2009 BFRL Project Description

Project Title: Development of an Indoor Intelligent and Automated Construction Job Site (IACJS) Testbed

09/05/2008

Principal Investigator: Kamel S. Saidi x6069

Co-Investigator(s): Itai Katz x3735, Nicholas Scott x3738

BFRL Program: Construction Integration and Automation Technology (CONSIAT)

Objective: To enable the integration of construction equipment, processes, sensing and control systems, and project execution through the development and application of the necessary measurement science.

Problem:

What is the problem? Industry studies have identified inefficiencies ranging from 25 percent to 50 percent in current methods for coordinating labor and managing, moving and installing construction materials.[1,2] Non-farm industries have realized their productivity advances largely due to the integration of information, communication, and automation technologies. The construction industry lags other sectors in developing and adopting these critical, productivity-enhancing technologies.

However, there is a lack of measurement science for evaluating (and thus proving) the performance of promising automation and integration technologies in construction and for enabling real-time monitoring and control of construction processes. Creating and validating the needed measurement science requires a neutral, representative, and accurately monitored environment in which the application of new construction technologies and processes can be evaluated. There are currently no U.S. facilities with the necessary resources and infrastructure to achieve this. Development of Intelligent and Automated Construction Job Site (IACJS) testbeds is identified as one of the key strategic tasks in the FIATECH Capital Projects Technology Roadmap (Element 4 - Intelligent and Automated Construction Job Site)[3]. The need for this capability was also indicated at the 2006 NSF-NIST Advanced Building Infrastructure Testbeds (NABIT) workshop[4].

[1] Tulacz, G. and Armistead, T., "The Top Owners - Large Corporations Are Attempting to Meet the Industry Halfway on Issues of Staff Shortages and Risk," Engineering News-Record, November 26, 2007.
[2] , P. and Daneshgari, P, "Ideal Jobsite Inventory Levels to Improve Productivity," Electri'21 Report, 2005.
[3] http://www.fiatech.org/projects/roadmap/cptri.htm
[4] Akin, O. and Garrett, J., "FINAL REPORT - NSF-NIST workshop on Advanced Building Infrastructure Testbed (NABIT)," September 24-26, 2006, Washington, D.C., submitted to Ed Jaselskis, National Science Foundation.

Why is it hard to solve? Developing a neutral, representative, and accurately monitored testbed environment for the construction industry requires considerable expertise in construction automation, sensing, and performance analysis. The data capture, storage, processing, access, and integration capabilities required for developing such a testbed represent a complex challenge that is not easily solved.

How is it solved today, and by whom? The development of the necessary measurement science for the neutral evaluation of integration and automation technologies in construction is not solved. Currently, universities are largely leading research in developing and experimenting with new automated construction methods, information and communication technologies, and construction processes. However, these efforts have been typically limited to task-level activities and have been implemented in the form of pilot demonstrations fielded through organizations such as CII and FIATECH. Although industry has participated in these pilot projects, they do so with significant reluctance due to the risks these pilots represent to their on-going projects. None of these organizations have the resources to develop a testbed where testing of new measurement science can take place within a neutral, controlled, monitored and representative environment, and at relatively low risk.

Why NIST? The IACJS Testbed is a critical element in developing the needed measurement science that will enable breakthrough improvement in construction productivity. This is directly related to BFRL's mission and vision and is directly aligned with the *Measurement Science for Breakthrough Improvements in Construction Productivity* strategic priority. This project is also directly aligned with BFRL's *Information, communication and automation technologies for intelligent integration of building design, construction and operation* core competency. BFRL is uniquely positioned to solve the problem described herein because of its exceptional combination of expertise in all of the relevant domains necessary to develop an IACJS Testbed and its existing network of collaborations with industry and academia on these topics.

Approach:

What is the new technical idea? BFRL will integrate several key construction automation, sensing, information integration and performance analyses capabilities into a testbed environment, which will be jointly designed by industry, academia, and other research organizations (including NIST). These capabilities will include technologies with which BFRL has unparalleled expertise as well as new technologies that will be identified by various industry stakeholders through a workshop (or a series of workshops) and implemented by BFRL researchers and in collaboration with university researchers. The IACJS testbed will enable standardized, repeatable testing and evaluation of new construction methods, processes, and information and automation technologies. It will employ modular packages of sensing, communication, control, and simulation equipment. For example, the testbed environment will include the ability to measure the position and orientation of construction personnel, equipment, and components with relatively high tolerances and to integrate that information with outside applications or virtual simulations. Capturing such performance information is a critical step in the process of developing the enabling measurement science.

Why can we succeed now? BFRL has developed significant expertise through related projects in several fundamental capabilities essential for developing an IACJS Testbed. These include:

- site positioning and tracking using GPS, indoor GPS, and ultra wideband technologies;
- realtime 3D visualization and planning using 3D range cameras, supervisory software, and augmented reality;
- as-built conditions monitoring using 3D imaging systems and on-site data collection;
- wireless data communications;
- control architectures using 4D/RCS for generic equipment control;
- site visualization and simulation; and
- information exchange and integration protocols.

These technologies and computational capabilities have advanced to such a degree that the development of an IACJS Testbed has become feasible. BFRL possesses the experience in implementing these technologies in construction applications and the expertise to integrate other emerging, highly advanced technologies into a testbed environment. BFRL's expertise in the above areas have already been sought and used by various research organizations. This project intends to capitalize on the knowledge and expertise developed as part of the above accomplishments in order to integrate these capabilities (and others) into a functional testbed.

What is the research plan? Based on the results from the FY08 NIST/ FIATECH workshop to identify the requirements for the IACJS Testbed, BFRL anticipates that both an indoor as well as an outdoor facility will be needed to cover the variety and scale of the various construction technologies that will be tested. The indoor facility (the focus of this project) will be located on the NIST, Gaithersburg, MD campus and will combine BFRL's aforementioned capabilities with other capabilities (that were defined through the industry workshop) under a controlled, well characterized, repeatable, and accurately monitored environment. Design and creation of a future outdoor facility (which this research will inform) could take the form of a movable infrastructure that can be set up at various locations or on actual construction sites as pilot projects.

BFRL will hold a series of web workshops to continue the functional requirements development for the indoor IACJS Testbed that was started at the FY08 workshop. BFRL will then identify a set of data-capture technologies that will meet the functional requirements and to develop initial implementation strategies. Examples of such data capture technologies are: 3D Imaging Systems, smart tags, and on-board instrumentation[5].

BFRL will complete Phase I of the instrumentation of the indoor IACJS Testbed. This will include the initial outfitting of the testbed with the following sensing capabilities: indoor GPS, active RFID, ultra wide-band locating systems, 3D imaging systems, and industrial grade total station measurements. In addition, BFRL will conduct a test of a new sensing technology (calibrated camera networks) for the indoor IACJS Testbed to evaluate its performance for tracking workers at a construction site (simulated) for safety and productivity analysis

[5] Sensors installed on-board construction equipment to monitor various parameters (such as orientation) of the equipment. An example of such an instrument is an inertial measurement unit, which uses accelerometers and/or gyroscopes to monitor motion.

applications. Finally, in FY09 BFRL will also conduct a pilot test of the calibrated camera network on a steel erection training site.

The indoor IACJS Testbed will be completed at NIST and new partnerships with industry, academia, and research organizations for testing and evaluating the performance of specific technologies, systems, methods, or processes will be formed. In addition, in conjunction with industry and academia, BFRL will develop methods and procedures to evaluate the performance of a construction technology, system, method, or process that was selected in FY08. Results and data from this effort will be published. The functional requirements and a conceptual design for an outdoor testbed will also be developed and published in FY10, and the results of the pilot test of the calibrated camera network will be published and the data made publicly available for research purposes.

Recent Results:

Outcome: The Reconfigurable Crane Apparatus (RCA). The RCA is a modular system comprised of a structural support frame, motors, winches, and a modular control architecture (based on RCS) that can be used to test various sensors and motion planning, obstacle detection, lift planning, and control algorithms (among others).

Outcome: Added a new tool and new technical capabilities to be used in the IACJS Testbed.

Output: Industry workshop in conjunction with FIATECH to identify the requirements for the IACJS Testbed (July 29-30, 2008). The objective of the workshop was to identify a draft, industry-driven set of requirements (capabilities) for the IACJS Testbed.

Participation of owners, constructors, software manufacturers, academia and other industry stakeholders in identifying an initial set of design requirements for the IACJS Testbed. (Note: This requirements development process will continue in FY09).

Scanned and modeled the highbay laboratory of building 226.

Developed a conceptual design for the NIST indoor IACJS Testbed

Selected structural steel erection as the construction process that will be the focus of efforts to develop methods and procedures to evaluate performance in FY09.

Standards and Codes: Development of the initial protocols and procedures for live-capture of data from the testbed will have direct impact on standards for capturing live-data from construction sites in the future. Standards for data capture from 3D Imaging Systems are already under development through ASTM E57 Committee on 3D Imaging Systems and may be tested within the IACJS Testbed. BFRL members are a key part of ASTM E57.