

Fiscal Year:	FY 2009	Task Last Updated:	FY 08/12/2009
PI Name:	Li, Rongxing (Ron) Ph.D.		
Project Title:	Enhancement of Spatial Orientation Capability of Astronauts on the Lunar Surface		
Division Name:	Human Research		
Program/Discipline:	NSBRI		
Program/Discipline--Element/Subdiscipline:	NSBRI--Sensorimotor Adaptation Team		
Joint Agency Name:	TechPort:	Yes	
Human Research Program Elements:	(1) SHFH :Space Human Factors & Habitability (archival in 2017)		
Human Research Program Risks:	(1) HSIA :Risk of Adverse Outcomes Due to Inadequate Human Systems Integration Architecture		
Space Biology Element:	None		
Space Biology Cross-Element Discipline:	None		
Space Biology Special Category:	None		
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Comments:			
Project Type:	Ground	Solicitation / Funding Source:	2007 Crew Health NNJ07ZSA002N
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No. of PhD Candidates:	4	No. of Master' Degrees:	0
No. of Master's Candidates:	0	No. of Bachelor's Degrees:	0
No. of Bachelor's Candidates:	0	Monitoring Center:	NSBRI
Contact Monitor:	Contact Phone:		
Contact Email:			
Flight Program:			
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Key Personnel Changes/Previous PI:			
COI Name (Institution):	Banks, Martin (University of California, Berkeley) Bhasin, Kul (NASA GRC) Yilmaz, Alper (The Ohio State University) Di, Kaichang (The Ohio State University)		
Grant/Contract No.:	NCC 9-58-SA01602		
Performance Goal No.:			
Performance Goal Text:	<p>1. Original aims of project The aim of this project is to develop a Lunar Astronaut Spatial Orientation and Information System (LASOIS) that will enhance astronauts' spatial orientation capability and reduce sensorimotor risks during future manned lunar mission operations. The detailed objectives are:</p> <p>1.1 To investigate methods for removal and/or alleviation of astronaut disorientation in a lunar surface operations setting by using integrated information technology, and psychological and cognitive research on spatial orientation and navigation.</p>		

Task Description:

1.2 To develop the Lunar Astronaut Spatial Orientation and Information System (LASOIS).

1.3 To train astronauts to enhance their spatial orientation capability in a LASOIS-supported simulated lunar environment.

Supported by LASOIS, astronauts will be capable of overcoming disorientation in lunar surface operations caused by microgravity and the altered visual environment through spatial information provided by the Earth control center and collected by a coordinated group of sensors from lunar orbit, descending path, and ground. The developed spatial orientation strategy, system and training will allow astronauts to have a systematic preparation for complex mission scenarios where spatial operations and efficient interactions and communications are required among the Earth-based control center, lander(s), lunar vehicle(s), outposts, and astronauts. This capability is extremely important for lunar operations that will have an extensive traversing region.

2. Key findings of the project

The following summarizes the key findings, research activities and results for the first project year:

2.1 Investigation of the typical scenarios and constraints of EVA (Extra Vehicular Activity) operations by astronauts of previous missions to provide a baseline for the design of LASOIS.

2.2 Investigation on different astronaut locomotion patterns on the lunar surface including walking, jogging, and hopping etc., as observed in Apollo mission documentation to develop new astronaut spatial orientation capabilities through LASOIS.

2.3 Building an initial version of LASOIS prototype (V1.0) consisting of cameras, MEMS IMU, step sensor, and orbital images, which is being tested at Moses Lake, WA at the end of July 2009. An OLED (Organic Light-Emitting Diode) very thin wrist display is on loan from Honeywell and will be used in the test.

2.4 Development of spatial information technology to handle the data from the sensors. Algorithms are developed to synchronize the step sensor and IMU using both hardware integration and intelligent data processing. Image based localization using stereo image frames at a video rate is developed and will be tested.

A set of tests of the LASOIS prototype V1.0 were performed at OSU. For example, a trajectory was derived using an industrial-grade IMU and a step sensor. Comparing the derived trajectory to a trajectory determined using GPS, a disclosure of 11 m for a traverse of 122 m was obtained (9%). The image based localization method used in MER mission is being modified and extended to fit the new camera configuration. Tests of placement of the cameras suggest that head mount and torso/chest are feasible, but chest mount would provide wider baseline, meaning higher accuracy. The combination of the IMU, step sensor, and cameras should provide continuous localization information at 2%.

An industrial-grade IMU (much better than the MEMS IMU) is ordered from Honeywell and will be used to reduce the accumulative errors that is significant in MEMS IMU.

2.5 Other research activities.

2.5.1 Study on possible solutions for astronaut localization from lunar surface beacon systems; 2.5.2 Study on star tracker technology for astronaut localization.

3. Impact of the findings on the objectives of the proposal

The project is on schedule. According to the Integrated Master Schedule (IMS) in the proposal, the designated first year tasks are carried out on time. We reviewed astronaut disorientation issues and problems experienced in Apollo missions and the possible scenarios and requirements in future lunar manned missions. This provided us useful knowledge for a better design of the LASOIS using new technologies. We completed system design for the LASOIS based on extensive analysis and experiments in the lab, on campus, and in the field. We completed study on sensor integration and developed technologies for data processing and spatial information derivation.

Integration of the step sensor and IMU allows us to identify the zero velocity of the foot where IMU is mounted. Using this knowledge we are able to use ZUPS (zero velocity correction) method to correct the significant cumulative error of the MEMS IMU (12%). The new industrial grade IMU with other integrated sensors should give us a much better accuracy of 2%. A set of tests of the sensors have been carried out, including the in-door laboratory, out-door fields on campus, in Columbus, at Moses Lake, WA and Silver Lake, CA. The database includes high-resolution satellite images, ground images and videos, measurements from multi-sensors, and ground truth measured by GPS and field survey. They are critical to the development and tests of the first version of the LASOIS prototype.

The individual LASOIS sensors were either not used or not used in the new integrated network way for astronaut navigation in Apollo missions. The LASOIS system will be further improved based on the tests of the current LASOIS prototype V1.0.

4. Proposed research plan for the coming year

4.1 Improvement of LASOIS prototype V1.0 by integrating all the possible sensors and considering different astronaut locomotion patterns in a micro-gravity environment.

4.2 Development of LASOIS prototype V2.0 with real-time navigation capability.

4.3 Improvement based on integrated data processing, performance analysis, and capability enhancement of individual sensors and together as a system.

Rationale for HRP Directed Research:

Research Impact/Earth Benefits:	<p>LASOIS will greatly enhance astronauts' spatial-orientation capabilities, reduce or even eliminate disorientation problems, decrease sensorimotor risks, and ultimately improve astronaut performance and safety while on the lunar surface. It will be the first time that such a spatial-orientation and information system was developed and used to improve human performance and human-robotic interaction capabilities in manned missions. Valuable expertise and experience accumulated during the research and development process, especially, the analog field test of the LASOIS system will significantly contribute to improvement of existing scientific strategies. The outputs of this project will provide NASA with data and knowledge supporting lunar surface science and lunar operations scenarios and help understanding and optimization of human performance capabilities to maximize scientific return in future lunar missions. With applications developed on the lunar surface, the system could be further extended to support and Mars manned missions in the future. In addition, the developed technologies can also be used to support personal navigation on earth. Other applications can include environment monitoring, military operations, and complex spatial sensor and sensor network research.</p>
Task Progress:	<p>The achievements over the last funded year have fulfilled the designated tasks in the proposal. The following briefly describes the progress of the project's research tasks:</p> <ol style="list-style-type: none"> 1. We reviewed the relevant literatures related to this project, such as the basic information of the Moon, the astronaut disorientation problems in previous Apollo missions, and the possible scenarios and requirements in future lunar manned missions. Useful knowledge has been obtained, which provides a better understanding to design and development our technologies and systems. 2. We completed system design for the LASOIS based on extensive analysis and experiments. 3. We completed study on sensor integration and developed technologies for data processing and spatial information derivation. An extended Kalman filter is being developed to integrate measurements from IMU, step sensor, and stereo cameras. A KLT tracker algorithm has been improved and implemented for astronaut navigation from video tracking. 4. The LASOIS prototype V1.0 has been developed and tested. It uses a combination of stereo cameras, IMUs, step sensors, and orbiter imagery. A set of tests of the LASOIS prototype V1.0 were performed at The Ohio State University. For example, a trajectory was derived using an industrial-grade IMU and a step sensor. Comparing the derived trajectory to a trajectory determined using GPS, a disclosure of 11 m for a traverse of 122 m was obtained (9%). By incorporating additional observations from stereo cameras, we expect that an improved localization accuracy of less than 2% can be achieved. 5. A spatial database at our test sites (including the in-door laboratory and out-door campus field at the Ohio State University and the analog sites at Moses Lake, WA and Silver Lake, CA) is being constructed including high-resolution satellite images, ground images and videos, measurements from multi-sensors, and ground truth measured by GPS and field survey. Detailed field test data and results from future test campaigns will be incorporated into the spatial database, which will be available to other NSBRI funded scientists and NASA researchers.
Bibliography Type:	Description: (Last Updated: 09/07/2020)
Abstracts for Journals and Proceedings	<p>He S, Wu B, Lee YJ, Skopljak B, Li R. "Inertial measurement unit (IMU) placement analysis for future lunar astronaut spatial orientation and information system." Student Poster. The 2nd Annual NLSI Lunar Science Forum, NASA Ames Research Center, Moffett Field, CA, July 21-23, 2009.</p> <p>2nd Annual NLSI Lunar Science Forum, NASA Ames Research Center, Moffett Field, CA, July 21-23, 2009. , Jul-2009</p>
Abstracts for Journals and Proceedings	<p>Li R, Wu B, Skopljak B, He S, Lee YJ, Yilmaz A, Jiang J, Banks M, Oman C. "Prototype development for a lunar astronaut spatial orientation and information system (LASOIS)." The 2nd Annual NLSI Lunar Science Forum, NASA Ames Research Center, Moffett Field, CA, July 21-23, 2009.</p> <p>The 2nd Annual NLSI Lunar Science Forum, Abstract Book, 2009. , Jul-2009</p>
Papers from Meeting Proceedings	<p>Li R, Di K, Wu B, Yilmaz A, Banks M, Oman C, Bhasin C, Tang M. "Enhancement of spatial orientation capability of astronauts on the lunar surface supported by integrated sensor network and information technology." NLSI Lunar Science Conference, Moffett Field, CA, July 20-23, 2008.</p> <p>Proceedings of the NLSI Lunar Science Conference, 2008. , Jul-2008</p>
Papers from Meeting Proceedings	<p>Li R, Wu B, He S, Skopljak B, Yilmaz A, Jiang J, Banks MS, Oman C, Bhasin KB, Warner JD, Knoblock EJ. "LASOIS: Enhancing the spatial orientation capabilities of astronauts on the lunar surface." 40th Lunar and Planetary Science Conference, The Woodlands, Texas, March 23-27, 2009.</p> <p>Proceedings of the 40th Lunar and Planetary Science Conference, 2009. , Mar-2009</p>