Linking Virtual Models with Physical Objects in Construction

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The Industrial PhD study concerns improving knowledge and information sharing in the construction process by an enhanced use of virtual 3D models with automatic object identification.

Virtual modelling and virtual models are not new inventions; hence the terms have been used in many contexts and also under different names. In construction practice and research names like object oriented model, information model, 3D model, product model, building information model (BIM) and virtual building model are often used interchangeably. A virtual model is a digital object oriented model of a physical object (a person, a building part, a room, a house, a city or a planet etc.). The virtual model often, but not necessarily, contains a geometrical 3D representation of the objects it models.

Virtual 3D models have in recent years proven their worth in practice relating to building design. Today it is current practice in Ramboll to create a virtual 3D model of the complete project before it is carried out. The immediate advantages of this are great and the author's own experiences have shown that the new working methods introduce fewer errors, better production basis, improved clarity and enhanced communication methods etc.

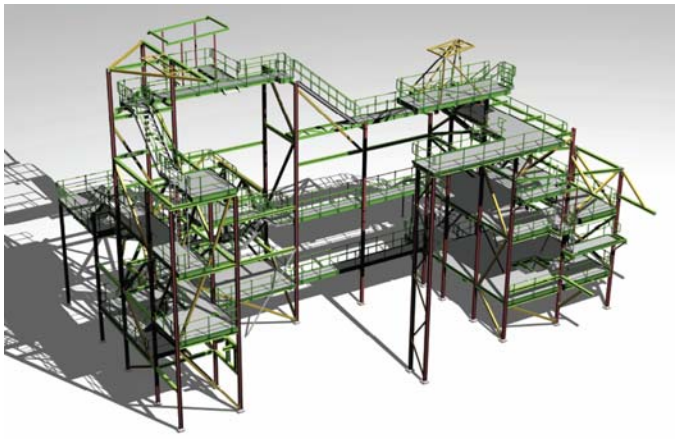
However, there is still much unutilised potential in the virtual models, especially in the construction and operation phases. A part of that potential forms the idea behind this Industrial PhD study. It is expected that a digital link between the virtual 3D models and the real objects in the construction process can improve the information and knowledge handling from design to construction and operation. When this link is introduced during the design phase by the consultants it can improve not only the designers' overview of the project, but also the one of the contractors and the end users. This will also lead to improved resource and logistic management both in construction and operation.

A concept for how the digital link can be made to achieve the more rational data and information handling in the construction process by use of virtual 3D models is developed during the Industrial PhD with focus on the people and activities that are part of the construction process.

The creation of a digital relationship between the physical reality and the time dependent virtual 3D model gives many opportunities to develop further applications which can analyse the building process, visualise time management, do automatic quality assurance etc. The documents prepared by the consultant in the form of e.g. bidding lists and descriptions are also obvious to link with both the virtual, the physical model and the suppliers' component databases containing instructions for installation and maintenance. Accordingly, also reuse and effective utilisation can be attained of the information created and used throughout the whole life time of the building. The digital link will also provide basis for an automatic up-dating of as built documentation.

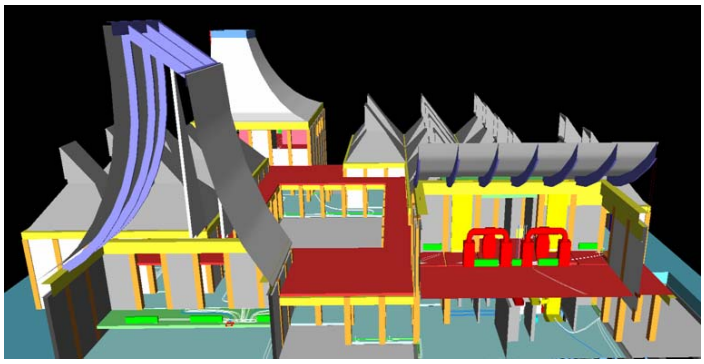
Background and supporting technologies

Before the wide introduction of personal computers in 1982, 3D modelling of buildings could only be done on very expensive work stations attached to mini computers with software like BDS, Intergraph, Medusa and Computervision. Object oriented design tools usable in the construction industry were introduced in the middle of the 1980's but their spread was limited due to many restrictions in the designer's work.



In recent years focus has increased on the use of 3D object oriented design in the construction industry, including Ramboll to a large degree. This is mainly because the 3D CAD tools used in design have now matured enough to be used in practice without introducing any extra costs compared to traditional 2D design tools. Rather, the new smarter design tools such as Tekla Structures and ArchiCAD yield time savings when they are used properly. The 3D object oriented CAD tools were first introduced in the design and shop drawing production for steel structures but are widely used today within both architectural and engineering design.

The PDES/STEP (STandard for the Exchange of Product model) standardisation process and later IFC (Industry Foundation Classes) is today's foundation of the possibilities in 3D object oriented design and is very important in future information handling in the construction industry.



To encourage the use of digital working methods in the construction industry, the Danish government initiated the project "The Digital Construction", in Danish called "Det Digitale Byggeri" (DDB), in 2002. The project ran from 2003 to 2006 and the focal point of DDB was the vision of an object-oriented working method, where all the project data is associated with the 3D virtual model that gradually develops through the construction building's life cycle. The visible results of DDB are a statutory order about requirements for the use of information and communication technology in construction ("BEK nr. 1365 af 11/12/2006"). It includes 10 formal requirements that have been mandatory since 1 January, 2007, on all governmental construction projects and projects with government subsidies of more than 50%. The requirements are within four subjects; 1) use of a web based electronic document management system for information exchange, 2) use of 3D object oriented models and delivery in IFC-format, 3) digital tendering based on standardised documents and use of a web based IT-system, 4) delivery of digital material for facility management (FM) in either IFC, XML or directly in the project owner's FM system. The 10 requirements are supplemented with instructions on implementation, working methods and agreements to fulfil these requirements. Similar initiatives have been launched in other Scandinavian countries and in the USA, where The National Institute of Building Standards (NIBS) has set up a committee to formulate the National Building Information Model Standard (NBIMS). The first version of an NBIM Standard defining a framework for the project, principles and methods was published in March 2007. Common for DDB and NBIMS is that they focus on implementation and practical adaptation of digital working processes rather than development of new technologies.

The governmental projects in Denmark only represent about 2% of the annually constructed gross area and therefore the impacts of the requirements are rather limited. Nevertheless, the process of preparing the requirements and supporting standards for working methods has had a positive influence on the overall use of IT in the Danish architectural and engineering industry. Hence, today virtual models are widely used in the sector.

The Internet and WWW, as we know it today, dates back to 1992 and is now facing some comprehensive paradigm shifts that will introduce new applications. First of all, the introduction of XML cleared the way for separating the storage and the access medium for digital information on the Internet. The following introduction of Semantic Web from 2000 with its supporting standards forms the basis of efficient future handling of information associated with meta data and data stored in information containers globally distributed on the Internet.

Another paradigm shift is the introduction of IPv6. The internet protocol (IP) specifies a hierarchical addressing system that enables unique identification of all units connected to the Internet. The present version 4 of IP is from the 1970's and consists of a 32 bit address which will not continue to be sufficient for all units connected to the Internet. IPv6 uses 128 bit addressing which gives 4 millions unique addresses per square metre which should be sufficient for supporting the growth of the Internet for at least the next 50-100 years.

These paradigm shifts form the potential for an Internet of things. It means a network where all physical objects such as humans, clothes, machines, building components etc. have a unique identification and where information about them can be structured and used rationally by humans and machines. There will be great potential in using the next generation of the Internet in interaction with virtual models in the construction industry.

Several interesting technologies exist which can be used to create a digital link between the virtual models and the physical objects such as GPS, photo and video recognition, bar codes, RFID etc. The RFID-technology (Radio Frequency Identification) has in other businesses proved its usability for automatic identification of objects. Therefore it is also expected to be applicable in the construction industry to link virtual models with physical components. Already in 1995 it was stated that "RFID technology is a promising technology for the construction industry that can be integrated into systems that can track materials, identify vehicles, and assist with cost controls" (Jaselskis et al., 1995). Still, 12 years later the applications of RFID in the construction industry are very rare and only on pilot level as discovered by Erabuild (2006).

Goals and intermediate objectives

The work in the Industrial PhD study is split in several intermediate objectives to encourage a targeted working process. The objectives include analysis of state the art in the study area, business analysis of prospective products and services, analysis of services and ontologies, contextual analysis of the building process, software prototype development and analysis of possibilities for practical implementation.

All the objectives are important to fulfil the final goal, a concept for how the potentials in linking virtual models with physical objects can be achieved.