From Product Data Technologies to Applications : illustrative cases in the AEC domain

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Abstract

Handling the fragmentation of the Building industry stands for one of the major challenge of this predominant economic sector in Europe and interoperability between a various range of dedicated applications is the main end-user requirement at a practical level. In that context Product Data Technologies (PDT) are regarded as a the most promising route to meet the objective. However, the elaboration and further deployment of PDT based applications requires the availability of both suitable Product Data Models that conveys the underlying semantics of these applications and software platforms allowing an easy usage of such data models at the implementation level.

Attention is first brought to the semantic level and STEP Application Protocols but also the Industry Foundation Classes are depicted as promising Product Data Models regarding the needs of the Architecture, Engineering and Construction domain.

CSTB STEP Platform is then presented that offers an implementation of STEP Standard Data Access Interface. Focus is set on the generic aspect of the platform regarding its ability to support any EXPRESS schema, but also on its architecture that encompasses among others persistence and OLE support.

Building upon these two components, illustrative applications are detailed that evidence the interest of PTD in the Building sector.

1. The Building Industry : IT Context, Needs and Approach

All along the many stages of a construction operation, a wide range of software applications are used. From the very first program brief to the later exploitation, maintenance and final demolition of the building, large projects require the involvement of numerous actors (client, architect, design engineers, specialists from different technical disciplines, technical controllers, construction companies) sitting at various locations, with different views and needs on the project (see Figure 1). Associated with such a process, the efficient edition and further exchange of consistent information among these actors is crucial. Whether they are architectural and technical (structure, acoustic, thermal, HVAC, lighting, etc) design drawings, technical specification documents, bill of quantities or exploitation & maintenance reports, all these pieces of information have to be conveyed in time where needed.

On the Information Technologies (IT) side, numerous software tools currently exist that cover most of the aspects and disciplines of a construction operation. However, these tools most often rely on their proprietary information representation format and cannot inter-operate. In practice, paper drawings or documents are therefore the common medium for exchanging information. As a consequence, the manual input of data from one tool to another, and the associated risk of errors, hampers dramatically the duration, quality and cost of the construction process.

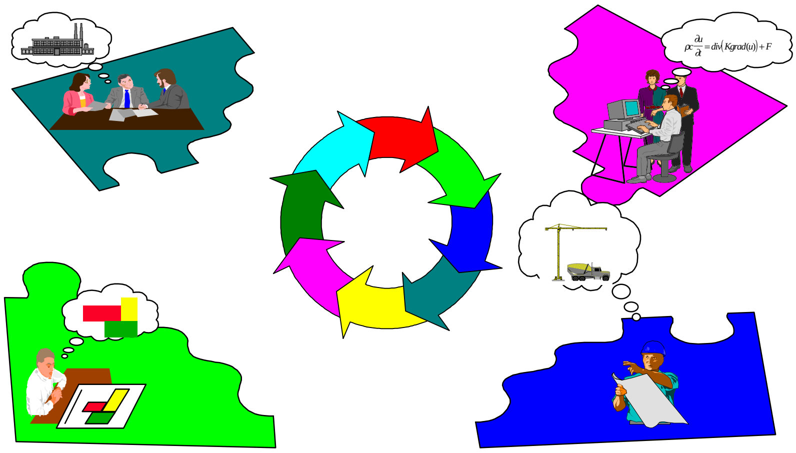

Figure 1 : Multiplicity of actors, sites and views on a Construction Operation

Concerning this issue, much research efforts have been spent these recent years to overcome the discrepancy of software applications. The main idea is to reconcile these islands of automation and allow them to inter-operate thanks to a Project Information System that will offer to each actor a consistent representation of the project information. Such a goal is addressed through a Product Modelling approach [Monc96] where a Project Model is elaborated that stands for a conceptualisation of the Project Information System.

2. Product Modeling : STEP and IAI contributions

Addressing the need for an explicit definition of the semantics involved in the description of a building, the goal of Product Data Technologies is to allow the exchange and sharing of information beyond the sole geometry. It comprises the application of Information Technologies to all aspects of a building [Zarli97] through a unified representation of the operation description captured in its elementary products and associating relationships throughout their life cycle.

Current international developments in this broad field are advancing rapidly and are leading up to emerging solutions as for product definition, product data communications, enterprise integration and co-operation. In particular the STEP and IAI efforts are worth being quoted.

2.1. STEP

ISO-10303 also referred to as STEP (Standard for the Exchange of Product data model) [ISO 10303-1] is a International Standard currently being developed under the auspices of ISO to support the computer based representation and exchange of product data.

The initial goal of the standard is to develop and promote neutral (i.e. independent of any proprietary representation, operating system or hardware platform) means for exchanging information between software applications.

One of the main results of STEP is the EXPRESS [ISO 10303-11] modelling language that allows a non-ambiguous description of the information through an object-oriented approach. STEP then offers a Physical File Format [ISO 10303-21] to formalise application instances of an EXPRESS schema. Furthermore, STEP specifies the Standard Data Access Interface (SDAI) [ISO 10303-22], that allows the manipulation of application instances through a dedicated Application Programming Interface. Various bindings of the SDAI towards specific software programming languages are also offered : C [ISO 10303-24], C++ [ISO 10303-23] for instance.

Apart from generic tools, STEP supports the elaboration of sector specific conceptual models referred to as Application Protocols (AP). Currently, several AP's definitions are underway. A few of them are addressing the building sector :

- AP 225 : Structural Building Elements Using Explicit Shape Representations
- AP 228 : Building Services: Heating, Ventilation and Air Conditioning
- AP 230 : Building Structural Frame: Steelworks
- Part 106 : Building Construction Core Model

2.2. IAI

Product Data Technologies (PDT) were in the recent past years still a research issue. Since the industry is becoming aware of the gains expected thanks to these technologies, PDT are nowadays entering resolutely the Building sector at the industrial level as demonstrated by the International Alliance for Interoperability (IAI) which is today gathering over 300 members in terms of construction companies, architectural offices (HOK, Turner Construction Company), engineering firms (Ove Arup, Naoki Systems, ...), product manufacturers and operators (AT&T, Carrier, ...). Organised through Continental or National chapters all over the world (e.g. North America, Germany, United Kingdom, Singapore and Japan), IAI devotes its mission to the development and promotion of a common semantic model for the building industry referred to as the Industry Foundation Classes (IFC) [Poyet97].

The later release of the IFC specification (version 1.5) has been delivered to the IAI members by March98. First integration of IFC components in commercial product should be available by the end of the year 98. As Autodesk, Bentley, Nemetcheck or Naoki, more than 40 software vendors in the building industry are developing pilot implementations and announced such an implementation of the IFC into their package (Autocad, MicroStation, AllPlan, ...). A first demonstration from the editors took place in Frankfurt at the ACS show in Frankfurt Germany on November 96, which involved 8 software vendors for the building industry, including Autodesk, Bentley Systems, IEZ and Nemetschek. Others demonstrations followed (e.g. MICAD 98 in Paris).

Coming to the IFC model, the specification of the model starts with the identification of particular processes within the construction operation that need to be integrated. In fact, IFC are elaborated as a means for the exchange of information between these identified processes. In practice, the development process of the IFC is incremental with a cycle period of one year. Consequently the scope of each release is sharp. The conceptual architecture of IFC enables such an incremental process thanks to a modular and layered approach (see Figure 2) :

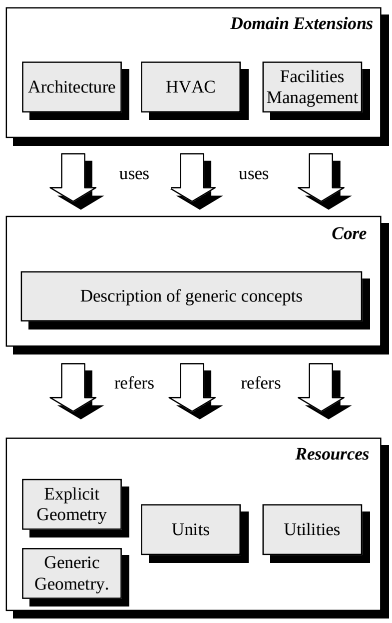

Figure 2 : Architecture of the IFC

The resources (geometry, units, etc.) describe the basic semantic bricks that are used to depict the common - i.e. technical-domain independent - concepts of a building project (the core). Some domain specific extensions are designed, using the concepts of the core.

The following figure (see Figure 3) illustrates the IFC model at a fine-grain level of details through the IfcSpaceElement concept. Derived from the EXPRESS language reference manual, the EXPRESS Graphical representation is used to describe this concept with its various attributes (e.g. Area, Volume), relations (e.g. PartOfZones) and subtypes (e.g. IfcSpace, IfcZone).

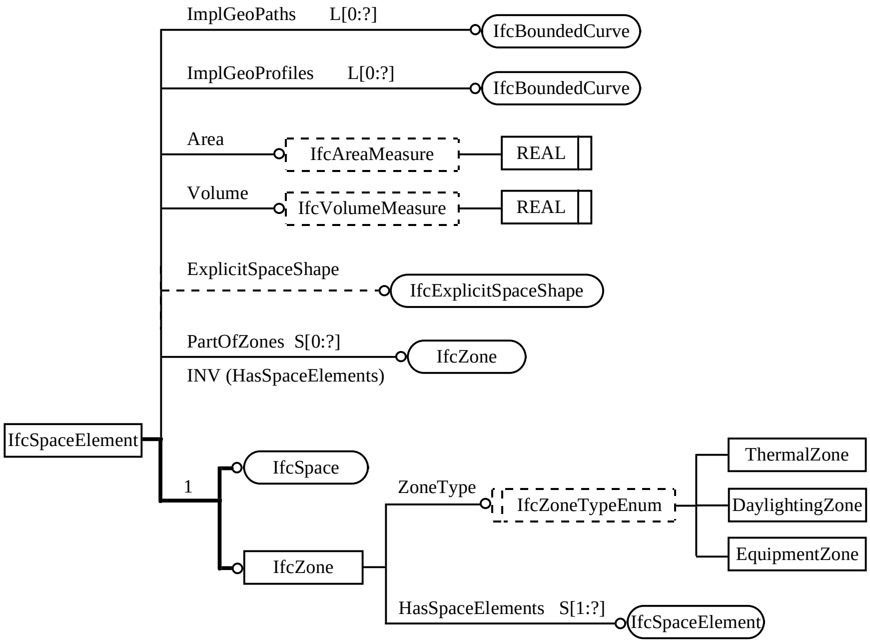

Figure 3 : the IfcSpaceElement in the IFC

3. From Product Modeling to Implementation

As mentioned, various Product Modelling efforts led to the development of different Product Data Models as key components for the implementation of software interoperability solutions. However, beyond the conceptual model, a software toolkit is required to take advantage of such models in practice.

The STEP Standard Data Access Interface (SDAI) specification and its accompanying language bindings is the normative route towards the implementation of software components that are able to load, manipulate and store STEP-EXPRESS specified information.

CSTB took such a route to develop a STEP compliant platform as an implementation of STEP C++ late binding specification. As a late binding approach, this implementation is independent of any particular information model, providing this model is formalised as an EXPRESS schema. Therefore any STEP Application Protocol or the IAI-IFC model for instance can be handle within this software platform.

NB : the algorithmic part of the EXPRESS language has not been treated at the generic level. However, in the particular case of the IFC, the DERIVED attributes and WHERE RULES computation clauses have been encoded.

The software architecture of the platform is presented in Figure 4. As mentioned, the core of the architecture is a C++ late implementation of the STEP-SDAI specification. Besides an EXPRESS parser allows the configuration of the platform with any compliant EXPRESS schema (e.g. the IFC). Parsing such a schema leads to the population of the SDAI dictionary that holds at runtime the necessary representation of the model for instance manipulation, type checking, etc. The STEP Physical File (SPF) parser and writer allow the loading and writing of ASCII files compliant with STEP-Part 21 specification. A persistent layer is offered that allows the database storage of application instances in ODBC compliant systems. On top of the architecture, an OLE server is also provided that extends the usage of the platform to other languages than C++, Visual Basic for instance. Experiments using Java as a OLE client language are also being made. This will open the STEP component to WEB compliant applications.

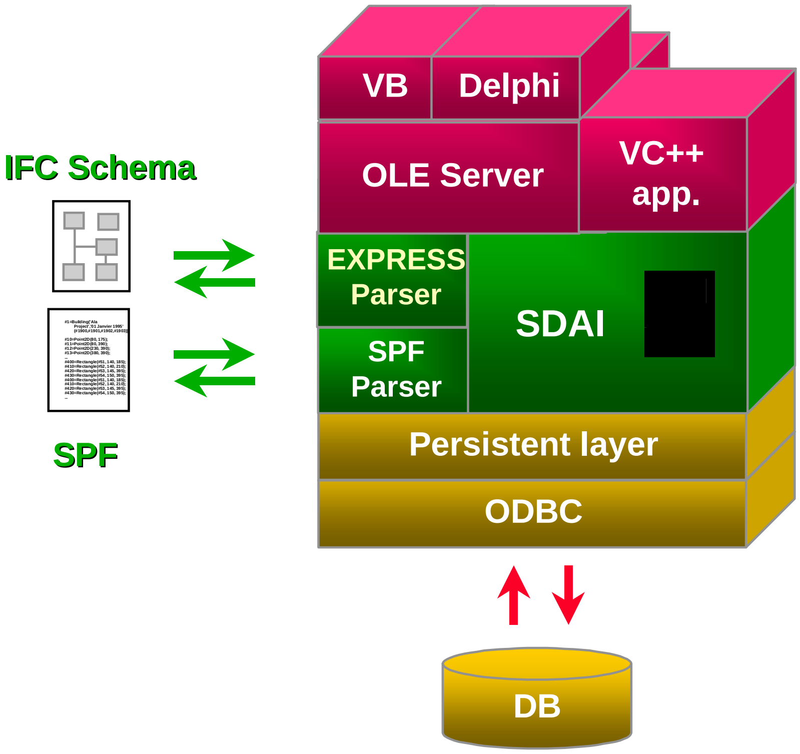

Figure 4 : CSTB STEP Component : Software Architecture

Available as a beta version, this platform has already supported various illustrative demonstrations such as MICAD 98 IAI presentation. Various usage cases are presented in the following section.

4. Illustrative Applications

4.1. Case 1 : Information Exchange scenario

The first scenario illustrates the exchange of information between various actors in the construction process through the exchange of IFC compliant STEP Physical Files. The inter-operability is assessed between various software tools used by these actors :

- The PC-BAT CAD system from BATISOFT supports the overall architectural design of the project. In particular, the many zones, spaces, walls and openings are designed at this stage.
- The GAIA CAD system from KEOPS illustrates the interoperability among CAD systems. GAIA is capable of loading the Project Design from the IFC format, converting the design in its own representation, then performing modifications on the design such as adding a wall and finally producing a revised version of the project as a new IFC file.
- CLIMAWIN from BBS SLAMA takes the revised project as an input and performs thermal calculations on it. Once the HVAC designed of the building is finished, the project is transferred to the quantity surveyor.

- MIAO-ARCHIPRO from XD2-ALL SYSTEM finally allows the computation of quantity take-off calculations of the project.

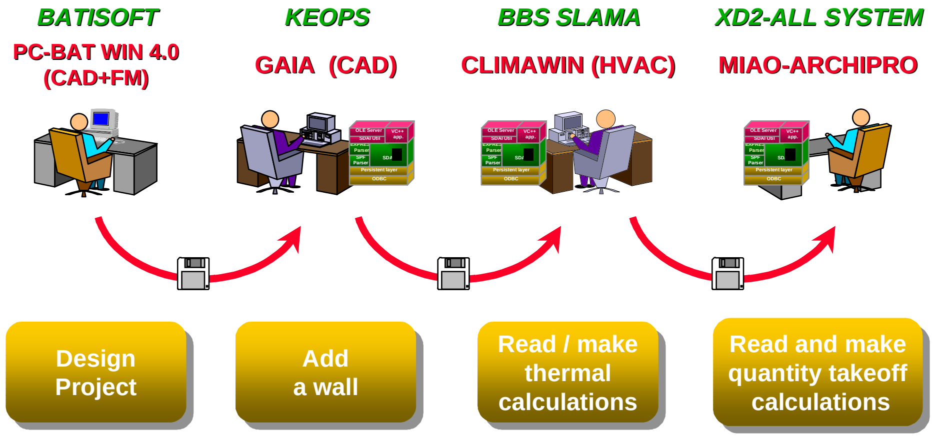

Figure 5 : Information Exchange scenario using the IFC

This scenario has demonstrated the capacity of the IFC to convey the semantics of a construction project throughout various software applications that support different stages of the construction project life cycle.

4.2. Case 2 : STEP AP225-IFC based interoperability

The second scenario illustrates the interoperability between ALLPLAN from NEMETSCHECK and AutoCAD from AUTODESK through 3 steps :

1. The construction project is first designed with ALLPLAN and converted in a representation that conforms to the AP225 STEP Application Protocol. As this stage a first SPF file is produced.
2. This SPF file is loaded within CSTB SDAI component configured with both AP225 and IFC EXPRESS schemas. Then a dedicated mapping program is run that converts the AP225 representation of the project in a IFC representation. This later representation is dumped as an SPF file.
3. The IFC compliant file is finally loaded within AutoCAD thanks to a dedicated plug-in developed within both CSTB SDAI component and AUTODESK ARX technology.

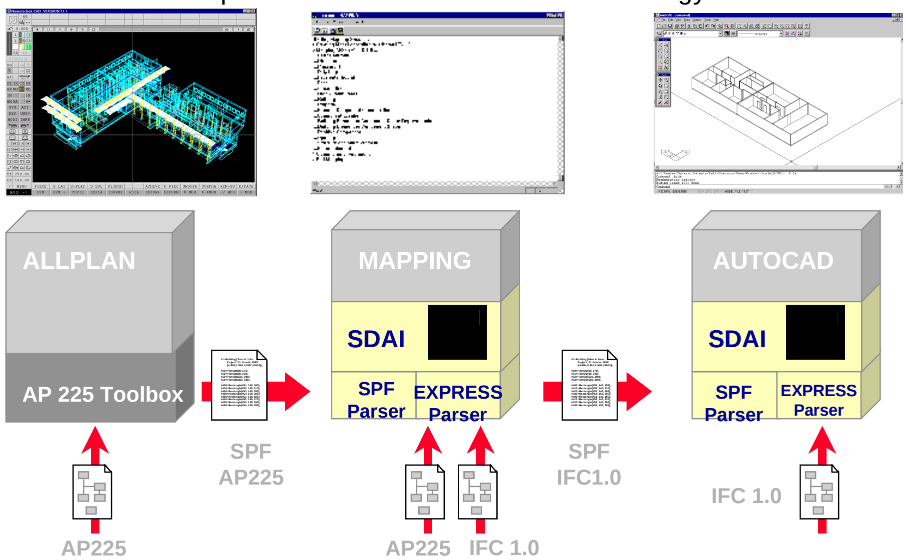

Figure 6 : CAD systems interoperability using AP225-IFC mapping

Here the interoperability between two CAD systems has been demonstrated using a mapping between the STEP AP225 Application Protocol and the IFC.

4.3. Case 3 : The Building Model Server

In this scenario, CSTB STEP Component plays the role of a persistent repository for the project description in which every client application can find and store information they need or produce. Three applications participate to this scenario :

1. The CAD system performs the architectural design of the project
2. An information browser allows a navigation in the Product Model of the building without possibility to modify anything in the design.
3. A quantity take-off application reads information in the project database and delivers the required calculations.

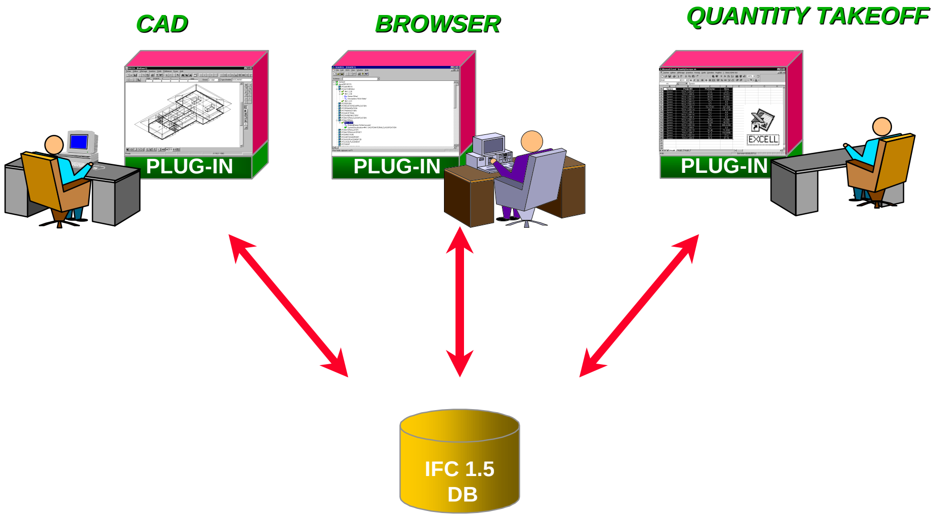

Figure 7 : a SDAI repository as a Building Model Server

To be complete, such a demonstration should have include transactional mechanisms and complementary access rights aspects to offer a real concurrent engineering environment to the construction project actors. Efforts are currently being made in that direction.

5. Conclusion

Interoperability among software applications is a crucial issue in the AEC sector. ISO through the development of the STEP standard is promoting solutions to this problem in terms of generic tools and sector specific Application Protocols. Software editors more recently gathered under the auspices of the IAI also show their interest in the approach by integrating IFC components in their packages.
With that respect, CSTB investigated and demonstrated the relevance of the STEP SDAI approach to the implementation of such toolkits offering an API to manipulate EXPRESS based data models. This relevance has been assessed through the description of various usage cases. In the near future, complementary experiments are planned that will validate the approach on a larger scale.

6. References

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