Report of the NIST Workshop on Data Exchange Standards at the Construction Job Site [1]

by

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ABSTRACT: The Building and Fire Research Laboratory of the National Institute of Standards and Technology, in cooperation with the Fully Integrated and Automated Technology (FIATECH) consortium, sponsored a workshop on data exchange standards at the construction job site in May 2003. The purpose of the workshop was to investigate the problem of exchanging sensor data at the construction job site. Some of the desired outcomes were to identify requirements for and barriers to sensor data exchange in construction, to identify and plan the steps required to establish raw sensor data-exchange standards, and to identify future research directions. A description of the workshop structure, agenda, and preliminary results are presented.

KEYWORDS: construction automation, intelligent job site, construction sensors, LADAR, data exchange standards

1. INTRODUCTION

The construction industry has indicated that knowledge of the status of a construction project is one of the most challenging problems faced by project management and jobsite personnel [1, 2]. Although construction measurement and sensing technologies and project information management software (PIMS) – such as scheduling and estimating software – have advanced considerably in the past 20 years, accurate and up-to-date knowledge of the current status of a construction project remains elusive.

New CAD technology is attempting to bridge the gap between scheduling and traditional CAD software thereby producing a new class of software technology known as 4D CAD. 4D CAD allows "visualization of the facility design and its changes over time and allows computer-based analysis of constructibility, cost, productivity, and other project performance variables dependent on an integrated analysis of time and space" [3].

However, both 4D CAD and other PIMS need to be supplied with updates from the jobsite about the state of the various construction activities, and at present these systems rely primarily on workers who manually enter up-to-date information. One of construction automation's premises is to introduce advanced measurement and sensing technologies onto the jobsite in order to automate the updating process. Ubiquitous sensing with real-time construction process monitoring and control are the prerequisites for creating an intelligent jobsite [5].

The workshop brought together general contractors, construction equipment manufacturers, metrology instrument

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manufacturers, sensor and product model data exchange experts, and construction researchers.

The discussion was focused on the data exchange issues involved in seamlessly integrating future and existing measurement and sensing technologies (such as LADAR, GPS, RFID, total stations, temperature sensors, strain sensors, etc.) with construction software and other hardware in order to improve productivity, quality, and safety, as well as prepare for future sensing and automation challenges (such as deploying fully-automated machinery on the jobsite). Sensors and sensor data exchange were emphasized throughout the workshop.

Some of the desired outcomes from the workshop were to identify requirements for and barriers to sensor data exchange in construction, to identify and plan the steps required to establish raw sensor data-exchange standards, and to identify future research directions.

This report presents information contained in the keynote addresses and results of the working group breakout sessions.

2. WORKSHOP FORMAT

The workshop convened over a period of 2 days. A total of 24 non-NIST participants attended the workshop. Participants included representatives from 3 leading US engineering, procurement, and construction companies and 3 leading instrument and equipment manufacturers. In addition, researchers from 6 universities and 2 specifications organizations were present. NIST researchers included personnel from the Building and Fire Research Laboratory's (BFRL) Materials and Construction Research Division and Building Environment Division, as well as personnel from the Manufacturing Engineering Laboratory's (MEL) Manufacturing Metrology Division.

The workshop was divided into three sessions. Each session included 2 topical presentations[3], a breakout session, and a full group discussion.

[3]All of the workshop presentations are available at: www.bfrl.nist.gov/861/CMAG/CMAG_workshop/

3. DETAILED AGENDA

3.1 Day One

Day one began with an introduction by the NIST Building and Fire Research Laboratory director, Dr. Jack E. Snell.

The introduction was followed by a two-part questionnaire that asked the participants to describe their view of an "Intelligent Job Site," and to state their personal desired workshop outcomes.

Following the administration of the questionnaire, Dr. William C. Stone, leader of the NIST Construction Metrology and Automation Group (part of BFRL), gave a presentation entitled "The Automated Construction Site: Data Exchange Problems" [6].

Dr. Stone's presentation discussed some of the challenges faced by the US construction industry and how technology can address some of those challenges. In particular, Dr. Stone talked about developments in LADAR (Laser Detection and Ranging) sensor technology and how it can be used in construction. Other topics discussed in Dr. Stone's presentation included:

- Robot positioning
- Object recognition
- Robot control
- Visualization
- Data management
- Barcodes
- RFID tags
- Smart Chips
- Long-range auto identification

Dr. Stone was followed by Mr. Harry Niedzwiadek, Architect of the Open GIS Consortium's (OGC) Interoperability Program, who gave a presentation entitled "The Sensor Web Enablement Framework (Status and Plans for Sensor Web Technology at OGC)" [7].

Mr. Niedzwiadek first introduced the audience to the OGC and then discussed the Sensor Web Enablement (SWE) framework and concepts of its architecture, applications, and development plans. Mr. Niedzwiadek also touched on the relevance of the SWE framework to the intelligent jobsite. He stated that the SWE framework provides a common, open service for "tasking, monitoring, and collecting observations for any and all sensors" [7]. Mr. Niedzwiadek also suggested that the SWE framework would make "sensors just another resource in jobsite applications: safety, security, materials management, asset management, maintenance management, equipment status, construction monitoring, performance monitoring, etc." [7].

Following the first two presentations the workshop participants were divided into 3 groups. Each group was presented with a list of questions regarding the intelligent job site and asked to discuss them.

The afternoon session of day one began with a presentation by Mr. Kang Lee, leader of the NIST Sensor Development and Applications Group (part of the Manufacturing Engineering Laboratory) entitled "The Smart Transducer Interface Standards (IEEE P1451)" [8].

Mr. Lee presented the work that has been done toward the development of the IEEE transducer interface standard (parts of which have already been established and published). In his presentation Mr. Lee stated that the P1451 standard provides "an industry wide, open standard" that can provide common analog, digital, and wireless "interfaces between sensors/actuators, instruments, microprocessors, or networks" [8].

Mr. Lee's presentation was followed by Dr. Michael Botts of the University of Alabama at Huntsville. Dr. Botts presented a talk entitled "Sensor Model Language (SensorML): XML-Based Language for In-situ and Remote Sensors" [9].

In his presentation, Dr. Botts described SensorML as "an XML schema for defining the geometric, dynamic, and observational characteristics of a sensor" [9]. SensorML allows software and hardware to communicate with different sensors regardless of the manufacturer as long as both parties speak SensorML.

Dr. Botts presented the following possible benefits of SensorML to construction [9]:

- Standard descriptions of all sensors in the community
- Easier assessment and discovery of sensors
- Common software for all sensors
- Archive of embedded/mounted sensor capabilities decades from now
- "Intelligent Jobsite" – construction progress, "in-time alerts" (e.g. stresses exceeded), robotic construction
- Fusion of disparate data from 4D site

Following Dr. Botts's presentation, the workshop participants were again divided into 3 groups. During the second breakout session the participants were presented with some guidelines and asked to discuss sensor interface and standardization issues related to construction.

3.2 Day Two

Day two of the workshop began with a presentation by Dr. Burcu Akinci of Carnegie Mellon University (Pittsburg, PA) entitled "Advanced Sensor Based Defect Detection and Management at Construction Sites" [10].

Dr. Akinci's presentation discussed the following five issues [10]:

1. Scan Planning
2. Sensor Planning
3. Object Recognition
4. Integrated "Living" Project Models
5. Automating Defect Detection

Dr. Akinci showed through case studies that "total saturation" of a job site with LADAR is inefficient while sparse coverage may inadvertently miss relevant information. Having a plan in place that specifies when and from where each scan should be conducted can help produce more effective information [10].

Dr. Akinci's presentation was followed by Dr. Kent Reed, leader of the Computer Integrated Building Processes group (part of BFRL). Dr. Reed presented a talk entitled "…now, for the rest of the story" [11].

Dr. Reed presented the case for integrated project delivery systems (PDS) that was developed by the Business Roundtable in 1997. That study showed that effective PDS resulted in an increase in return on investment for the owner, reduced project cost, and improved operability of the completed project.

Dr. Reed continued with a brief history of the efforts that have been expended on construction integration and interoperability research to-date and touched on some of these in more detail. He concluded with a list of issues that still need to be addressed in order to achieve true integration and interoperability in construction.

Following Dr. Reed's presentation, the workshop participants were divided into 3 groups once again. The purpose of the last breakout session of the workshop was to discuss the issues that still need to be addressed in order to begin work on a standard/protocol/schema for sensor/instrument data exchange at the construction job site.

The ideas that resulted from the breakout sessions were then discussed among all the workshop participants.

Following the group discussion, Mr. Alan Lytle, Robotics Engineer at the NIST Construction Metrology and Automation Group gave a short talk about FIATECH in which he described the consortium, its recently published Capital Projects Technology Roadmap, and the planned Smart Chips pilot projects.
Mr. Lytle's presentation was followed by an open discussion session during which the participants were asked to express their opinions freely and to discuss possible actions that could be undertaken.

4. RESULTS

This section presents preliminary results of the workshop's breakout sessions and final open discussion session.

4.1 Breakout Session One Results

The following is a list of some of the questions and comments that came up during the first break out session on day one of the workshop:

- Need a life-cycle model of a construction job site and of the intelligent job site and of the processes involved in each (including information flows).
- Need to know what the sensor limitations are (e.g., can a sensor distinguish between a painted wall and an unfinished one?)
- Automating the collection of data at the job site is critical.
- What will be the organizational challenges of achieving the intelligent job site?
- Showing the cost benefit of implementing new technologies is critical to the owner. How will that be overcome?
- A sensor can become just like another project resource on the intelligent job site.
- What is the latency period in "real-time" data exchange at the intelligent job site and how will that be handled?
- What will the wireless networking issues be and how will they be solved (e.g., security of the data and coverage area interference)?
- Material tracking remains a very big problem on the current construction job site. How will that be solved on the intelligent job site and how can it be addressed today?

4.2 Breakout Session Two Results

The following is a list of some of the questions and comments that came up during the second break out session on day one of the workshop:

- Construction equipment manufacturers would prefer to buy sensors that are robust enough rather than developing their own.
- EPC contractors will not invest in an expensive technology because the business case is not there.
- Most people in the AEC field will not be interested in low level technical details

addressed in IEEE 1451. IEEE 1451 and SensorML are complimentary standards/protocols, but the overlap should be clearly defined.

- Having a standard for sensor data exchange may encourage people in the construction industry to use more sensors.
- If every component has sensors on it, does it improve the capability to construct and improve the constructed product, or both?
- The format of the sensor data must be compatible with standard software.

4.3 Breakout Session Three Results

The following is a list of some of the questions and comments that came up during the break out session on day two of the workshop:

- Standards empower vendors and sensor data exchange standards will empower the sensor industry.
- Sensor manufacturers need a consortium to help in the standardization effort.
- As an example, there are currently no standards for LIDAR's.
- The construction industry is too conservative and thus sensor manufacturers must take the lead in the standardization effort and they must present case studies to the construction industry to get proper buy-in.
- Standards can both promote and prevent innovation.
- A sensor can be any device that collects data (including humans).
- What is the difference between data and information?
- Overcoming the technological barrier to developing a sensor data exchange standard will be easier than overcoming the political barriers.
- Need to model the data exchange requirements during the entire life-cycle of a construction project.
- The standard should consider both the sensor user and sensor manufacturer points of view.

4.4 Open Discussion Session Action Items

The following is a list of action items that were developed during the open discussion session on day two of the workshop.

- Analyze the potential merging of 1451 and SensorML and provide a short report to interested parties
- Investigate the formation of an expert group to work within the OGC environment
- Initiate a forum for the sharing of relevant information related to the workshop
- Match our understanding of construction-related LADAR use with the GIS/Remote-sensing community (does the current schema in SensorML meet the need?)
- Publish a white paper outlining driving requirements (with buy-in and prior standards research) to suggest some initial ideas to OGC
- Develop a description of an intelligent jobsite
- Prioritize the "information" needs on the job site and use the described need as a basis for selecting the initial sensor(s) to target for the standards effort
- Investigate whether the data exchange standards effort is targeted at sensors/instruments for the specific construction process or for the project life-cycle
- Define a "sensor" as applicable to the data exchange standards effort
- Define "data" (information) as applicable to this effort
- Consolidate literature on cost analysis of automation in construction

5. CONCLUSIONS AND FUTURE WORK

The workshop on data exchange standards at the construction job site was held on May 29 and 30, 2003 at NIST in Gaithersburg, MD. The workshop brought together people from the construction industry, equipment manufacturers, and research institutions (among others) to discuss the barriers and challenges to sensor data exchange in construction and the steps required to establish raw sensor data-exchange standards. The preliminary results of the workshop were presented above.

Future work includes analyzing the workshop results further and publishing the findings in a final report. In addition to the action items presented above, the findings from the final report will also be investigated and a research roadmap will be developed.

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