Remotely Operated and Autonomous Mapping System (ROAMS)

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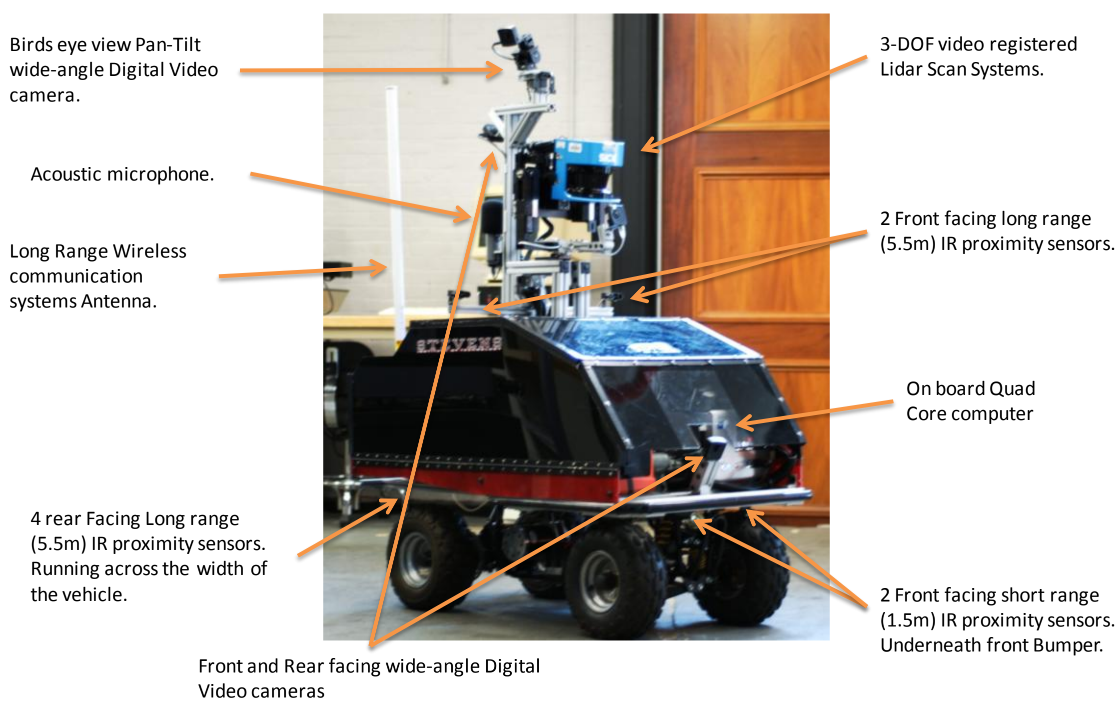
Abstract

Accurate three dimensional maps are important for applications which require geometric and visual information of environments. These applications include 3D map building for autonomous robot navigation, map generation for simulation and modeling applications as well as rendering of synthetic/virtual reality 3D environment for analysis and training purposes. Robotic systems present great potential for generating these maps faster, more accurately, more conveniently and in some case more safely than manual 3D mapping systems currently in use. This is especially true for applications which require mapping of large scale or hazardous/hostile environments.

The development of a relatively low cost mobile 3D mapping robot prototype named ROAMS (Remotely Operated and Autonomous Mappings Systems) which can enable rapid generation of high resolution 3D maps of indoor/outdoor environments is presented. The Robotic system generates 3D maps using a video registered Lidar scanning system integrated with a multiple degree of freedom actuator. Techniques for improving the resolution and point distribution of Lidar data through the use of video images and actuator speed control are also investigated and presented.

ROAMS is outfitted with environmental awareness sensors and a long range wireless communications system to enable remote operation and monitoring through the use of software based Operator Control Unit (OCU). The OCU enables mapping of large scale or human inaccessible environments by a single operator from a remote location. The robotic vehicle is also used as a test platform for conducting studies and real-time experiments on autonomous operations.



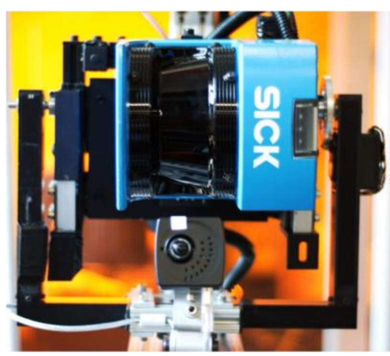
System Overview

A variety of sensors, including multiple digital video cameras, acoustic sensors, IR proximity sensors, GPS sensor and multiple speed and position sensors, are used to provide situational and environmental awareness to the remote operator and feedback to the vehicle. The software based OCU used for controlling and monitoring ROAMS can be operated form any standard pc and includes an integrated network bandwidth monitoring system to manage the throughput from the various sensors for low latency control and monitoring. This OCU can be operated from a central command center with long range wireless communication capabilities or from a mobile command center such as a chase vehicle. ROAMS employs electric motors for actuation, is battery powered and can fit in most standard sized doors and small elevators which make it practical for both indoor and outdoor applications. An onboard Quad core computer is used for acquiring and processing data from the onboard sensors as well as communicating with the OCU and controlling the onboard actuators.

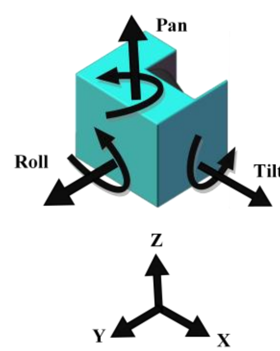
ROAMS utilizes a standard 2D Lidar Scanner mounted on a unique three axis rotary actuator. The actuators enables a single Lidar to be used for a variety of application, including 2D obstacle detection for navigation, and stationary 3D mapping, which usually require multiple Lidar systems to perform. During mobile navigation the roll actuator is used to rotate the Lidar to a horizontal scan orientation, and the tilt actuator is used to adjust the elevation angle of the Lidar. For 3D mapping the Lidar is rotated to a vertical scan orientation and the pan actuator is used to rotate the Lidar to perform a 3D scan. The position of the pan actuator is simultaneously acquired during each scan and used as the third dimension.

In its current state ROAMS acquires 3D Lidar Data only while it is stationary. A 3D map of a large area is created by acquiring overlapping scans from multiple locations and viewpoints using local co-ordinates for each scan and merging the scan into a single global co-ordinate system using ICP based 3D map registration [1, 2]. Video registration is used for texturing of scan points to provide photo realistic 3D maps, and techniques are also implemented to improve the resolution of the Lidar Scan with the aid of video data. These techniques make use of the higher resolution video data for calculating interpolation points in between Lidar Scan points and have shown to significantly increase the visual quality of 3D scan especially for planar and smooth surfaces. Algorithms for improving the point distribution of large range scans through the control of the pan actuator speed as well as path planning for optimal scan area converge are also examined and presented. These algorithms have helped to decrease the non-uniform point distribution generated by rotary based Lidar scanner for different measurement distances.

Lidar Scan System in Horizontal configuration (Used for 2D navigation)



Lidar Scan System in vertical configuration (Used for 3D mapping)



Rotational and Linear degrees of Freedom of Lidar

References

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2. Nuchter, A.; Lingemann, K.; Hertzberg, J., "Cached k-d tree search for ICP algorithms," *3-D Digital Imaging and Modeling, 2007. 3DIM '07. Sixth International Conference on* , vol., no., pp.419-426, 21-23 Aug. 2007