LASOIS: ENHANCING THE SPATIAL ORIENTATION CAPABILITIES OF ASTRONAUTS ON THE LUNAR SURFACE. R. Li[1], B. Wu[1], S. He[1], B. Skopljak[1], A. Yilmaz[2], J. Jiang[2], M.S. Banks [3], C. Oman [4], K.B. Bhasin[5], J.D. Warner[5], and E.J. Knoblock[5], [1]Mapping and GIS Laboratory, CEEGS, The Ohio State University, 470 Hitchcock Hall, 2070 Neil Avenue, Columbus, OH 43210-1275, li.282@osu.edu, [2]Photogrammetric Computer Vision Laboratory, CEEGS, The Ohio State University, [3]Visual Space Perception Laboratory, University of California, Berkeley, [4]Man Vehicle Laboratory, Massachusetts Institute of Technology, [5]NASA Glenn Research Center.

Introduction: In future manned lunar missions, the ability of suface-based astronauts to remain spatially oriented on the lunar surface can have a serious impact on mission success and safety [1]. Astronauts may become disoriented due to low gravity, tenuous atmosphere, the fractal geometric properties of lunar regolith, lack of visual cues and distinctive landmarks on the lunar surface, difficulty in judging distances, and other difficulties [1, 2]. They may also experience physical and psychological difficulties on the lunar surface due to vergence-accommodation conflicts, non-Lambertian reflectance, and binocular disparity [3]. Therefore, it is highly desirable to develop technologies to enhance the spatial-orientation capabilities of astronauts on the lunar surface by providing consistent global and local orientation and navigation information [4].

This paper presents the initial efforts in developing a Lunar Astronaut Spatial Orientation and Information System (LASOIS) to enhance the spatial-orientation capabilities of astronauts on the lunar surface. Psychological and cognitive research on spatial orientation and navigation will be incorporated in the design and implementation of LASOIS. To develop LASOIS, the typical scenarios and constraints of EVA (Extra Vehicular Activity) operations by astronauts on the lunar surface will be investigated to provide a baseline for the LASOIS design. An integrated sensor network will be established that incorporates data from orbital, lunar-surface, vehicle on-board, and on-suit sensors. Spatial information technology will be developed and integrated to turn this vast amount of data into usable spatial-orientation information. LASOIS will have a client/server architecture and will provide lunar astronauts with real-time self-localization and path-generation support capabilities.

Typical Scenarios and Constraints for Astronaut EVA Operations: Typical scenarios for astronaut EVA operations on the lunar surface that will be examined for navigation purpose in this research include round-trip excursions to a scientific target from the lander/outpost by LRV (Lunar Roving Vehicle, e.g., the Small Pressurized Rover) (~ 10 km) or from the lander/outpost/LRV by foot (~ 500 m) [5]. Some measurements observed during the Apollo EVA operations will be employed to determine the constraints that are necessary for astronaut positioning [6, 7]. For example, in the Apollo missions the speed of the LRV driving across the lunar surface was about 10 km per hour, while the walking speed of astronauts was about 2 km per hour. The maximum slope traversable by the LRV or the astronauts was about 25 degrees. These typical scenarios and constraints will be incorporated into the design and implementation of LASOIS.

Lunar Integrated Sensor Network: As illustrated in Figure 1, an integrated sensor network comprised of orbital, lunar-surface, vehicle on-board, and on-suit sensors will be studied. Orbital sensors will include navigation, communication and reconnaissance satellites in orbit around the Moon (such as the planned Lunar Reconnaissance Orbiter). Lunar surface sensors will include surface beacons deployable on the lunar surface. This beacon system may use a wide range of frequencies including radio, microwave, ultrasonic, and visible light sources to transmit the relative positioning between an object and surface beacon reference points. On-board vehicle sensors (including wheel odometers, IMU, and engineering navigation cameras) can be mounted on roving vehicles. On-suit sensors include possible sensors mounted on the astronaut's space suit, which may include MEMS IMU, light-weight stereo cameras, step sensor, and a special display interface. The combined sensors will provide measurements and observations to generate navigation and localization capabilities. The interface will provide display functions for 2D and 3D spatial information along with any necessary simple interaction functions.

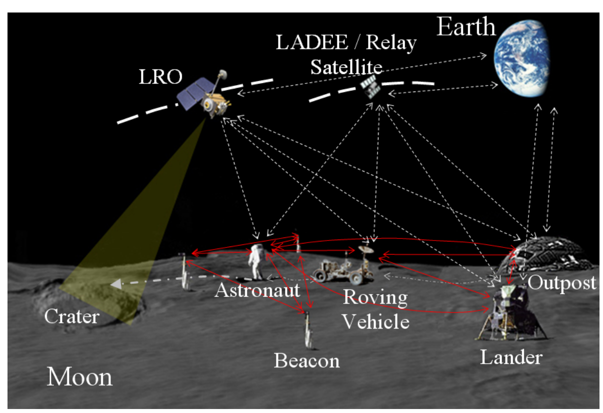

Figure 1. Conceptualization of the integrated sensor network for LASOIS. (Photo credit: NASA/OSU).

Spatial Information Derivation and Application: Spatial information technology will be developed and integrated to turn the vast amount of data from the integrated sensor network into necessary spatial-orientation information usable by astronauts for lunar surface exploration [4]. Key technologies to be employed will include: 1) astronaut spatial localization by integration of measurements from multiple sensors using, for example, an extended Kalman filter [8], 2) astronaut spatial orientation by tracking of terrain targets [9], 3) adaptive selection of map and/or navigation information, 4) self-adjusted visualization of map and/or navigation information, and 5) minimization of vergence-accommodation conflict for visual performance enhancement [3].

In addition, astronaut locomotion patterns (walking, jogging, hopping, etc.) as observed in Apollo mission documentation [6, 7], will be modeled according to stride length and interval using simulated data. The developed model will be incorporated into the design and implementation of LASOIS to improve astronauts spatial localization capabilities.

LASOIS Architecture: Based on the above-mentioned baseline operational scenarios and constraints, lunar integrated sensor network, and spatial information technologies, LASOIS will be implemented by integrating the acquired sensor information. This integrated information in turn can provide the astronauts with real-time self-localization and path-generation support capabilities. Figure 2 shows the LASOIS conceptual architecture.

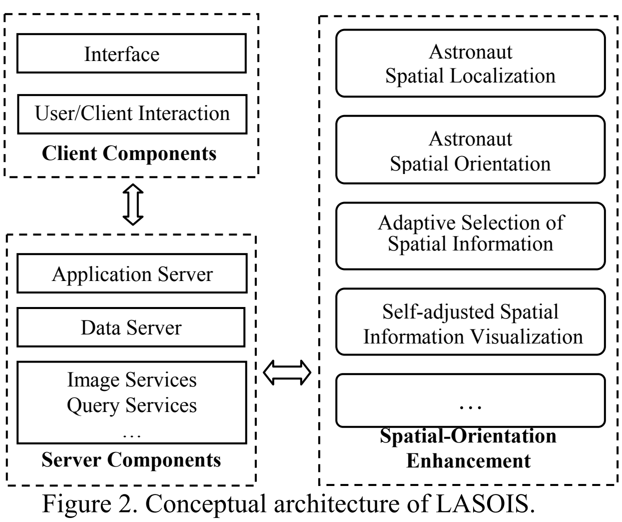

Figure 2. Conceptual architecture of LASOIS.

LASOIS will consist of a client/server architecture. A global data server can be established at the Earth-based control center, while different local data servers can be deployed on lander, outposts, LRVs, and/or stand-alone LCTs (Lunar Communications Terminals). Global and local data servers will be synchronized, coordinated and updated simultaneously. The client server will be of a light-weight design with minimal power consumption. On-suit sensors will collect real-time data, which will be sent to a nearby local server. All the related data processing will be conducted on the server side. All 2D and 3D spatial information along with some interactive querry functions can be delivered to the astronauts through a liquid-crystal display (LCD) touch screen having an intuitive interface developed in compliance with human-computer interface (HCI) standards. This interface will be mounted on either the astronaut's arm or helmet (Figure 3).

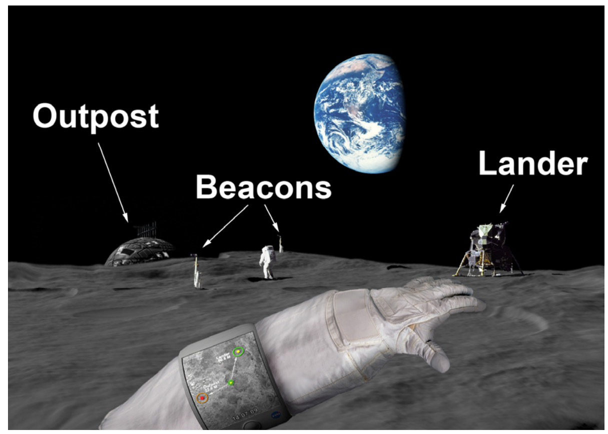

Figure 3. Artist's rendering of the astronaut's view of LASOIS. (Photo credit: OSU/Kevin Gecsi).

The LASOIS prototype will be tested in a lunar-like desert environment, and the developed technologies and systems will be made available for human landed lunar missions in the near future.

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