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Model Interoperability in Building Information Modelling

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Abstract The exchange of design models in the design and construction industry is evolving away from 2-dimensional computer-aided design (CAD) and paper towards semantically-rich 3-dimensional digital models. This approach, known as Building Information Modelling (BIM), is anticipated to become the primary means of information exchange between the various parties involved in construction projects. From a technical perspective, the domain represents an interesting study in model-based interoperability, since the models are large and complex, and the industry is one in which collaboration is a vital part of business. In this paper, we present our experiences with issues of model-based interoperability in exchanging building information models between various tools, and in implementing tools which consume BIM models, particularly using the industry standard IFC data modelling format. We report on the successes and challenges in these endeavours, as the industry endeavours to move further towards fully digitised information exchange.

Keywords Building Information Modeling · Interoperability

1 Introduction

The design and construction industry is undergoing a significant shift away from the use of two-dimensional CAD and paper for design towards three-dimensional, semantically rich, digital models. This trend has reached a point where this technology, generally referred to as Building Information Modelling (BIM), is being used in some form by the majority of the industry. A recent survey by McGraw Hill Construction [1] found that in 2008, 45% of architects, engineers, contractors and building owners surveyed used BIM on 30% or more of their projects. Usage of BIM is forecast to continue growing sharply in coming years.

One of the challenges faced by the industry is the use of BIM not only as a tool in the design process, but as the interface for the exchange of information between the different parties involved in projects. A typical construction project will necessitate collaboration and information exchange between a variety of parties, including the client, architects, engineers, estimators and quantity surveyors, contractors and regulators. Traditionally, information was exchanged in the form of drawings and documents. As each of these parties moves towards the use of BIM tools within their own organisation, there is a significant incentive to instead use digital design models as the medium for exchanging information. However, these parties frequently use different tools, either from different vendors or specific to their business domain, and this diversity of tools poses a challenge for model exchange.

The Industry Foundation Classes (IFC)[2], defined by the buildingSMART alliance, represent the accepted industry standard for design models. IFC models are semantically rich in that they capture not only the 3-dimensional geometry of the objects, but metadata related to many other aspects of the building. For example, if we consider an instance of a door object, this door will be situated in a wall, on a defined building storey, within the building. It will have attributes asso-

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ciated with it that describe its thermal performance, costing, fire safety performance, etc. Which building components need to be accessed to resolve an issue can be determined by tracing system descriptions within the model, for example, the thermal zones system, cost breakdown structure and the fire safety system. The necessary attribute definitions and the system descriptions are derived from legislative requirements and analysis software input requirements.

Many of the significant BIM tools currently used by industry support import and export of IFC files. We have used IFC as an interoperable format over a number of years, both as a mechanism for exchanging models between tools, and as an input format for software tools that we have built for design analysis and automation. This paper presents our observations of the successes and challenges of IFC as an interoperable standard for building models.

The paper is structured as follows. In section 2, we present a background to BIM and its present and anticipated use in the design and construction industry, including a profile of the use of BIM in a cross-domain industry organisation. Section 3 then presents a brief description of the IFC standard, in terms of its history, structure and role as an interoperable standard. Section 4 presents observations of the present successes and failures of IFC as an interoperable standard, and of BIM in general.

2 Building Information Modelling (BIM)

Building Information Modelling is an interdependent network of policies, processes and technologies [3], which together constitute a "methodology to manage the essential building design and project data in digital format throughout the building's lifecycle" [4]. BIM tools are being increasingly incorporated into collaborative design and modelling processes, with the promise of substantive benefits for the efficiency of the design process [1].

The construction of a building or group of buildings is a complex endeavour, involving many parties and numerous diverse activities. Even small projects are beyond the scope of any single company to complete in isolation, and larger projects will necessitate the interaction of potentially dozens of organisations including clients, architects, engineers, financiers, builders and subcontractors. The process can be likened to that of co-design in computing, in which the domain knowledge of hardware and software engineers are distinct and successful completion of the project requires intense cooperation during design, manufacture and maintenance/management of the system.

The information models that are used are also large, complex, and highly inter-dependent, and includes architectural components, engineering systems for structural, electrical, HVAC (heating, ventilation and air-conditioning), and mechanical services, as well as details of cross-cutting concerns such as project management, scheduling, and cost planning/estimation.

Traditionally, the dominant medium for exchanging information between parties has been as drawings and other paper documents (e.g. bill of quantities, cost plan, building specification), and this remains the case for many projects today. Although many organisations use some software tools for the definition of their design models, the models are frequently rendered as 2D drawings when they are sent to other organisations.

The information exchanged serves not only to inform the receiving party, but as a record of what information was or was not conveyed, so that, in the event of a dispute or problem, responsibility for a decision may be clearly determined. Companies are comfortable with the use of paper drawings for this purpose, and are still reluctant to sign off on digital information represented in three dimensions, often with additional information compared to the paper equivalent. For example, architects often associate material types with building objects in order to make the building look right for a client presentation, and not necessarily because that is the material to be used in construction. When the model is then given to the engineer or quantity surveyor, it might be unclear whether the material has been selected intentionally, or simply for visual effect. Which parts of the model are definitive, and which are illustrative? This is important from a legal liability perspective.

Understanding of liability implications is also an important reason why the current use of digital models mainly involves exchange of models as files, as opposed to inspection of and linking to models using service-oriented or distributed object technologies.

Despite these concerns, the use of BIM has reached tipping point in the industry [1]. Use of 3-dimensional CAD tools is commonplace amongst architects, and is also seeing significant uptake in other sectors such as amongst engineers, owners and contractors. In addition to being used in the design process, BIM is also beginning to be used for design analysis, including quantity surveying and cost planning, environmental assessment, acoustic and thermal performance assessment, scheduling and simulation, and checking designs against codes and regulations. As tools for these activities gain in popularity, it is going to become more crucial that software packages manipulating the models are able to interoperate reliably and without necessitating significant human intervention.

2.1 BIM in an industrial context

Project Services is a comprehensive building design and project management division of the Queensland Government's Department of Public Works. As such, they have a wide-ranging view of the use of digital model exchange between stakeholders in a variety of construction projects. Figure 1 illustrates the organisational understanding of the design process within Project Services, including the tasks involved in the design process, the tools involved in each of these tasks (roughly corresponding to the range of design/analysis disciplines that are implicated in the process), and the nature of the exchange of information between different interdependent tools (as IFC or non-IFC 3D models, 2D models, or textual representation).

As can be seen, 3-dimensional models are the predominant medium for interchange, particularly between the architectural and engineering disciplines. However, even within this, a range of IFC and proprietary formats are used, depending on the presence and quality of support for IFC within the respective software tools. There are also a range of scenarios where 2D models are used, and others, particularly for the analysis of models, where information is passed in a textual form not closely linked with the 3-dimensional model.

While this diagram clearly depicts the information and software interdependencies between the various disciplines, it does not address the dimension of time in the design process. This represents something of a downfall in the current approach to BIM, a pervasive underlying ambiguity concerning the levels of data abstraction and integration appropriate to the models at different stages in the design [5].

The importance of 3-dimensional exchange of information between design and analysis tools is best illustrated by considering one of the most basic (although far from simple) analyses that must be performed on a design: that of detecting clashes between elements in physical space. Figure 2 shows the services models[1] from a Project Services design for the Mango Hill/North Lakes Police Station, a suburban police station located in Brisbane. The individual models for architectural (2a), structural (2b) and mechanical (2c models, as well as the combined model (2d), illustrate the complexity of the data being modelled, particularly in terms of geometry. Clearly it is important that elements in these models to not occupy the same physical space. Although systematic clash detection is often only done at the end of the process, the various designers review the overall model for these issues on an ongoing basis as the constituent models evolve. Both the formal and the informal analyses are entirely dependent on being able to reliably exchange these models between designers, and between design and analysis tools.

[1] Other models for this project, including electrical, hydraulics, interiors and landscaping, are not shown here.

3 Industry Foundation Classes (IFC)

The industry standard for exchanging Building Information Models is defined by the Industry Foundation Classes, or IFC[2]. IFC was first specified in 1996 by the International Association for Interoperability (IAI), and has seen a number of minor and major revisions since then (the popularly used versions today are 2x2 and 2x3). The IFC specifications are currently administered by the buildingSMART alliance.[2]

From a technical point of view, IFC is defined using the ISO 10303 [6] suite of specifications for data modelling and exchange, otherwise known as STEP (Standard for the Exchange of Product Data). STEP consists of a range of specifications, most notably a language for specifying data schemata (STEP/Express [7], in which the IFC language is defined), a mapping (Part-21 [8])) for text-file representations of models conforming to that schema, a mapping (StepXML [9]) for XML file representation of models, and mappings to APIs for accessing models programmatically (notably Part-22 [10], Standard Data Access Interface, or SDAI). Of these technology mappings, the most significant in terms of interoperability is currently the Part-21 mapping, which effectively defines the IFC's file format.[3]

Since the release of version 1.0 in 1996, IFC (the latest version being IFC 2x3) has seen significant take-up by many of the major CAD tool vendors. In the architectural sector in particular, the major vendors all claim support for import and export of IFC, including Graphisoft,[4] Bentley,[5] Nemetschek,[6] and Autodesk.[7] Take-up in other sectors is much more variable. The software tools of some, such as structural, mechanical and electrical engineering (including the Revit tools from Autodesk), and steel detailing (notably

[2] http://www.buildingsmartalliance.org

[3] The XML mapping is also defined, as ifcXML, but in the experience of the authors, this is rarely used.

[4] http://www.graphisoft.com

[5] http://www.bentley.com

[6] http://www.nemetschek.net

[7] http://www.autodesk.com

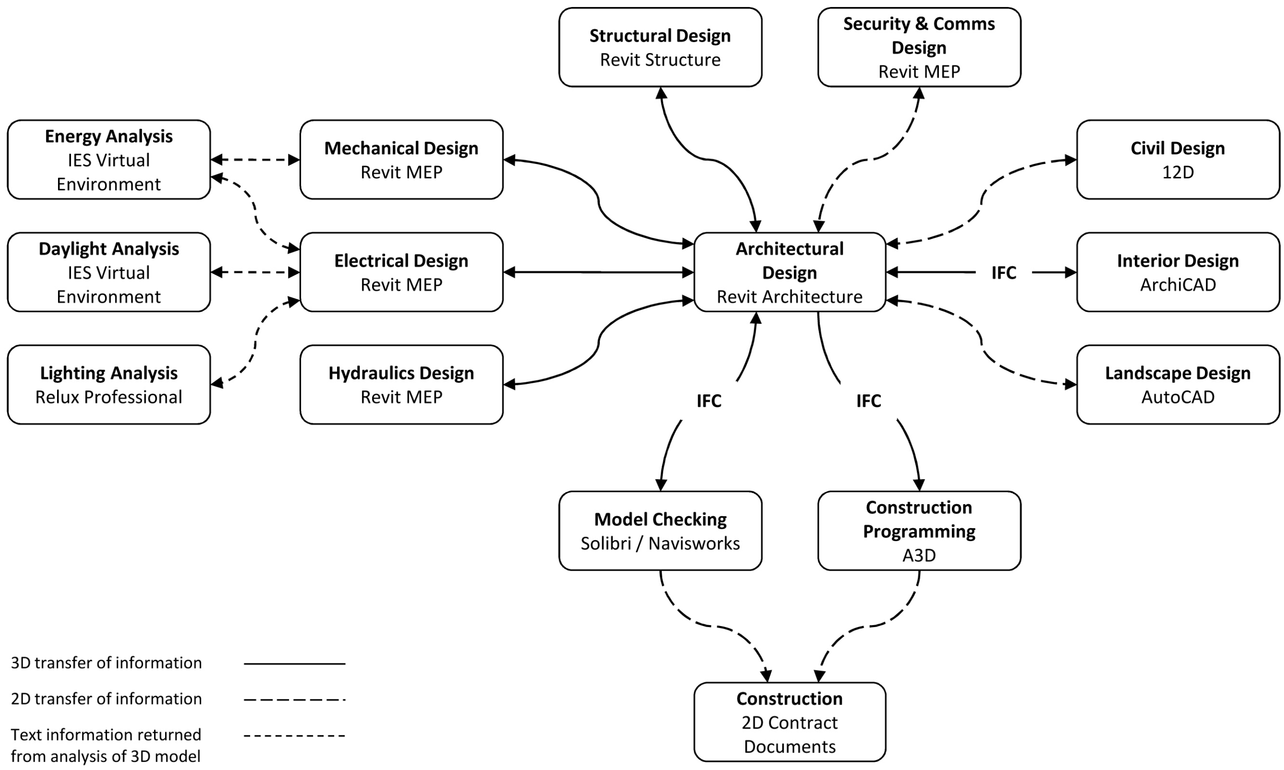


Fig. 1: Activities and associated software involved in the design process of Project Services

Tekla Structures[8]), have support for IFC, whereas in others, such as environmental analysis, cost estimation, civil engineering or facilities management, support is less common.

The IFC language is, by any definition, very large and very complex. The language definition of IFC version 2x3TC1 includes 327 data types, 653 entity definitions,[9] and 317 property sets.

The language includes constructs for a very wide range of modelling features, including (but not limited to) 3-dimensional geometries, to basic building elements (slabs, columns, beams, doors), facilities management, electrical, mechanical and other subsystems, and structural analysis constructs, to identity, organisational, process and cost modelling constructs. The specification is broken up into platform and non-platform domains, but even the core platform constructs comprise well over 300 classes. The size and scope of IFC mean that few (if any) individual tools implement the entirety of the language.

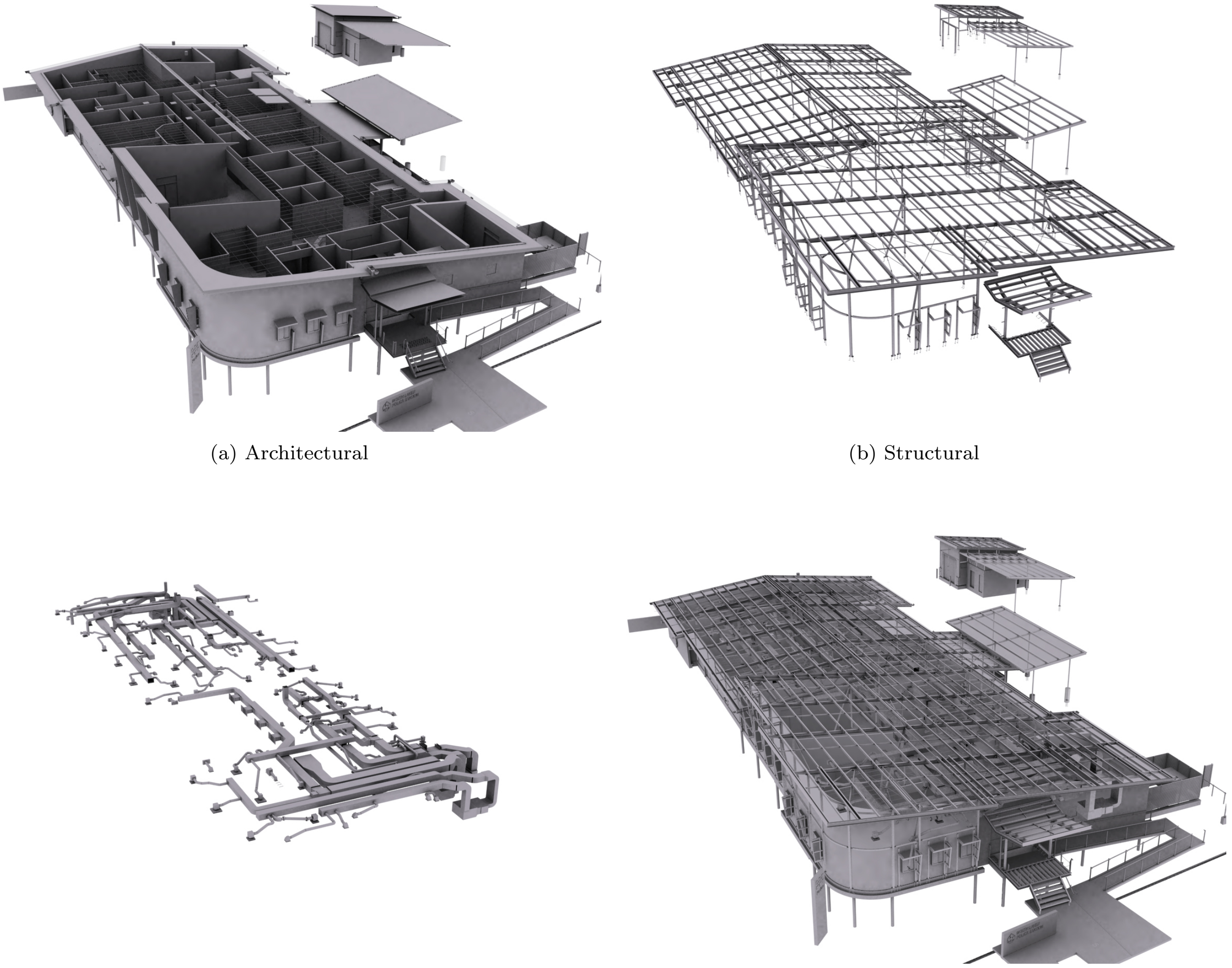
The complexity of the language is exacerbated by the possibility in many sub-domains for alternative modellings. This can be affected by both software developer implementation decisions and the choice of domain modelling technique by the user. The geometry constructs, in particular, provide myriad ways of modelling the same structure. As a simple example, a block structure may be modelled using a boundary representation with planes for each side, or as an extrusion using a polygon and a vector. A more subtle but more problematic example might be the alternative modelling of a low wall as either a wall object, a thick slab object, an upstand beam, or even a kerb. Each of these objects have different semantic meaning, so although the objects might look no different on a 3D rendering, they will be treated differently by analysis tools.

For cases where the IFC does not provide a particular modelling construct, the language includes a mechanism for the modelling of IfcProxy objects, which serves as a kind of extension mechanism. For example, in the case of landscaping, there is no IFC construct for trees or shrubs, so these are often included (with geometries) as IfcProxy objects.

In addition to the size and complexity of the language itself, individual IFC models tend to be very large. The size and level of complexity present in a model for a large building, including the geometry and

[8] http://www.tekla.com

[9] By way of comparison, the UML2 metamodel [11], often considered by metamodellers to be a large metamodel, defines 260 metaclasses.



(a) Architectural (b) Structural

(c) Mechanical (d) Combined

Fig. 2: Model images from a Project Services design for the Mango Hill/North Lakes Police Station. Figures 2a, 2b, 2c are of individual models, while 2d depicts the combined model

semantic information for all building elements, is considerable, even when split into different models according to concern. For example, Figure 3 shows the model of mechanical services for a 19-storey office building, with an inset showing a single model element, an absorption chiller, with some of its metadata. The main systems are modelled in full, but the detailed design of individual floors is shown only for two example storeys. The part-21 IFC file for this model is 360 MB, and the model consists of more than 7.3 million computational objects. Although this is not a small project nor a particularly simple one, it is by no means an extreme case in size or complexity.

The current process for testing the IFC compliance of BIM tools involves the use of a standardized suite of large test models, subject to visual inspection in the tool. There is also a prescribed set of modifications which are then made to the models, which are then rechecked. The procedure does not, at present, include assessment of the tool's handling of semantic information in the model.

4 BIM Interoperability

In this section we provide observations about the issues observed surrounding the use of IFC for exchanging design models between a range of different tools. To do this, we make reference to the KISS classification of interoperability levels. The KISS (Knowledge Industry Survival Strategy) initiative aims to examine

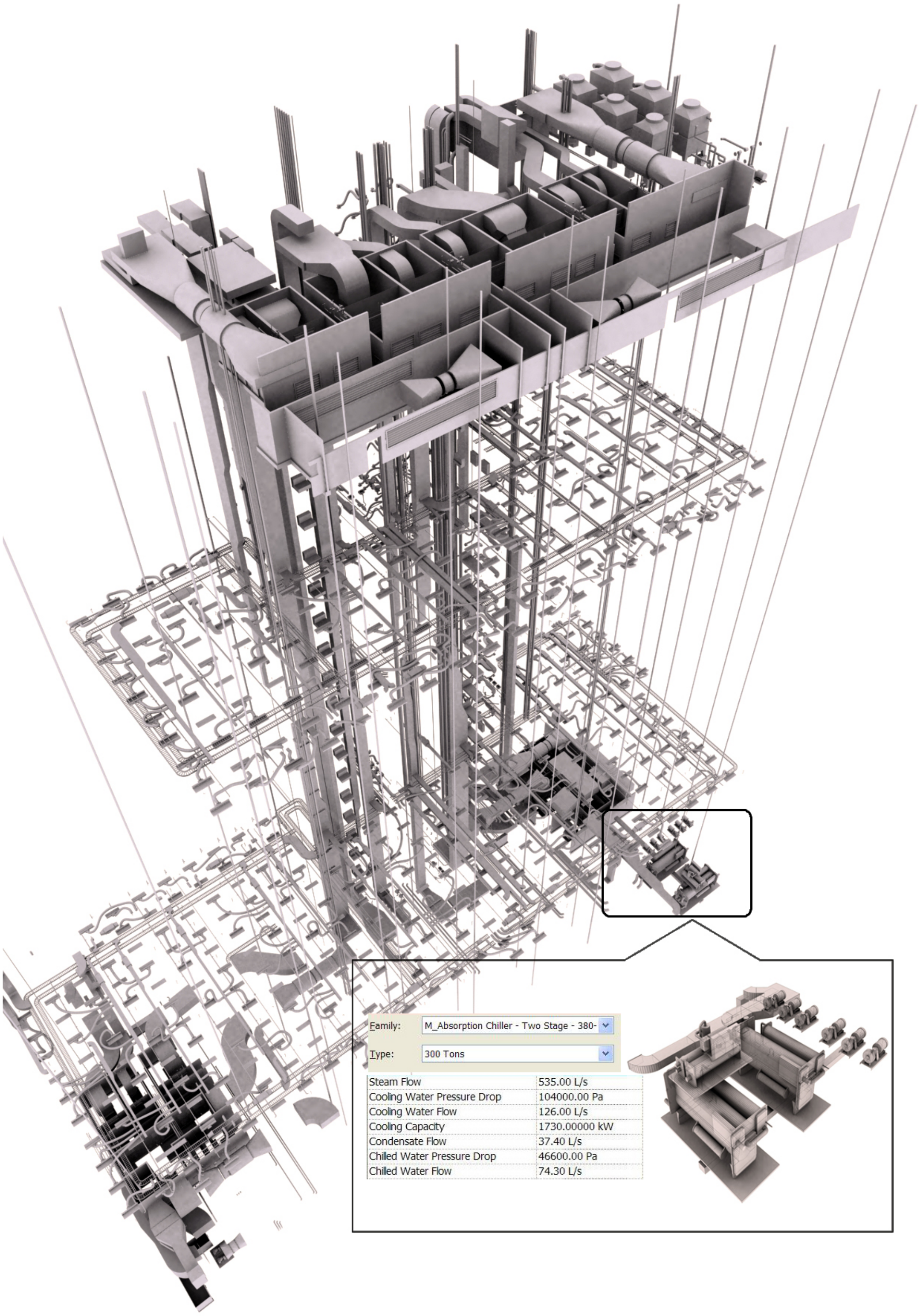


Fig. 3: Model of mechanical services for a 19-storey office building

the role domain-specific modelling languages can play in capturing, preserving, and exploiting knowledge, by considering the fundamental values and principles that underpin their use. As part of this, they reason about model-based interoperability by considering the problem at a number of different levels, shown in Figure 4, (taken from the KISS initiative website [12]).

4.1 File and syntax levels

From the point of view of IFC-based interoperability, we consider interoperability at four levels. File level interoperability is the ability of two tools to successfully exchange files. Syntax-level interoperability is the ability of two tools to successfully parse those files without errors[10] Visualisation-level interoperability relates to the ability of two tools to faithfully visualise a model being exchanged. Semantic-level interoperability relates to the ability of two tools to come to a common understanding of the meaning of a model being exchanged.

There are few problems encountered at the file and syntax levels of interoperability. Over years of using 2-dimensional CAD tools, many organisations in the design and construction industry have developed processes and conventions for managing files, and some of these apply well to BIM, at least during the early stages of uptake. However, in the long term, changes will occur within working methods as organisations attempt to exploit the advantages provided by improved access to 3D object models. At the current level of uptake by industry, the type and extent of these changes in work processes are difficult to predict.

Some problems are observed due to the very large size of the models being used. Some systems have restrictions based on memory consumption or number of objects in a model, which can result in models either not loading, failing to render in 3D, or even failing to generate 2D drawings correctly. For example, the mechanical services model shown in Figure 3 is too large for systems built on toolkits such as EDM,[11] whereas in a tool like the DDS CAD Viewer,[12] it will load but cannot be rendered in 3D.

[10] Syntax-level interoperability also encompasses the ability of tools to interoperate without errors using an API-based interface but in the case of IFC, although it is available through the JSDAI specification[10], this is rarely used.

[11] From Jotne EPM Technology AS, http://www.epmtech.jotne.com

[12] From Data Design System (DDS), http://www.dds-cad.net

4.2 Visualisation level

The precursors to digital model exchange in the construction industry were paper drawings, and the models being represented are essentially geometric in nature, so it is not surprising that visualisation has long been the priority for the interoperability of IFC. To date, this has been largely successful. With a few exceptions, models produced in one IFC-compatible tool are generally able to be visualised in another. In the more general case, however, claims about support for different model formats are less reliable. For example, many of the environmental/energy analysis programs (which are not IFC compatible), struggle with the proprietary formats that they are supposed to support.

One such exception, mentioned in the previous section, is when the size of the model precludes its visualisation in a given tool. Another issue is the use and reuse of geometries. Models from Revit Structure, for example, can sometimes have IfcOpening or other objects appear out of position in other tools, due to the way that position and dimension information is modelled in the case of objects that are copied or reused.

Another outstanding issue is that of alternative visualisations. An architect will choose colours and textures for their model that reflect its actual appearance, whereas a quantity surveyor or someone checking the model against a regulatory code will frequently opt for a colour scheme that best distinguishes building objects based on semantic information, such as their type (e.g. having a slab and its supporting beam be different colours, despite both being concrete) or material (using different colours for different grades of concrete, or for concrete vs. plasterboard, even if they are to be painted the same colour). Because of the different objectives in play, the model can appear different in different tools. IFC includes language support for the definition of different representations for objects, but to date there is no consensus on how to manage these. For example, there is no tool-independent way of grouping or labelling different representations into, for example, levels of detail or visual-versus-symbolic viewpoints.

4.3 Semantic level

As discussed in the previous section, the principal goal for IFC was originally that of visual model exchange between tools, and thus far, this has met with a degree of success. However, as the construction and digital design industry moves further into BIM, the opportunities for leveraging models depend increasingly on models that can be reliably interchanged and interoperated on a semantic level. Semantic interoperability poses more

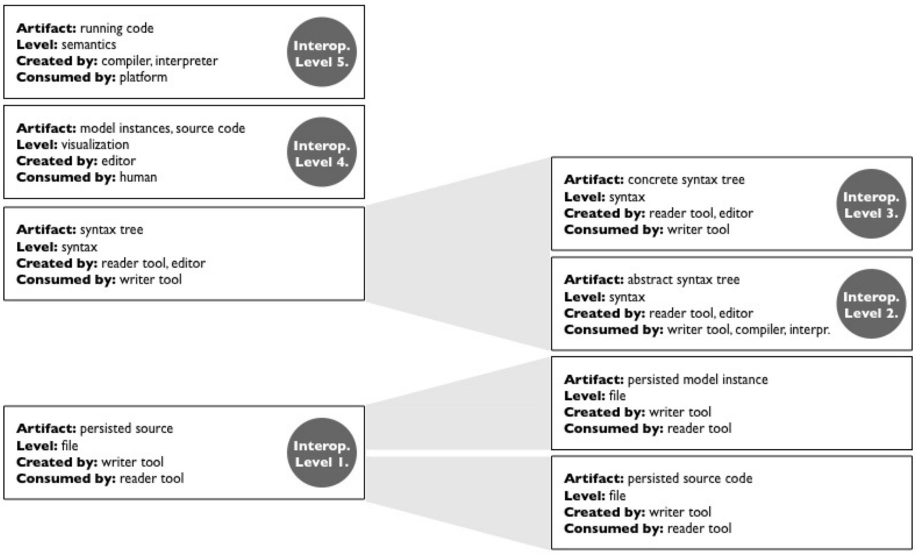


Fig. 4: The KISS classification of interoperability levels

issues, ranging from relatively simple technical problems, to deeper problems tied to modelling style within the community that exchanges models.

Some of the simple problems include a loose approach to the use of object identifiers. For example, some tools do not preserve object identifiers (GUIDs) when editing models, which causes problems for tools which provide more sophisticated versioning and change-tracking functionality, such as Jotne EPM Technology's EDM Model Server.[13] These tools depend on GUIDs to version models at the individual object level, rather than for the whole model, and to permit intelligent merging of models pertaining to different stakeholder viewpoints. Although they can have a large impact on interoperability, the solutions to problems like these are simple (tools need to preserve GUIDs). This is not the case for more complex issues such as modelling style, as are described in the following sections.

4.3.1 Modelling style

The potential of these semantic model exchange opportunities has been made visible in a number of projects. For example, Ecquate's LCA Design [13] tool allows the designer to evaluate the short-, medium- and long-term emissions of a building, by inspecting the materials and other information about a building in combination with databases of emissions data. The Automated Estimator tool [14] allows a quantity surveyor or cost engineer to automate large parts of the time-consuming quantity takeoff process, by using a rule engine that categorises and itemises building objects based on material, relative position and other properties. Projects such as Solibri's model checker,[14] and Jotne EPM Technology's EDM-rulechecker,[15] allow for the checking of models against codes such as accessibility or fire regulations.

One of the keys to the uptake of these kinds of analysis tools is the stylistic consistency of the models that are provided to them, in terms of the encoding of information within the very flexible constructs provided by the language. If the objects (in particular materials and object types) being used in a model are not consistent with those expected by the analysis tools, then the analyst will need to spend time "fixing" the model, which reduces the value of the tools. For example, some models will encode structural steel members as being of material "Structural Steel" with the grade of steel (e.g. C350, C450) encoded in the object description, whereas others will have the grade of steel as the material type. If a quantity takeoff tool anticipates one encoding but encounters the other, it will not compute the correct quantity of steel.

There are efforts underway to address these issues of modelling style. The IFD (International Framework for Dictionaries) specification [15] and library[16] provides an ontology for the definition and storage of building model objects that can be reused on different projects, and has been used in a number of jurisdictions (typically national) to encourage consistent use of modelling constructs. Technical solutions such as this require the

[13] http://www.epmtech.jotne.com

[14] http://www.solibri.com

[15] http://www.epmtech.jotne.com

[16] http://www.ifd-library.org

involvement of stakeholders in order to define the disciplines and conventions that should be used when modelling, e.g. in Australia the ongoing National Guidelines and Case Studies project within the CRC for Construction Innovation.[17]

4.3.2 Coverage Issues

There are a number of interoperability problems that arise because of coverage issues, either coverage of the IFC language by implementing tools, or coverage of the domain by the IFC language.

Cases do arise where a tool fails to produce a correct visual rendering because it encounters an IFC construct that it does not understand, but these are rare, since the geometric and visualisation constructs are shared across IFC, and these constructs are typically well covered by tools. More common, though, is the situation where an alternative modelling is chosen due to a shortcoming of the designer's tool palette. For example, if the designer wishes to place a low kerb or upstand beam in front of a wire closet, but the tool's palette does not provide such a construct, the designer might insert a slab or wall element instead. This will look correct, but will pose problems for analyses such as quantity takeoff. These problems, of having to create and export custom components, are particularly prevalent in designs incorporating non-traditional geometries.

The other situation where coverage is an issue is where IFC does not provide a modelling construct. For example, if a designer wishes to place a water tank, IFC has no construct to represent that. The designer has the choice of either representing the tank using curved walls and slabs, or of using an IFC proxy object. Both of these solutions pose challenges for analysis, since the construct/s will not be understood by the analysis tool, but judicious use of one of the IfcProxy constructs is the most robust method of handling this issue. The most important way to address this latter problem lies, like that above, in the development and adoption of modelling conventions and guidelines for these cases. However, implementation of the proxy mechanism within tools also needs to make it as easy for a user to add a new proxy object as it is to use a semantically misleading construct that presents the same visual appearance.

4.4 Alternative Representations

Beyond the lack of agreed mechanisms for managing different geometric representations (as discussed in the previous section), there are often much more complex problems of different representation paradigms. An example of this can be seen in Figure 5, which illustrates the difference between an architectural design model and an energy simulation model. The architectural model uses solid geometries, since a faithful physical representation is important. The energy simulation model is only interested in the wall's thermal coefficient, not its thickness, so uses "centreline" geometries. As seen in the figure, this can lead to a "gap" between adjoining walls. This will cause the energy simulation software to consider two separate physical spaces, on either side of the wall, as a single physical space, which will lead to incorrect analysis numbers. The design representation does not directly translate into an accurate analytical representation, and the model must be transformed (typically manually) before it is suitable to be used for a performance simulation.

Another example can be seen in modelling roads, where it is common to begin with string-based representations of roads and associated elements (signage, markings, drainage and electrical information), using vectors for edges instead of surface models. Switching to a surface-based form requires complex transformations of the model. This idea of mapping between representation paradigms will become a more significant problem as BIM is expanded to include more disciplines, particularly models beyond a single building, including urban planning models. Examples of this include ongoing buildingSMART projects investigating the use of IFC for Bridges and for GIS.

4.5 Parametric modelling

One of the current trends in design is the use of parametric modelling. Parametric modelling tools allow the user to parameterise different properties of their models, so that the design as a whole can be readjusted by simply adjusting a parameter. For example, the design of a high-rise building might be parameterised by the number of stories, or the width of the building footprint. Individual elements in the model can then change their properties, or even be created or removed, as a function of these parameters. Different tools support differing levels of parameterisation, ranging from simple shared simply-typed variables, through to structural or cladding systems that will repeat in complex patterns.

Presently, models that incorporate parameterisation can only be exported into IFC by fixing the parameters and exporting a snapshot of the design. This is obviously less than ideal, particularly when exchanging models early in the design process. However, from a technical point of view, incorporating support for para-

[17] http://www.construction-innovation.info

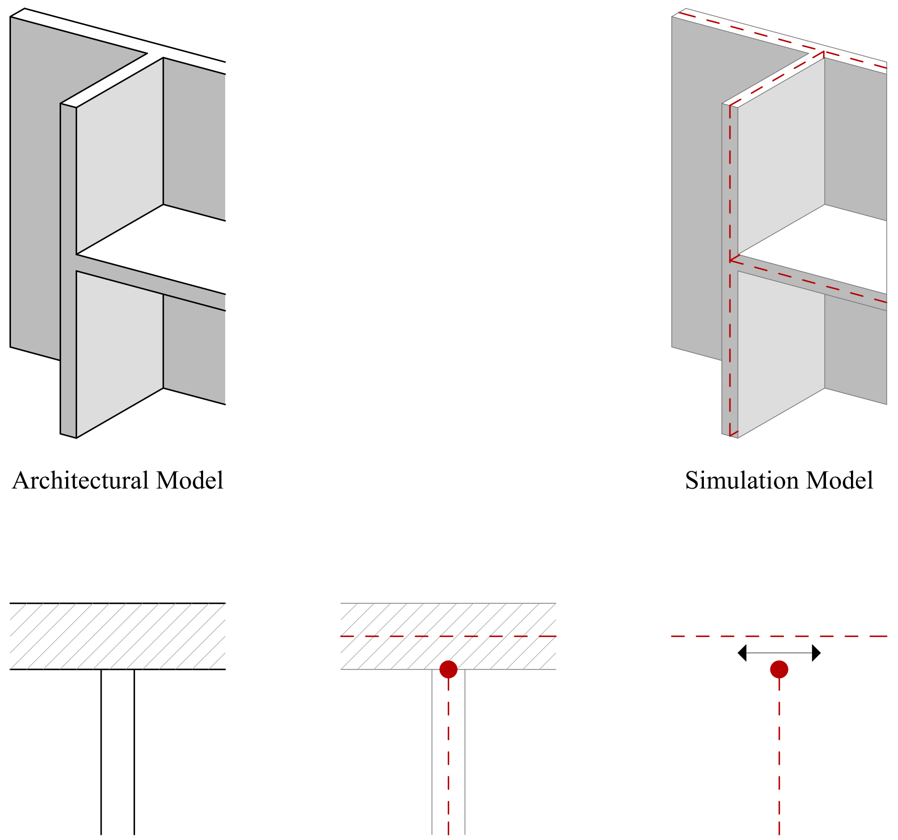


Fig. 5: The difference in representation between an architectural design model and an energy simulation model

metric modelling into the IFC language would involve a significant reworking of the IFC standard.

5 Conclusion

5.1 Interoperability in BIM

The transition from paper-based exchange of design models to processes based around the use of digital models represents an important shift in the design and construction industry. Using digital models opens the possibility of automating a number of the analyses done during design, with important consequences for the speed and efficiency of the design process, and for the quality of the resultant designs. In an industry so heavily dependent on collaboration, challenges of interoperability must be addressed in order to maximise these benefits.

The IFC is an ambitious example of model-based interoperability, covering a wide range of modelling information, and across a wide range of sub-domains. When evaluated against the KISS hierarchy[12] of interoperability levels, it has thus far met with relative success in providing file- and visualisation-level interoperability within a subset of domains, most notably in architecture and structural design. However, it faces challenges as it moves into more situations demanding semantic interoperability, and as its use is broadened to include more sub-domains, both anticipated and unanticipated.

The principal semantic interoperability challenges revolve around the quality and consistency of the models produced. Efforts are underway to provide for consistent modelling both through technical solutions and through the engagement of stakeholders to determine what constitutes good modelling practice. The success or failure of these efforts will go a long way towards determining the extent to which BIM succeeds in transforming the industry.

5.2 Lessons for general model-based interoperability

IFC and its use in the design and construction industries represents an instructive example for model-based interoperability. Although there are some characteristics of the domain that distinguish it somewhat, there are nonetheless lessons to be learnt about the time line of dealing with problems related to interoperability, in terms of the issues that are faced and techniques that can be used to resolve them.

The most significant defining characteristics of BIM as a domain for interoperability are collaboration and scale.

One of the reasons that interoperability has been, and continues to be, an important issue for the architecture, engineering and construction (AEC) industry, is the inherent collaborative nature of the domain. Large projects can involve up to 20 different companies from almost as many disciplines. Even small projects will typically have a half dozen companies, and all projects need to communicate designs to regulatory bodies for compliance to building codes, disabled access regulations, fire safety, etc. Exchange of information across organisational boundaries, and across disciplines, makes interoperability a big issue. In the case of AEC, this cross-organisational nature has hampered the use of models for information exchange.

Both the models handled by BIM, and the IFC language used to represent them, are very large and complex. In the case of the models themselves, this has to date been chiefly a consequence of the use of expressive 3-dimensional modelling constructs. The use of these constructs is limited to physical-world modelling languages, but does have applicability to a number of other domains, e.g. manufacturing, automotive, aerospace or industrial design. This aspect of IFC no longer poses real problems, and one would think that other industries could fairly reuse the geometric aspects of the IFC language and, potentially, their implementations.

In the IFC language, though, the scale comes about because of the ambitious breadth of the modelling language, covering the structural, architectural, electrical, mechanical, and many other aspects of the domain. In addition, the domain itself is intrinsically broad; even considering only buildings, it ranges from bus shelters to airports. The breadth of IFC has been somewhat problematic for interoperability, in that no one tool can implement all of the language. The two approaches to addressing the breadth of a large language and its coverage by tools, are of profiling the language, or of structuring it using the "family of languages" approach. The former is currently under investigation by IFC (as well as other languages like OWL), while the latter has been proposed, but not yet fully developed, by languages such as UML. It seems too early at this point to evaluate the use of these techniques for real-world model interoperability.

One of the significant observations to be taken from the IFC experience of interoperability is that the hierarchy shown earlier in Figure 4 represents not only a hierarchy of interoperability levels, but a time line of problems. In the case of IFC, it is only after file-, syntactic- and visualisation-level interoperability has been largely achieved, that semantic-level interoperability issues become clear and can be addressed. Other modelling languages that have difficulties with syntactic interoperability, e.g. XMI in the MDA space, might be less aware of the scope of semantic interoperability challenges.

The most significant of these semantic-level issues for IFC has been that of inconsistency of modelling style, and this is a significant issue for general model-based interoperability. From the perspective of modelling language design, it is tempting to suggest that a modelling language should be sufficiently clear and complete in its definition that alternative modelling styles should not be possible. Certainly, for languages whose use is restricted to a small domain or a single organisation, this can be done. However, in the case of a domain such as that covered by IFC, the variation of design practice, and even more significantly the difference in regulations between different jurisdictions, make this infeasible. The reality is that certain parts of the language must be left flexible in order to support these unforeseeable variations.

Solutions to the model consistency problem may be methodological, such as efforts by local or discipline-specific industry groups to define modelling style guides. Alternatively, they may be technical, such as using ontologies or transformations to bridge between alternative modellings, or using model checkers to evaluate a model's compliance to a set of well-formedness rules, or support from implementing software to guide the modeller rather than constraining them in the language itself.

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