

Visitor Research Report

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Area of Research: Immersive Virtual Human Exploration

Period of Visit: June 1, 2009 – August 21, 2009

Goal:

Immersive Virtual Human Exploration (IVHE) is one of 9 Revolutionary Technical Challenges (RTC) that is meant to provide long time research opportunities for NASA LaRC. The objective of IVHE is: *“Explore the solar system using data-driven fully immersive virtual environments to factually simulate the actual environment. By fully integrating all 5 senses, the user can explore space without leaving Earth.”*

Thus, IVHE allows people to experience and explore the solar system from the comfort and safety of the Earth. This is necessary because exploration, and especially space exploration, is a very expensive and costly affair. A rough calculation shows that, approximately, only 0.000006 % of the human population has been to space. There are certain biological limitation that prevent humans from extracting all the information possible from an environment. For example, humans can only view the visible part of the EM spectrum. But there is a plethora of information found in other parts of the spectrum. Incorporating data from these spectra into a virtual environment will facilitate the extraction of all the knowledge possible from the environment.

The goal over the summer was to develop a proof-of-concept for IVHE using a mobile robotic test bed.

Strategy:

The mobile test bed chosen for the proof-of-concept was the Platform for Scientific Instruments (PSI). The PSI is a robot that contains navigation, imaging, and scientific instruments. The IVHE team was in charge of making 3-dimensional model of the environment using a Sick LMS 291 LiDAR and then fusing it with imaging and other scientific data.

The LiDAR scans using a single beam of laser and a rotating mirror. This gives ranges along a particular plane in 3-dimensional space in polar coordinates. If the LiDAR is rotated along an axis lying on the plane, a full scan can be done. This is achieved in practice by mounting the LiDAR on top of a Pan-Tilt unit. From the LiDAR scan, a point cloud can be constructed with the origin at the center of the LiDAR. To be able to scan from multiple locations, the position and the orientation of the LiDAR have to be known. The position is computed using a Global Positioning System (GPS) and the orientation is computed using an Inertial Measurement Unit (IMU).

The tasks necessary for the proof-of-concept were:

- Carry out error analysis using theoretical models
- Test hardware
- Process measurements

Accomplishments:

The error analysis of the LiDAR scans showed that measurements would be precise, but not very accurate. This means that a point cloud at a location, when considered individually, would be very accurate, but point clouds taken at 2 separate locations would not recreate the environment faithfully. The largest contribution to this error was the accuracy of the IMU estimation of orientation.

All the instruments was controlled using Labview. One of the first challenges was to learn Labview and be able to successfully communicate with the hardware. At first, some rudimentary tests were carried out using the LiDAR to see what the data output would be like. The GPS receiver was mounted on a truck and driven for a test run. The data from the software of the receiver was displayed on Google Earth. This trajectory was also recreated in MATLAB using the measurements from Labview to be familiar with coordinate transformations. Some orientation estimation and numerical integration using IMU measurements was also carried out. The integration of the LiDAR with the Pan-Tilt unit was tested by making simplistic 3-dimensional scans.

The PSI, being a very large and complex robot, was not ready as expected. The existing software and conflicts with the needs of other instruments meant that there was not as much freedom on the control of the Pan-Tilt as required. A remedy for this situation was to begin parallel development on another independent scanning platform. This platform was made using a tripod, a small Pan-Tilt unit, and the LiDAR. This setup allowed the scanning platform to be relatively mobile and allowed much greater control over the scanning resolution.

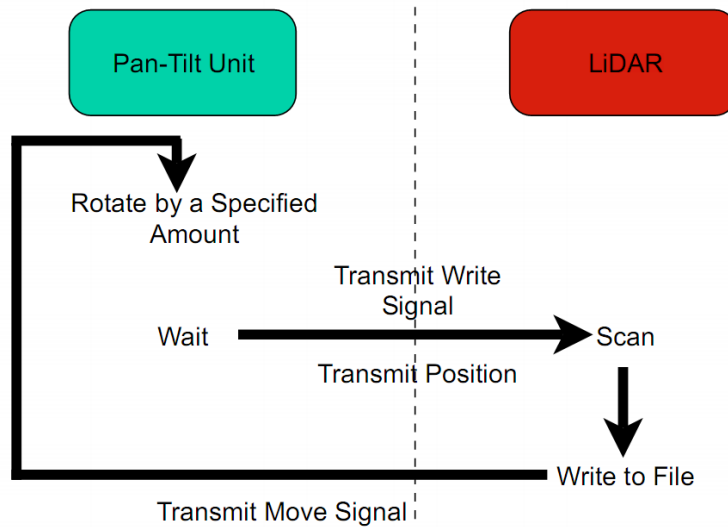


Figure 1: Scanning Mechanism of Independent Platform



Figure 2: Independent Scanning Platform

The independent scanning platform is comparable to terrestrial surveying LiDARs, but at approximately 1/10th the price. The range and resolution are not as high as with the terrestrial LiDARs, but that is due to the physical limitations of the Sick LiDAR. This platform is capable of creating some very detailed scans. An example of a scan in the woods is shown below.



Figure 3: Point Cloud of a Scan in the Woods

After trying to process some scans, it was obvious that MATLAB is not suitable for dealing with point cloud. This is because MATLAB did not deal with the points in an efficient manner. Although, MATLAB was very useful in processing the data, especially the ability to select and remove arbitrary points. For the very large scans, some other software had to be found that could be used to visualize the point cloud.

Some good trial versions of commercial software that were tested are shown in Table 1.

Table 1: Software Tested for Viewing Point Clouds

Software	Developer	Cost [USD]
Point Cloud 1.0	Sycode	295
AccuTrans 3D	MicroMouse Productions	20

Point Cloud 1.0 gives the user more control over the camera and the points than AccuTrans 3D, but it also has a much higher price tag.

Future Work:

Future work for IVHE over the period of a year is:

- Combine multiple scans
- Make scans of sites more analogous to extra-terrestrial sites
- Fuse data from other sensors
- Investigate alternative mobile platforms
- Look at other software

Future scans should be made inside caves and lava tubes to emulate places that could be explored on Mars. Good examples of such sites are caves in New Mexico and lava tubes in Hawaii.

For combining multiple scans, a way of estimating the position and orientation of the LiDAR at the beginning of each scan is proposed. The orientation of the LiDAR refers to the orientation of a reference frame fixed to the LiDAR in which, the point cloud is expressed. The location and orientation of the first scan should be taken as the origin. The location and the orientation for all the other scans can be found by using recognized features. For scans inside man-made structures with flat walls, planes can be fit onto the point cloud of the walls, floors, and ceilings. The orientation between consecutive scans can then be found using the orientation of the normals of the walls. Corners can be used for positioning. For scanning inside caves and other natural environments some flat plane of known reflectivity and size. This plane can be placed at the origin of each scan after it is completed so that the location and orientation of the next scan can be determined. Other planes can be placed at arbitrary locations to ensure better estimation of state.

A company, DelftTech, located in The Netherlands has a software that can combine 2-dimensional images with 3-dimensional LiDAR scans. The company aims to also combine the data with other sensors such as infra-red, pressure, etc. One of the goals is to approach the company and test out the software to see if it is relevant for the project. There is also an open source software called SceneViewer, which is only suitable for viewing point clouds. This software should also be investigated as it would be a free alternative.

Pending Publications: -None-

Seminar Presented:

A seminar was given on 21 August 2009 at NIA headquarters.