2009 BFRL Project Description

Project Title: Methods and Metrics for Conformance Testing for Construction Project Data Standards

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BFRL Program: CONSIAT: Construction Integration and Automation Technologies

Objective: Develop the measurement science for producing conformance test suites and test scripts for construction project data exchange standards and for measuring the completeness of conformance testing. The industry will use these methods and metrics.

Problem:

What is the problem? The 2004 NIST report[1] on the cost of inadequate interoperability in the U.S. capital facilities industry identified almost $500M lost per year due to the manual reentry of data. With the increased focus on Building Information Modeling (BIM)[2], many in the construction industry are expecting that interoperability with data exchange standards is a seamless process. Studies by the Industry Foundation Classes (IFC) Implementation Quality Group, the European consortium Erabuild[3], and the Architecture, Engineering, Construction and Owners/Operators Test Bed[4] have identified significant interoperability issues in the current use of IFCs as a construction project data exchange specification. Although the construction industry is adopting building information modeling and working on product data and building data exchange specifications, there are no proven and adopted methods and metrics for: (1) consolidating information exchange requirements and aligning data dictionaries; (2) defining validation test suites; (3) defining conformance test suites; (4) measuring the coverage of conformance test suites; or (5) measuring the conformance of software implementation to BIM data exchange specifications. This enabling measurement science is fundamental to the

[1] "Cost Analysis of Inadequate Interoperability in the U.S. Capital Facilities Industry, NIST GCR 04-867, http://www.bfrl.nist.gov/oae/publications/gcrs/04867.pdf

[2] The National BIM Standard defines BIM as a digital representation of physical and functional characteristics of a facility. A BIM is a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life-cycle; defined as existing from earliest conception to demolition. A basic premise of BIM is collaboration by different stakeholders at different phases of the life cycle of a facility to insert, extract, update or modify information in the BIM to support and reflect the roles of that stakeholder. http://facilityinformationcouncil.org/bim/index.php

[3] http://www.senternovem.nl/Erabuild/more_information/News/nieuw_pagina.asp

[4] AECOO Request for Technology, http://www.opengeospatial.org/

development of validated data exchange specifications and the establishment of reliable and repeatable processes for assessing the conformance of software implementations and to establish interoperability. The measurement science for these methods and metrics is lacking.

Why is it hard to solve? The problem is hard to solve because the foundational measurement science for semantic analysis and the codification of information requirements into data exchange specifications is missing. Compounding the challenge are the complexity of the building information models, the broad mixture of different disciplines and vocabularies which must be accommodated, and the increasing intricacy of specialized software applications and information management practices employed in construction. There is a lack of infrastructure for the rigorous and repeatable conformance assessment of software implementations of data exchange specifications.

How is it solved today, and by whom? The problem is not solved. The current process IFC Certification does not guarantee interoperability. Many projects (ATC-75[5], Georgia Tech architectural precast[6], AECOO Testbed[7], GSA BIM Space Guide[8], and others) are reinventing the wheel and have no standardized methods and metrics to apply to test and develop interoperability. There has been some related work done in academia about detecting differences between product data standards or files and in how to generate a product data model based on a process model. None of the efforts has addressed the need for enabling measurement science, performance metrics, and an integrated approach to validation testing, conformance testing, and interoperability.

Why NIST? This project addresses BFRL's core mission to promote U.S. innovation and industrial competitiveness by advancing measurement science, standards, and technology. This project supports the BFRL strategic priority for measurement science for breakthrough improvements in construction productivity and the BFRL core competency in information, communication and automation technologies (ICAT) for intelligent integration of building design, construction and operation. BFRL is uniquely qualified in pursuing this research due to its involvement and understanding of product data standards such as ISO 10303 (STEP), IFCs and CIS/2, its interactions with the International Alliance for Interoperability (IAI), many CAD software vendors that have implemented product data models, and end-users of those data exchange specifications and earlier work on developing and validating date exchange specifications and conformance test suites.

Approach:

What is the new technical idea? BFRL will combine model-based approaches to developing data exchange specifications with available conformance assessment methods and tools for validating data exchange specifications and for generating conformance test suites. BFRL will develop measurement science for structuring test suites, analysis of test case coverage

[5] ATC-75 Project: Development of IFCs for Structural Components, http://www.atcouncil.org/atc75.shtml
[6] BIM for Precast Concrete, http://www.fiatech.org/pdfs/projects/nibscpf1107.pdf
[7] http://www.opengeospatial.org/projects/initiatives/aecoo-1rfq
[8] http://www.gsa.gov/Portal/gsa/ep/contentView.do?contentType=GSA_BASIC&contentId=21768&noc=T

and test script generation. BFRL will use its partnerships with two industry data exchange initiatives to test the initial results for efficacy, efficiency and robustness for (1) defining validation test suites; (2) defining conformance test suites; (3) measuring the coverage of conformance test suites; (4) measuring the conformance of software implementation to a data exchange specification, and (5) measuring interoperability among software applications. The measurement of coverage, conformance, interoperability and the definition of validation and conformance test suites are interrelated problems. They all require sets of characteristics by which information required for them can be evaluated, measured, or generated.

Why can we succeed now? With the increased focus on building information modeling, interoperability, and construction productivity, and the increasing capabilities and variety of software applications being used for construction projects, the construction industry is demanding reliable and repeatable data exchange and integration. Advancements in software engineering and test script generation are sufficiently mature to now extend these to the complex information models used for construction projects. BFRL is collaborating with ITL and MEL to adopt and extend the relevant results from their work to these challenges.

What is the research plan? A study was completed to (1) understand conformance testing methods and tools that have been successful in other domains; (2) to quantify how existing construction project data standards are validated; and (3) to assess the current certification and conformance testing processes for these standards. This has identified the key principles to apply, appropriate tools to investigate and high priority needs for developing new fundamental methods and metrics.

Typical methods for inspecting the contents of product model instances, such as IFC files, are to visualize them with an IFC viewer, in CAD software, or to view the file structure with a tree viewer. These methods only provide a visual confirmation of the model represented by the file or to inspect individual entity attributes. No methods are in place to provide a rigorous determination or measures of the contents of an IFC file.

A conformance assessment tool is being developed to evaluate the coverage of IFC product data model files. The software tool provides a platform for evaluating which characteristics are important in determining the coverage. Beyond simple string or numeric values, features such as object shape, position, orientation, and relationships will be evaluated.

Metrics will be developed to evaluate the use of string, numeric, shape, position, orientation, and relationships. The metrics will be used to evaluate individual IFC files, groups of IFC files that model similar concepts such as beams, columns, windows, walls, and floors, and IFC models of complete structures. Different metrics might have to be developed depending on the type of structures being modeled and the set of files being evaluated. The metrics will also be generalized so that they can be applied to other construction related product models.

Based on the knowledge of how existing test files provide coverage of a product data standard, methods will be developed to generate test files. The types of generated test files could provide coverage for different concepts in the standard for (1) individual objects such as beams and columns; (2) higher level concepts such as a room that includes floors, walls, doors, windows, and spaces; and (3) for different types of domains such as structural engineering or HVAC. The

metrics developed to evaluate existing IFC files will play an important part in developing the metrics for generating test files. The methodology will be based on existing software conformance testing developed in the NIST Information Technology Laboratory. This research is based on generating conformance test files from XML schemas. The challenge will be to extend the research beyond generating simple numeric or text values to generating information that defines, shape, position, orientation, and structure. Combinatorial methods will also be investigated to determine what the minimum set of test files is to satisfy a particular exchange requirement.

The expected outcomes of this research include: (1) methods, metrics and tools for evaluating existing sets of test cases used for construction product data models; (2) methods to generate test cases to ensure coverage of a project data exchange specification; (3) smaller sets of conformance test files that provide better coverage of a project data exchange specification; (4) the ability to generate test files concurrently as a product data standard is developed to speed up the adoption of the standard and certification of software products using the standard.

Recent Results:

Outcome: The NIST CIS/2 to VRML and IFC Translator, available through http://cis2.nist.gov/. There have been over 3000 downloads of the Windows version of the translator and thousands of CIS/2 files have been translated with the web-based online version.

Outcome: Development of a publically available software tool and method to measure the coverage of IFC files.

Impact: Industry attains robust capabilities to assess the contents of CIS/2 and IFC files. This results in broader adoption of the data exchange protocols and integration across the structural steel design and fabrication processes, leading to improved industry competitiveness.

Anticipated Results:

Output: Lipman, R., "Details of the Mapping Between the CIS/2 and IFC Product Data Models for Structural Steel", Journal of Information Technology in Construction, submitted March 2008.

Impact: Industry adoption of the methods and tools for conformance testing enables the reliable selection and integration of new software tools and streamlined processes for breakthrough improvements in construction productivity.

Standards and Codes: The direct impact of the research will be improved methods and metrics for conformance assessment and test suites and files used in the construction industry data exchange standards such as IFC and CIS/2. Staff participates in many committees related to those standards.