

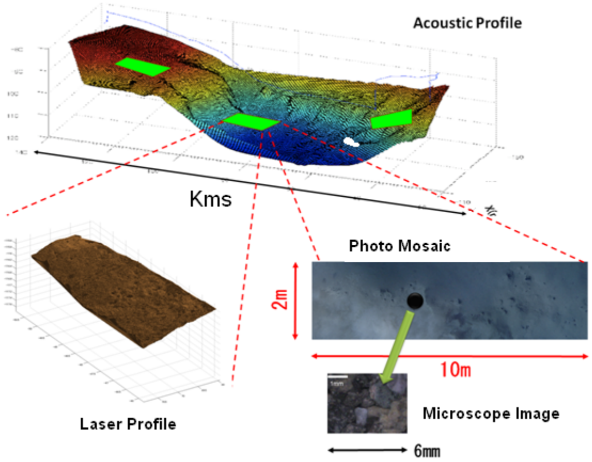

Fig 1. Multi-resolution survey technique

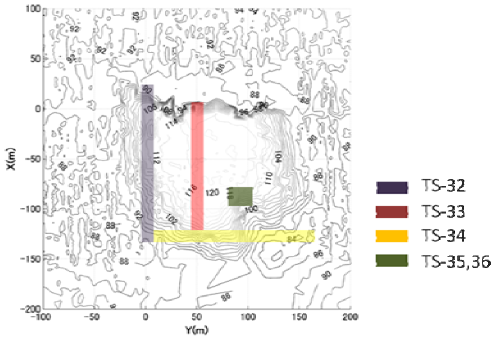

Fig 2. Area surveyed during KY10-04 cruise

Length	1.1 m
Width	0.7 m
Height	0.71 m
Weight	240 kg
Max. Depth	1,500 m
Max. Speed	1.7 knots
Duration	5 hours
Thruster	220W×4 100W×2
OS	VxWorks
Battery	50.4V NiMH 9Ah×4

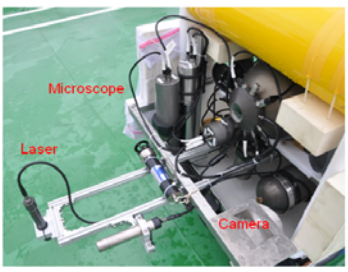

Fig 3. Laser profiling hardware setup as mounted on the AUV Tuna Sand during the cruise

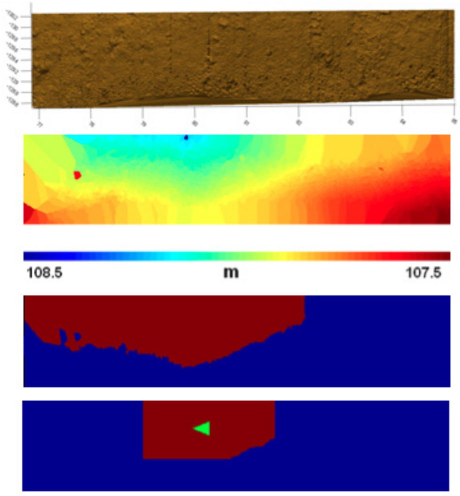

Fig 4. Landing Algorithm detecting landing site in the area scanned by laser profiling

Fig 6. Color bathymetry generated by pixel mapping

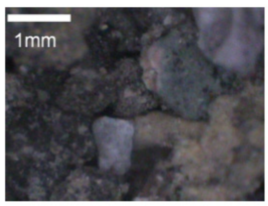

Fig 5. Microscope image showing coarse grain structure of the seafloor