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Towards use cases in sparse architectural data exchange

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Data exchange continues to be one of the most challenging problems in the Architecture-Engineering-Construction (AEC) sector. One aspect that has still not been covered to date is a clear definition of use cases in which a data exchange occurs. The definition of data exchange with reference to use-cases is beneficial, because exchanged data may be limited to include only elements that are needed in the current context (sparse data exchange), so that interfaces between applications can be kept simple. Our work draws on experiences in healthcare data exchange, which has successfully implemented exactly these concepts in the past years.

Keywords: data exchange; use cases; standardization; frameworks; small is beautiful

1 Introduction

Data exchange in the AEC sector is currently built around data formats which are containers for a multitude of potentially useful information; however, this potential is not fully utilized *when importing* into an application, since only certain aspects of the data may be interesting. Vice versa, applications may supply only a sparsely-filled file *when exporting*; thereby failing to provide data that would indeed be useful.

At first, it might seem that the answer to these data provision problems are already provided by current Building Information Modelling (BIM) approaches and according standards such as the Industry Foundation Classes (IFC). However, we argue that these problems of overrepresentation and underrepresentation have nothing to do with the data model being used, but rather come from the *lack of consideration of the context in which the data is to be exchanged*. For example, both a Computer Aided Design (CAD) package and building physics software might make use of IFC. This does, however, not guarantee that information needed on either side will be present in the exchanged file - it merely guarantees the syntax and semantics of data being present.

If data interchange would focus on *use cases*, meaning 1) in *what context*, 2) *which information* is to be exchanged using and 3) *what data format* software vendors could concentrate on adding new use cases rather than invest in supporting new file formats. The transmitted data will be sparse – i.e. “*good enough*” to fulfil the use case, but not more. As a matter of fact, interfaces would be kept simple and easier to keep stable.

Quite luckily, the presented ideas are not new. In fact, healthcare data interchange has introduced them about a decade ago, in a framework called

Integrating the Healthcare Enterprise (IHE). Taking these already-defined concepts into architecture is the main contribution of our work, which is further broken down into:

- a description of the IHE framework, with special emphasis on use cases for sparse data exchange (Section 3)
- the transfer of these concepts into the AEC domain, using the example of a CAD package coupled to an evacuation simulation (Section 4)
- an in-depth discussion of potentials and limitations of the presented concept, both technologically and with regard to the professional world (Section 5)

2 Related work

The need for a collaborative data exchange lies in the nature of planning projects, in which actors across multiple disciplines hold data in a variety of representations. The key question of how to bring information from A to B has a long history in the AEC sector: Early product model formats such as IGES concentrated on the syntax of the exchanged entities, but failed to supply additional semantics. This restriction was lifted to a certain extent with STEP, which also considered functional aspects of a product model. Recent exchange formats such as IFC further introduce an object-oriented representation of entities, which is a basis in all BIMs. The taxonomies found in these approaches are coherent but fixed, based on strict hierarchization and inheritance as known from object-oriented programming (OOP). Newer approaches work on lifting this predetermined structure by additionally representing and transmitting design knowledge (i.e. semantics of entities, inheritance relationships, etc.).[1] Further work diversifies the interchanged knowledge into General Knowledge and Specialist Knowledge as ontologies tailored to the involved discipline.[2] The additional representation of process knowledge was presented for instance by Gero and Kannengiesser.[3] A step-wise *data interchange triggered by use cases* has, however, not previously been looked into.

1 **Ugwu O.O.** et al (2005). Ontological foundation for agent support in constructability assessment of steel structure – a case study. In: Automation in Construction, 14:1, pp 99-114

2 **Carrara G.** et al (2009). Knowledge-based Collaborative Architectural Design, International Journal of Design Sciences and Technology, 16:1, pp 1-16

3 **Gero J.S.** & **Kannengiesser U.** (2006). A function-behaviour-atructure ontology of processes. In: Design Computing and Cognition ’06, pp 407-422

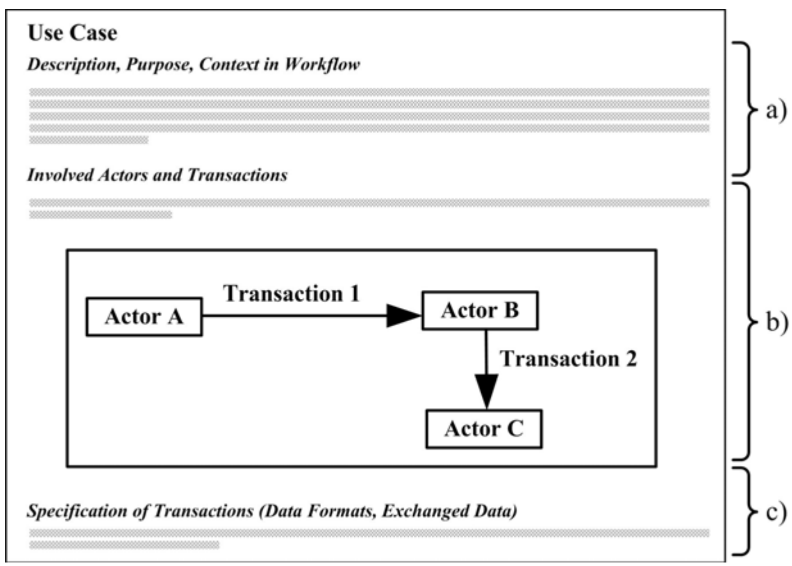


Figure 1 IHE use case consisting of (a) general description (b) workflow and (c) technical specification

3 Use cases in healthcare interoperability

In the healthcare sector, data is segregated in between multiple information systems, each of them storing data according to the needs of the involved medical discipline (e.g. laboratory, radiology, administrative staff). Previously, data interchange between these systems was being conducted in a custom-tailored manner, by exchanging precisely the data needed in a standardized format. However, this approach was costly and hard to support, given that every hospital had its own landscape of systems and, accordingly, its own way of implementing data exchange among them. In order to improve the situation, a framework specifying exactly what data would need to be exchanged in precisely what form was therefore released under the name *Integrating the Healthcare Enterprise* or short *IHE*.[4]

IHE defines data interchange use cases (i.e. typical situations in a workflow in which data interchange occur) by first giving a brief description, intended purpose and context in the workflow (Figure 1a). This rather non-technical description of scope is elaborated in a community process among industry partners and professionals.

After that follows a definition of the use case as seen from workflow perspective, in the form of a diagram listing data exchange *transactions* among two or more *actors* of the workflow (Figure 1b). These actors can be thought of as being software components, in the simplest form: two information systems wishing to exchange data. Transactions describe a sequence of actual data transfers, i.e. messages being exchanged. As systems in healthcare are always on-line, this usually happens synchronously.

The most important part of a use case is the specification of each transaction by prescription of data formats and their filling (Figure 1c). In this context, IHE does not invent new formats – it rather uses formats that are well-established and regulates how they are to be filled with data that has to be transferred. The work behind this specification is usually done by industry partners, again in a community process.

A use case which has been fully specified becomes ready for a trial implementation phase (usually lasting one year). In this phase, industry implements the specification into their software products and gives feedback on shortcomings or possible augmentations that should be made. After the trial phase has ended, the use case is released for general implementation and subsequent testing, in the following fashion: Twice a year, IHE holds huge developer gatherings (so-called *Connect-a-Thons*), in which all software that claims to implement a specific use case is tested for interoperability. Applications implementing the same use case are therein required to each take the role of the different use case actors, and perform the necessary transactions between them. If there is no error, IHE certifies that the partners have correctly implemented this actor. An application having successfully tested all actors and transactions of a use case is furthermore handed a formal certificate (*Integration Statement*) that can be used when advertising the product or to comply with tenders: Usually, software is required to have a certificate no older than two years, thus ensuring that continuous testing has been taking place.

4 **RSNA** (1998). Integrating the Healthcare Enterprise, Radiological Society of North America [www.ihe.net]

4 Towards use cases in AEC interoperability

Software being used in the AEC sector is fundamentally different than that in healthcare:

- healthcare systems are online systems, i.e. centralized servers being reachable around the clock, with a variety of interconnections to allow for message passing
- AEC software is decentralized, typically running on a single workplace

In technical terms, this difference leads to the usual *asynchronous data exchange* for the AEC domain (file export / import), whereas healthcare systems can communicate *synchronously* over the network. Clearly, a centralized communication layer linking different decentralized applications together would be possible, e.g. in the form of a common BIM server to which applications can publish messages containing data while at the same time being informed of messages to which they have subscribed. The description of such a server is, however, beyond the scope of this paper. A good starting point for further work on this subject would be for instance Beetz and Chen et al.[5,6]

For the rest of this paper, we assume three different modes of data exchange:

- an exchange using files, i.e. by repeated steps of exporting/importing. In this case, intermediate communication of files happens asynchronously, using any means of transport in between (e.g. email)
- an exchange between different applications running in parallel (either on the same machine or on different hosts in the same network)

This scenario is synchronous, as applications may pass back and forth messages and get results without requiring further user interaction to facilitate the exchange. In technical terms, this requires applications to be implemented so that they listen on a specific port for incoming messages (i.e. an application becomes a server). Third, we assume that each application is connected to a BIM server that facilitates a publisher/subscriber data exchange (as outlined before).

5 Beetz J. (2009). Facilitating distributed collaboration in the AEC/FM sector using Semantic Web Technologies, PhD Thesis, TU Eindhoven

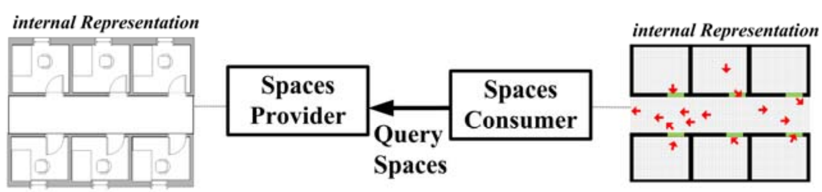
6Chen P.H. et al (2004). Implementation of IFC-based web server for collaborative building design between architects and structural engineers. In: Automation in Construction, 14:1, pp 115-128

General Space Group Query

Description, Purpose, Context in Workflow

Provides a way in which Spaces (i.e. bounded regions of a building spot or building) can be exchanged, supplying a query as criterion. Relates to: IFC 1.0, IfcSpace.

Involved Actors and Transactions



Specification of Transactions

„Query Spaces" uses ECMA-357 (E4X) as query language and IFCXML 2x3 as data format. If no query is given, all spaces are returned in the following fashion:

...further details on data format and prescription of data items having to be sent...

Figure 2 Use case in which a Spaces Consumer queries spaces of a Spaces Provider

Basic Use Case

As next step, a prototypical development of a use case is outlined, taking the case of interoperability between two applications wishing to exchange space data (i.e. bounded areas within a building) as example. The use case will be called “General Space Group Query” (Figure 2) and can be employed in a wide range of areas, e.g. adjacency analysis during early planning or topological considerations. The use case considers the interchange of space data between the actors “Spaces Consumer” and “Spaces Provider” using a transaction “Query Spaces” as means. The use case prescribes that data semantics introduced by IFC 1.0 (Entity IfcSpace) will be used in the data format IFCXML, Version 2x3. The query itself has to be formulated as defined per ECMA-357 E4X, a query language targeted at xml.[7] Table 1 lists an example of query and response, for illustrative purposes.

7 **ECMA** (2005). ECMAScript for XML (E4X) Specification, Ec-ma International [www. ecma-international.org/-publications/standards/Ec-ma-357.htm]

The choice of prescribed standards would in reality be based on a community process, and thus could arrive at a completely different choice (e.g. using DXF as data format and an xml containing query parameters explicitly rather than using a query language). Because the use case is composed of just one transaction, the physical data exchange is simple in all three modes of transfer (asynchronous/file, synchronous/parallel, synchronous/BIM server). The true value of the concept comes into play when using multiple (possibly nested) transactions, described in due course.

Table 1 Space Group Query example. The set of spaces is given as IFCXML V2x3, these can be narrowed down using the filtering capabilities specified in the E4X standard. Note that the example for the returned content is abbreviated – in reality; it may additionally contain doors and furniture, linking them to the space via IFC containment and referencing mechanisms

Space Group Query as ECMA-357 (E4X)	Response as IFCXML Version 2x3
IfcSpace.(InteriorOrExteriorSpace == “internal”)	< IfcSpace id="…"> <Name>E12</Name> <LongName>Office Room 12</LongName> <CompositionType>element</CompositionType> <InteriorOrExteriorSpace> internal </InteriorOrExteriorSpace> </IfcSpace>

Use Case Composition

Software is written in a layered fashion, with lower layers performing work on behalf of higher layers of functionality. Use case composition allows for this approach in an efficient manner, as basic use cases like the “General Space Group Query” presented earlier can be re-used. In the following example, we look at a CAD application exchanging data with a pedestrian flow simulation (Figure 3). The reason for taking such apparently different application types into the example is deliberate, since we want to show that the concepts presented herein are applicable not only inside AEC, but may extend the field further even to fields that are not encompassed by usual BIM data structures such as IFC.

- The use case starts with the CAD application acting as “Flow Consumer”, initiating the transaction “Retrieve Flow”. As input parameters, an E4X query describing the spaces for which flow is to be computed and utilization matrix (expected occupancy for each space, in a custom xml format given in Table 2) has to be supplied. Typically, the latter data will have to be provided by the user, since a CAD package does not usually store data about expected occupancy.

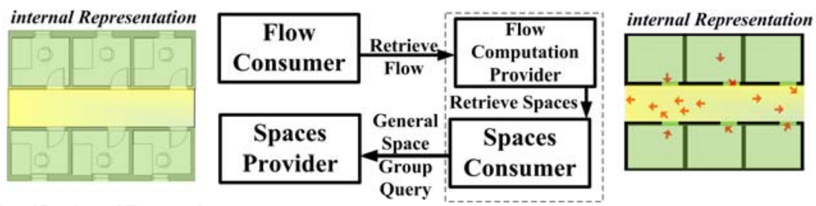
- The pedestrian flow software acts as “Flow Provider”. Upon being invoked, this actor triggers a transaction “Retrieve Spaces”, which utilizes an underlying “Spaces Consumer” actor in the same way as presented in the basic use case example. After having obtained the spaces using the supplied E4X query, the pedestrian flow simulation internally computes the occupancy (using e.g. a pedestrian egress model as technical means). As result of this simulation, the occupation of each space is returned, again in custom xml syntax.

Pedestrian Flow Computation

Description, Purpose, Context in Workflow

Obtains the pedestrian flow of a spatial configuration. This use case leverages „General Space Group Query“ which supplies the space data needed. It makes use of ECMA-357 (E4X) as well as a custom xml format, described in due course.

Involved Actors and Transactions



Specification of Transactions

„Retrieve Flow“ uses a ECMA-357 (E4X) as query language selecting relevant spaces. Flow will be provided as custom xml, using a per-space <attribute referencing=“*Space-ID*“ value=“*occupancy*“ type=“number“ unit=“persons“/> as input for the Flow Provider. […]

...further details on data format and prescription of data items having to be sent...

Figure 3 Use case which uses composition. A Flow Consumer sends a request to a Flow Computation Provider, which internally uses the use case in Figure 2 to obtain spaces

Again, the choice of file formats that were involved in the transfer would be determined in a community process, using available standards as means. However, in contrast to healthcare interoperability, it may not always be possible to avoid creating a new data format, which is why we have chosen to use a custom xml for the presented example.

From a physical data exchange perspective, use case composition is ideally suited for cases in which software is online (i.e. the synchronous/parallel and synchronous/BIM server scenario). A file-based exchange might involve too many import/export steps to be practical.

Table 2 Retrieve Flow example using E4X as query language and a custom xml schema for describing occupancy and the computed density of persons as attributes referencing spaces

Retrieve Flow parameters	Response as IFCXML Version 2x3
query: IfcSpace.(InteriorOrExteriorSpace == “internal”) *occupancy*: <attribute referencing=”E12” value=”10” type=”number” unit=”persons”/> …	<attribute referencing=”E12” value=”3” type=”number” unit=”level-of-service”/> …

5 Discussion

The presented concepts for sparse data exchange based on use cases require, first of all, a re-thinking of data exchange on the physical level. The usual (asynchronous) file-based approach has severe limitations when dealing with data exchanges consisting of multiple steps. Therefore, we strongly argue for the introduction of centralised communication which means to enable a synchronous transfer. Current tendencies in this respect are already underway, either in the form of BIM servers or central repositories that allow version control and collaboration among project partners.

From a semantic standpoint, we have shown that standards such as IFC can capture data representation needs, but not the typical interchange process that may employ only a limited set of data entities ("sparse data"). Use cases are beneficial for a definition of the latter aspect, capturing the data needs *according to the workflow* in which the data is transferred. Furthermore, the presented concept links data exchange to the data formats *used by the involved domains*, which might be reluctant to adopt each other's standards. Healthcare interoperability has seen a wide range of these trans-disciplinary disputes (eventually extending to the standards that are now in place), and reacted not by dictating one, but rather superimposing a framework that regulates their use for specific interchange scenarios. If the AEC sector wants to extend its scope, utilizing same approach would be worth consideration.

Coming to the benefits and shortcomings of the presented concepts, the main idea is to supplement activities underway in the standardization field, not replace them. Therefore, argumentation in favour of the presented content focuses on gaps that exist in the now-common data exchange, i.e.:

- transferring as little data as possible in formats mutually agreed upon by the involved fields, thereby keeping interfaces simple and stable
- Seeing data exchange in the context of the intended workflow, such that applications should support new use cases rather than new data formats.
- regular verification of data exchange by interoperability testing (e.g. Connect-a-Thon) among the exchanging applications, rather by bi-lateral agreement on interfaces by involved companies

On the negative side, we are seeing that interoperability based on use cases can only come as far as the process in which the exchange occurs is clearly captured and remains static. Because data transfer is optimized such that it is "good enough" for fulfilling the use case (but may include little more) exploration of the data in unforeseeable ways is extremely limited. Also, it remains yet unclear whether dynamic steps in the design process can be captured in the proposed form.

For software users, the potentials of the presented concept lie in an optimization of daily work routine steps having to do with data exchange. More specifically, a user would see steps for which he would normally have to enter another software product being directly available in his platform (e.g. as in the use case composition example, there could be "Retrieve Flow" button in the CAD software). In the background, the necessary exchanges would be invoked and the result of the computation returned in a way that makes sense for the requesting domain. Exchange of files per mail, which often leads to problems of versioning and timeliness (e.g. recipient is currently on holiday) would be alleviated by using synchronous communication among software packages that are able to communicate on-line. Recent tendencies of using software in the cloud (software as a service, pay-per-use models) are already aimed at making software available in this manner.

6 Conclusion

We have brought the concept of a data exchange based on *use cases*, which captures *in what context which data* needs to be transferred, using previous work in healthcare interoperability as a basis. The reason for this lies in the fact that standards (e.g. IFC) focus on *data representation*, but give no hint at what data might actually be present once it comes to the actual exchange. Prescribing exactly what data is to be sent in which context enables software vendors to keep their interfaces simple, tailored to the workflow in which an exchange occurs. Furthermore, it also allows verification of software claiming to be interoperable in a straightforward manner, using the domain knowledge of the use case as test bed.

For the user, the potential of the presented concept clearly lie in the improved interchange between applications of different domains. The used integration approach does not define new standards, but leverages formats already established in the specialist field. This also means that users of different professions can work together by using their (domain-dependent) information, which are later linked together by the use case.

Acknowledgements

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