Preservation of Meaning in Mapped IFCs

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ABSTRACT: The development of high-level standard representations of buildings has been welcomed by the majority within the industry. Such standards allow for semantic interoperability between the large number of design tools which are available to practitioners in the A/E/C and FM industries. However, with such standards comes greater reliance on the information contained within the models which are transmitted, and interpreted, automatically between design tools. Unlike geometry-based standards (e.g., DXF, IGES, DWG, etc) where there was always an expectation of human interpretation, this semantic data must be correct to fit within the interoperable world we have developed. Testing of the semantic interoperability of a small number of commercial design tools has shown that this level of trust is not yet able to be assumed and that further work needs to be done to ensure that we can preserve meaning when moving semantic information between design tools.

1 INTRODUCTION

The IFC standard (IAI 2006) has been incorporated into the pre-eminent computer-aided design tools (CAD) used by the majority of the architecture, engineering and construction (A/E/C) professions and now increasingly in facilities management (FM). IFC provides a high-level semantic description of a designed building. With IFC version 2x2 there are over 500 classes of information that can be utilized to describe aspects of a building and their relationships to each other. The standard also allows for a variety of descriptions of the building's geometry sitting beside the semantic objects which comprise the building.

The IFC standard provides for unfettered transfer of semantic information between the major design tools used in A/E/C-FM and should ensure that the most up-to-date, and accurate, information is available to all professionals. This is a long held dream of those in this industry.

With building data encoded into these semantic constructs there is now a greater reliance on the accuracy of the data being transferred. While previous geometry-based standards (e.g., DXF, IGES, DWG, etc) were used for similar interoperability tasks there was widespread recognition that the translators were not always accurate and human interpretation of the mapped geometric information was always necessary. In some respects this was easy to do when all the data being transferred had a visual representation. The IFC standard, however, is mostly semantic and there are many classes of information which do not have geometric representations (e.g., schedules). So checking the data is not as easily accomplished by a human as previously. The fact that the data is described at a semantic level, and that design tools are certified as conforming with the standard entices users to accept that the transferred data will be correctly interpreted.

1.1 *Testing for interoperability*

Previous investigation has revealed that the flow of IFC-based information in and out of the major CAD tools (certified by the IAI as IFC compliant) is not without some transformation, even when no work is done on the building design within the design tool being tested (Ma et al. 2006).

This is not a particular surprise. Previous work on the development of mapping languages and support environments for those languages (Amor 1997; Amor & Faraj 2001; Grundy et al 2004) identified a range of 'impossible' mappings and mappings where the semantic scope of what was mapped differed between representations. The surprise would be if there was perfect semantic interoperability between the IFC standard of over 500 classes of information and the internal model of design tools which have evolved in their specialist areas, in some cases for decades.

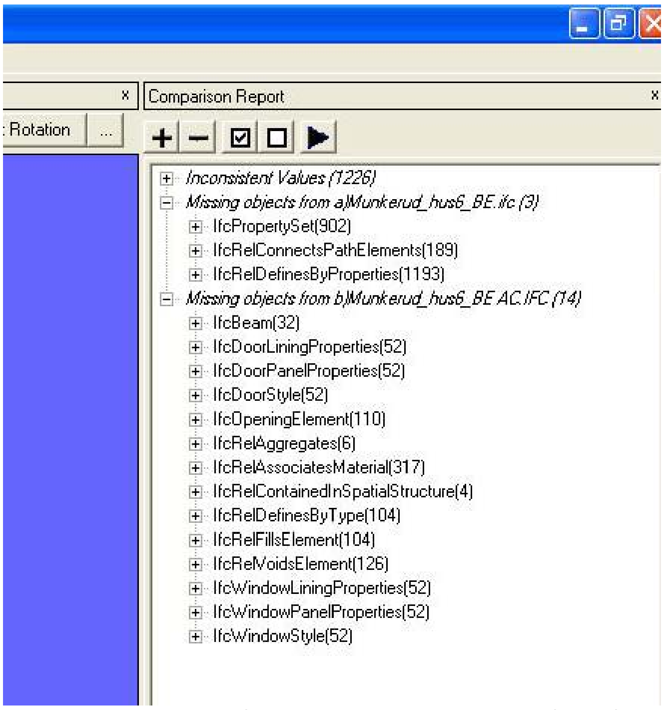

Figure 1. Summary of changes to an IFC data file after a round-trip through a CAD package.

Transformations identified when performing a round-trip of IFC data into and straight back out of major CAD tools include the addition, or removal, of objects representing physical constructs from the original description of the building (e.g., beams, see Figure 1) as well as changes to attribute values in the models. Given that these objects have very clear semantics, and identity, within the IFC data model this is obviously of concern to those who must rely on the accurate transfer of information between design tools. This leads us to examine why in certified design tools the meaning of models is not always preserved as expected.

2 IFC CONFORMANCE TESTING

Certification of design tools is a process undertaken by a software vendor according to the rules laid down by the IAI (1996). There are two basic parts to this process. The first is a self testing process where a company utilizes the formal test cases for the exchange view they propose to support. When their design tool is able to conform to the requirements around the formal test cases then they put their deign tool forward for testing at a public interoperability workshop where: "The purpose of the workshop is to demonstrate to an appointed representative of the IAI that interoperability is achieved under live data exchange conditions with other IFC applications." (IAI 1996). A design tool which successful completes both of these processes is deemed to be IFC compliant as is authorized to carry the IAI Certification logo for the particular version of IFC that their design tool was tested against.

This approach fits with the standard view of conformance testing as described by Kindrick et al. (1996). Testing takes two forms (see Figure 2). In one form a particular design task is executed in the design tool and the resultant model exported as an IFC file. This IFC data file is then analysed to ensure that the design tool created structures of the correct type. The second form imports the IFC data file into the design tool to analyse whether the correct structures were instantiated within the design tool.

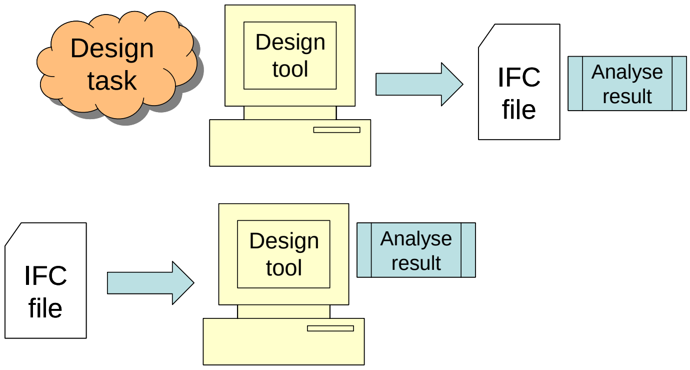

Figure 2. Two types of conformance testing (adapted from Kindrick et al. 1996)

Such conformance testing can provide reassurance that the design tool complies with the transfer standard in terms of the structures created and the semantics of individual test cases. It is also relatively cheap to perform as each design tool is tested individually. However, this approach doesn't address larger issues of whether the tool is interoperable with other design tools.

The IAI's interoperability workshop is an approach to providing this reassurance (see Figure 3). Though it is structured to concentrate on particular design tasks and only requires interactions with a small number of design tools. To guarantee full interoperability this testing would have to be performed with every design tool which utilizes the particular exchange view.

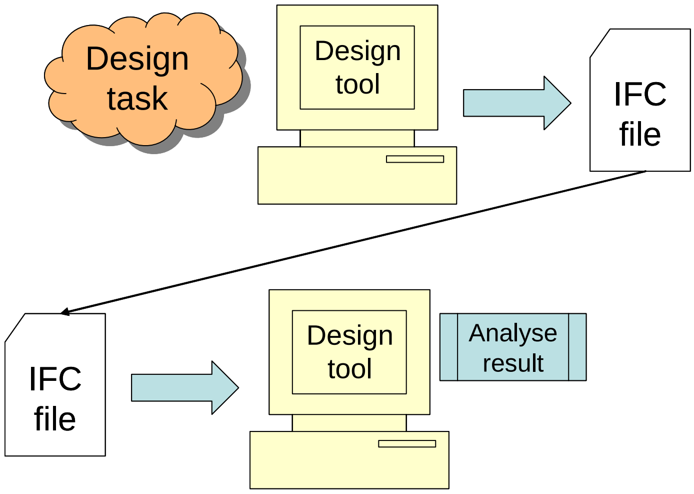

Figure 3. Interoperability testing (adapted from Kindrick et al. 1996)

3 ROUND-TRIP TESTING

A different level of testing, aiming to increase the level of interoperability testing without having to test the design tool against all other certified design tools, is provided by round-trip testing. In this approach an IFC data file is imported into a design tool, not modified at all, but exported directly back out again. Whereas conformance testing only provides a viewpoint of either the input mapping from the standard to the design tool's internal data structures, or the output mapping from the design tool's internal data structures to the standard, the round-trip testing looks at the operation of both mappings in relation to each other.

As seen in Figure 4 there are two IFC files of exactly the same building which can be examined in this approach. By identifying any differences between the two IFC data files it is possible to determine how interoperable a design tool is with itself over a wide range of formal (and informal) test cases.

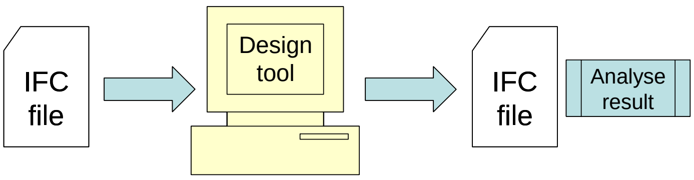

Figure 4. Round-trip testing of a design tool

This testing should occur after conformance testing, when the design tool authors are comfortable that their design tool applies the standard correctly when importing or exporting data. This suite of tests determines whether the design tool preserves the semantics of the data in particular exchange views which passes through both of the mappings implemented in the design tool.

4 INTEROPERABILITY ISSUES

4.1 *Syntactic issues*

There are a range of issues that could be expected from this testing if just looking at the syntactic level of data in the two IFC data files. At the object level it is possible that during the mappings:

– An object is added. For example, if the design tool requires more artifacts to represent a particular construct than is required in the standard.
– An object is removed. For example, if a particular artifact is not supported within the design tool and so the object information is not maintained during the mapping.
– An object is modified. For example, where the design tool has a different method of representing an artifact than in the standard.
– The globally unique ID of an object is changed. This should never occur as this ID is inviolate.

At the attribute level it is possible that during the mappings:

– An attribute value is added. For example, a default value is applied during a mapping.
– An attribute value is removed. For example, a particular attribute is not stored within the design tool.
– There is loss of precision in a numeric value. For example, a different data type is used between the design tool and the standard.
– The number of references to other objects is modified. For example a design tool has a maximum number of allowable references (e.g., walls enclosing a space).
– An attribute value is modified. For example, a different calculation is applied to derive a value.

4.2 *Semantic issues*

While the syntactic checking will likely throw up hundreds of differences in any test performed (see Ma et al. 2006) it is clear that some of these changes are irrelevant, or even expected, when a design tool manipulates a data file. For example, the majority of design tools insert objects and attributes to document that they have processed a data model along with the date and time this occurred and who was involved in processing the data model. This type of modification does not change the semantics of the building under investigation and is necessary for quality assurance processes. It is the other changes, such as the addition or removal of physical objects in the data file, that have a semantic impact. Looking at these changes from a semantic perspective a set of categories emerges:

– Meta data associated with the design tool's processing of the data model. This type of information has very little impact on the building model but creates a timestamp in the data model to show what design tool processed it and who was operating the design tool at that time.
– Geometric representations of physical objects can be modified due to the internal geometric model of the design tool. The issues that arise from these changes are the same as exist for geometric information transfer with standards such as DXF, IGES, DWG, etc. This type of change may have an impact on the data model, but in most instances the attributes of the physical object are unaffected by this type of change. There are three main types of geometric modification. One is the addition of greater detail in the same geometric

representation. One is where an alternate representation is introduced (e.g., from a bounding box representation to a full description of the object's geometry). One is where aspects of the geometry have changed due to artifacts of the mapping process.

– Unsupported property sets represent information associated with an object in the exchange view but which is not maintained by the design tool. The loss of this type of information was frequently encountered in the analysis of mappings. This is of concern as much of the real detail about an object's parameters are located within property sets.
– Incorrect usage of the standard has been observed in a small number of cases. Here a class of physical object has been used in a manner not expected. This seems to exist to allow for the modelling of physical objects that have no class specified in the standard. For example, beam objects used to model other physical artifacts in the building.
– Destroyed meaning is where objects are dropped, added or modified without discernable reason. Again this has been observed in a small number of cases.

The meta data and geometric representations are not of great concern as they exist for legitimate reasons, or are expected, but usually not important, modifications. Unsupported property sets could be easily rectified by design tool companies maintaining links between objects and their associated information. Incorrect usage of the standard should be flagged to the user importing data into their design tool rather than silently dropped. The category where the meaning of the model is altered should not exist and further work is being put into identifying why this occurs.

5 CONCLUSIONS

Testing of the difference between input and output IFC data files passed through commercial design tools, certified as IFC compliant, has highlighted deficiencies in how these tools map the data in and out. Our analysis of these deficiencies indicates that the majority of changes do not affect the semantics of the data model. There are some changes identified with the preservation of property set information which could be easily rectified by software developers for the design tools. Once all of these changes are taken into account there is still a small number of differences which indicate problems with how a design tool maps its data to and from internal data structures. To ensure that the meaning of building models is preserved there needs to be further work identifying how these changes come into being and how they can be fixed, either in the standard or by individual design tool developers.

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