PROPERTIES OF THE VIRTUAL BUILDING

Properties of the Virtual Building

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Abstract

The paper discusses properties of future digital Virtual Buildings from the client, design, construction and operation and maintenance perspectives. In this context the author defines a Virtual Building as "a formalized digital description of an existing or planned building which can be used to fully simulate and communicate the behavior of the real building in its expected contexts".
The paper focuses on: (1) requirements formulations of future Virtual Building models, (2) the necessity and possibilities to build redundant, overlapping descriptions of buildings and (3) why and how formal temporal building process properties may be included in the descriptions. The author believes that it is not possible or desirable to create a single non-redundant model to represent a building from concept to demolition. In this discussion an account is also taken of the influences of meta level information models, dependencies between multimedia presentation and application model views, the introduction of platform-independent Internet-based solutions, and the IT-support tools in future intelligent and responsive buildings.

Keywords: virtual building, modelling, multimedia, meta classification, temporal data

1 Introduction

Introduction of IT-tools into all aspects of the building process has been going on for a few decades now. IT integration is becoming a more important issue in the building industry (i.e. integration of design/construction/usage/maintenance activities and documentation within and between projects) and it serves to enhance team collaboration, to facilitate partnership and virtual organization formations, etc. Society has also seen during the last decades how 'programming languages' have developed into new generations, 1st, 2nd, 3rd, 4th, and 5th; with the main purpose of bringing the end user closer to direct manipulation of the application models and making systems easier to build and maintain. The ultimate goal of these efforts is a virtual reality environment where designers create, directly manipulate, and test the end building products in their 'real' contexts. A supplementary historic recapitulation of building modelling trends and intelligent buildings is shown in Figure 1 given below.

2 Climbing the abstraction ladder

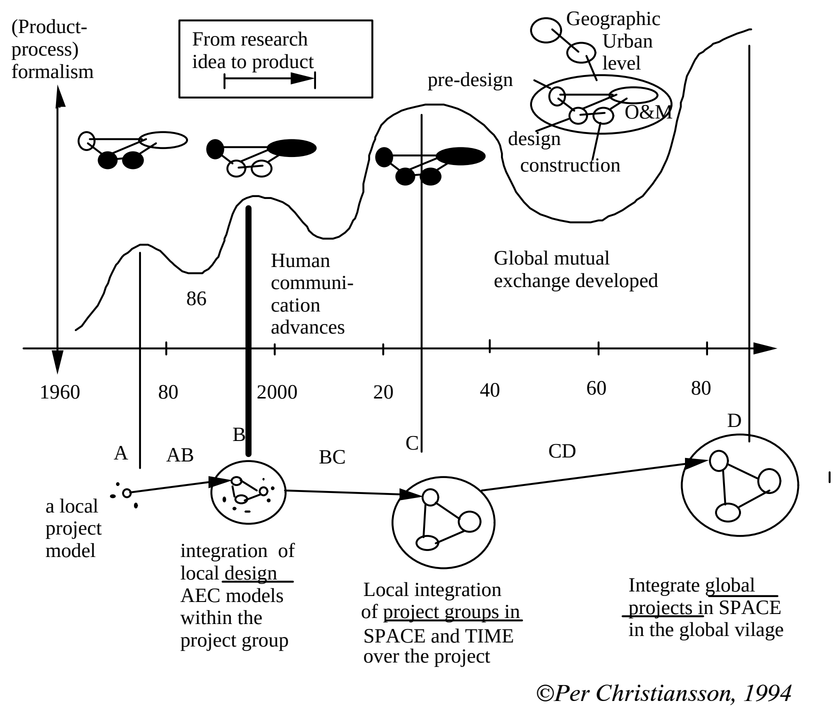

Fig. 1: The formalized descriptions of the building process oscillates to higher formalism levels (Christiansson, 1994)

The building industry has now been engaged for 40 years in building formalized digital descriptions (models) of the process, and particularly of the building itself. Figure 1 (Christiansson, 1994) outlines the development so far and also tries to provide a forecast.

- Integrating building parts to a Product Model, (1970),
- User tools perspective. 3D modelling (1975),
- Cad database integration (1980). Disintegrate physically in networks (1980). Object orientation starts (1985). CIB W78 conference in Lund ‘Conceptual modelling of buildings’ (1988)
- Integrate mixed representations. Knowledge bases (1990). Integrate networks on services level ISDN (1990), INTERNET accelerates. Process modelling (1990)
- Connectionist product/process models (2000), everywhere accessible DKN [Dynamic Knowledge Net today World Wide Web] (2000).

What next?

- Unlearn, virtual agents, pattern communication, (20XX)..

Communication history:

- 70s (end) IGES. USA Initial Graphics Exchange Specification (1979),
- 1983 IGES/PDES. USA Product Data Exchange Specification/using step ISO/STEP Standard for Exchange of Product Model Data,
- 1988 PDES/STEP General AEC Reference Model,
- IGES 5.0 only available communication standard.

During the last 5 years (i.e. roughly 2 'Internet years') considerable standardization efforts have made progress. The industry now has the ISO DIS 13567 Layers in CAD (Björk et.al., 1997), Industry Foundation Classes, IFC 1.5.1 (IAI, 1998), and the STEP standard, ISO-10303 (ISO, 1998).

The industry must also take into consideration other supporting communication (de facto) standards such as EDIFACT, VRML (Virtual Reality Markup Language), PDF (Portable Document Format), QTVR (QuickTime Virtual Reality), Resource Description Framework, RDF, and eXtensible Markup Language, XML, (RDF, 1998). See also (Whatis?com™, 1999).

3 What's new?

3.1 The virtual building concept

Information technology will have a great impact on how the industry will design, construct and use both new and existing buildings in the times to come. The enabling technologies, described above have made great progress in several closely related fields. This will lead to changes in the following building application related areas (see also Figure 2).

- Not one non-redundant model, but *overlapping representations* of building products and processes
- *multimedia interfaces* with realistic access to underlying models
- efficient utilization of personal competencies through *computer supported team collaboration*
- efficient, interactive *building documentation*
- increased possibilities for *project experience* capture and re-use
- introduction of *intelligent and responsive buildings* in practice

The main enabling information technologies are

- efficient *access* tools to physical computer networks
- standards/protocols for *services* on the Internet
- emerging *object oriented* distributed global operating systems
- *multimedia* (this includes virtual reality) interfaces in networked environments
- use of mixed and extended *knowledge representations* in networked environments

- reliable, cost effective and high capacity *information storage devices*.

3.2 Virtual building definition

In this section the author introduces the Virtual Building definition, (Christiansson, 1993): "a formalized digital description of an existing or planned building which can be used to fully simulate and communicate the behavior of the real building in its expected contexts". IT tools can in this connection be used to:

- *design, build and use* the virtual building
- *interact* with the digital building model from idea to demolition
- *simulate the behavior* of the final building during erection, use and demolition
- check the *performance* against requirements on the final building
- support various *building processes* (from idea to demolition)

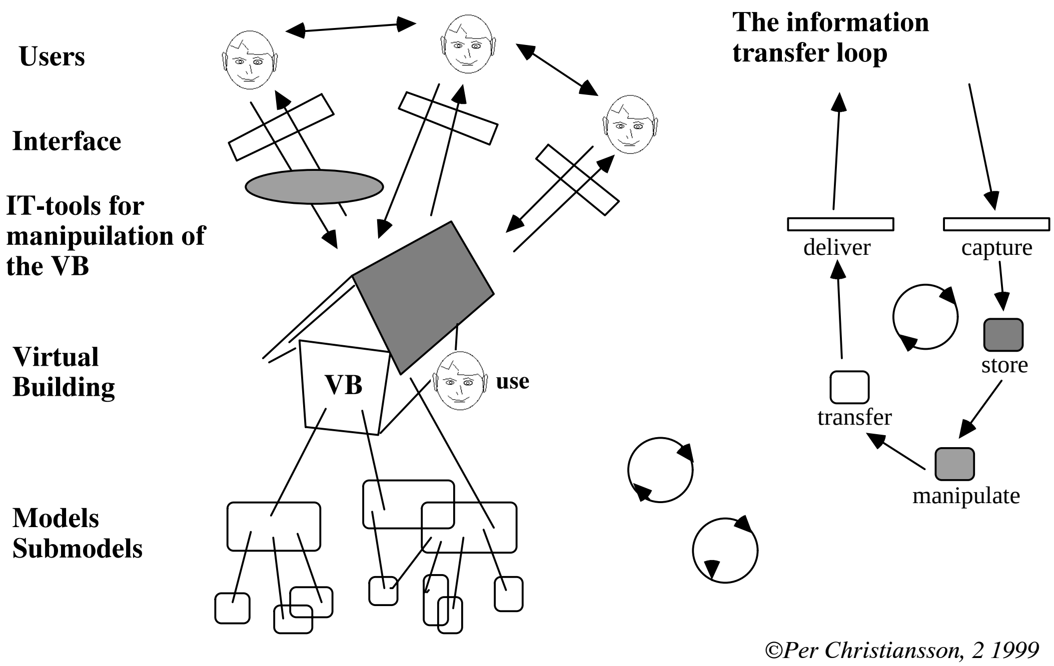

Fig. 2: The virtual building and its sub models are accessed through multimedia interfaces with different degree of realism and provisions for collaboration

3.3 Performance of the final product : Responsive buildings

During the latest 20 years, IT has been introduced to make the buildings more intelligent and responsive to external loads, for example, weather, fire, energy requirement variations, change of use, protection, communication. Today the industry talks about intelligent and responsive buildings, though the concept is not new according to the short history account given below.

- 1982. AT&T creates the concept 'Intelligent Buildings' from marketing considerations. The Informart building with available technique is set up in Dallas.

- 1984-1985 New concepts discussed in the USA, 'Automated Buildings', 'High Tech Buildings', Shared Tenants Services' STS, and 'Smart Houses'.
- In 1986 a national Intelligent Building Workshop at Lund University was hosted (Christiansson, 1987) where some problem areas were listed: environmental issues, competencies needs, information vulnerability, flexibility demands, lack of holistic views, new contracting and procurement forms, lack of communication standards for installations systems, etc.

During the ten years after the mid 80s, not so much happened in practice. R&D projects where undertaken which lead to the development of communication standards like the LonTalk Communications Protocol (http://www.echelon.com), European Installation Bus (EIB) (http://www.eiba.com), and new standards for wireless networking (Jonsson, 1998). Now the industry can await an accelerated interest in utilizing the benefits of intelligent and responsive buildings for user services, building operation and maintenance, and interaction with services in the digital city. It is the author's view that VB will be of great importance to facilitate design and to simulate the behavior of the intelligent and responsive buildings.

3.4 The design process

It is envisioned that the Virtual Building, VB, will be used ('time') and regenerated ('t_{gen}', see figure 3) at different time points during design and will contain information about the final building product on certain detail levels, ('level'), and for alternative solutions/versions, ('alt'). As design progresses the instantiated solutions may be studied with respect to time for erection, use and demolition of the design artifact i.e. VB(time, t_{gen}, level, alt)=performance), as shown in Figure 3.

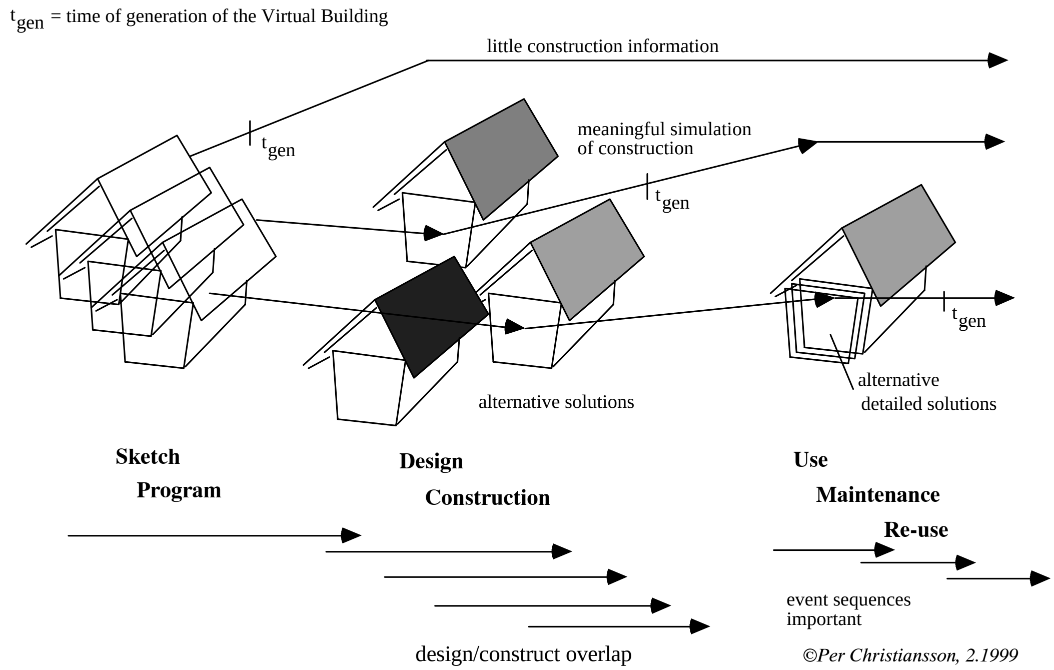

Fig. 3: The Virtual Building can be used to simulate all phases of the life time of a building as well as give input values to new projects

Figure 4 outlines the complex situation during the instantiation of the Virtual Building model. The functional requirements displayed in Figure 4 will influence the design of the different systems in the final building, as well as how these are related and coupled. In Figure 4, requirements are translated to functional requirements which in the design process lead to instantiated design parameters which lead to new functional requirements etc. Complex time dependent functional couplings will arise. Engineers and architects must design systems to ensure load carrying capacity, sufficient space separation, adequate supply systems (water, electricity, information, heating, communication control, etc.), as well as providing functional transportation systems, security systems, systems to guarantee comfort, and facility and property management systems, to name a few. The same VB must also be able to support different design paradigms which can be classified as creative, innovative or routine (Gero and Maher, 1993).

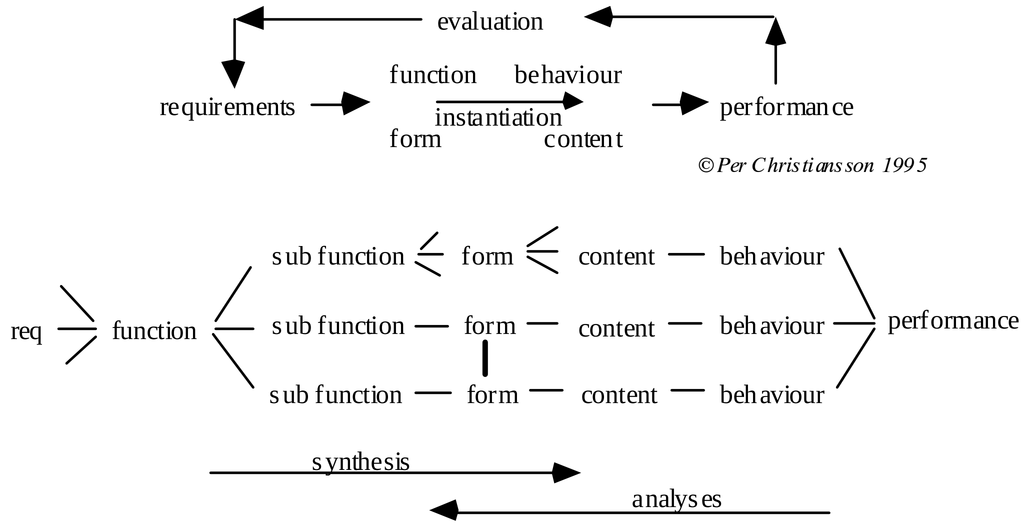

Fig. 4: The design process cycle

3.5 Handling redundancy in the virtual building.

The degree and type of redundancy in the Virtual Building model depends on factors such as type of project, organizational environments, design culture, and stage of development of the VB model. In case of a very standardized type of product there will be little need to handle redundant information.

In Merriam (1993) the following definitions are found:

- *Redundant* - (1a)" exceeding what is necessary or normal"
- *Inconsistent* - (a)" not compatible with another fact or claim, (b) … containing incompatible elements"
- *System* - (1)" a regularly interacting or interdependent group of items forming a unified whole. (3)… An organized set of doctrines, ideas, or principles usually intended to explain the arrangement or working of a systematic whole."

The envisioned VB of the future will give building designers and users many opportunities to handle redundant information which may be very beneficial. It will be able store alternative solutions to ensure that inconsistency will not arise between forms/contents during fulfillment of functional requirements (e.g. installation clashes, steel and wooden door).

Powerful computers of the future will allow designers to rebuild the building on the fly, as many times as *desired.* During this simulated building process checks can be made for inconsistency in the derived solutions and the solutions development processes. In order to narrow an expanding solution space, designers and users must introduce decision points after which sub designs are fixed. Further, warnings can be given for manual interaction if the solutions are under-sized (e.g. no ventilation ducts sketched, which causes the fire protection system to be undefined with regard to possible fire spread, or prompt the responsible persons to check buildabilty with regard to dynamic effects on neighboring structures). In the future, helpers, in the form of software agents may be developed and introduced in the VB to prompt the building process participants during consistency checks.

Other recent papers relating to redundant data (Christiansson, 1998) describe how hypertext (with redundant information) can be meta structured using RDF (RDF, 1998), enabling efficient indexed meta level cross search in documents contents, and describe efforts in the European Esprit Condor project to model semantic linking between different Electronic Document Management, EDM (Rezgui and Cooper, 1998).

4 Virtual building in context

4.1 Environmental loads

The Virtual Building will exist in a context defined by

- Geographical and sociological *location* of the real building project.
- Building project *participants*.
- Digital *information environment* (past experiences, external product data, etc.)
- Application *software environment*.
- Computer *hardware* and *operating systems* environment.
- Computer *communication* services protocols.
- Computer *physical* network environment.

The environment affecting a building presents external loads of different kinds on the VB (i.e. loads from weather, city resources supply systems, sunlight access, etc.), as does the usage of the building (i.e. change in utilization, user comfort profiles, user services and maintenance demands). One external load, 'access load', rarely considered, is derived from the fact that digital data has a limited access life time, as shown in Figure 5.

Practitioners will also need to develop support systems to interpret digital data (for example, pattern recognition IT).

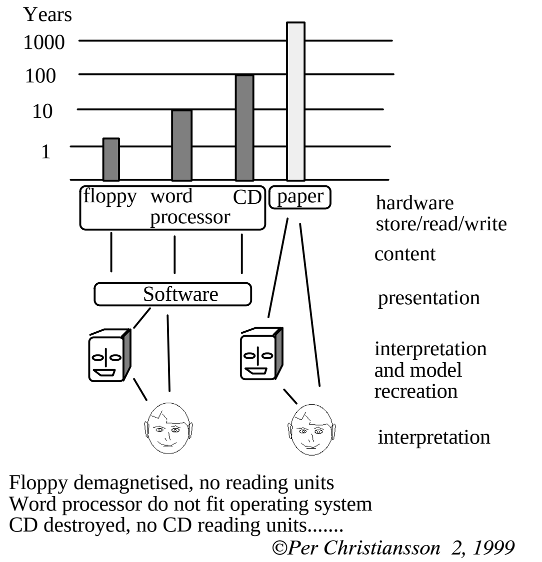

Fig. 5: Digital data media has limited access life time and must continuously be renewed

The Building Process is composed of sub processes which may be well formalized (in production lines) in the case of manufacturing of supply or building components. Practitioners of the future may, in connection with 'industrialized individual building', develop a closer interaction between the more unique once-in-a-lifetime building project and the static linked supply processes (information and products on demand). An example of this is provided in Figure 6. In the SERFIN system (Technical Building Maintenance on the Internet) meta structured information can be searched through Building Part, Material, Problem type, Environment and Action vocabularies and/or pure free text. (Christiansson, 1997).

4.2 Temporal Aspects of Data

In the future, industry will have greater possibilities to handle temporal data in databases since e.g. temporal extensions to SQL (Structured Query Language for relational databases) which now, after 25 years of evolution of SQL, are beginning to be implemented (Snodgrass, 1994). This means that users can add time dependent data to the databases and do searches where they can handle both point-based and interval-based temporal data. A temporal SQL is proposed which has similar syntax as and is backward compatible to standard SQL (Böhlen and Jensen, 1997).

With temporal data introduced into the VB, new opportunities arises:

- we can store snapshots of different building processes and *backtrack* to make a re-design or re-simulation with changed requirements (regeneration of the VB),
- it should be easier to document and retrieve *causal connections* over *time* and *space* in the VB,
- storage of *lines of reasoning* and possibilities for analyses of their relations
- effective use of the time parameters in the *life time documentation* of building behavior

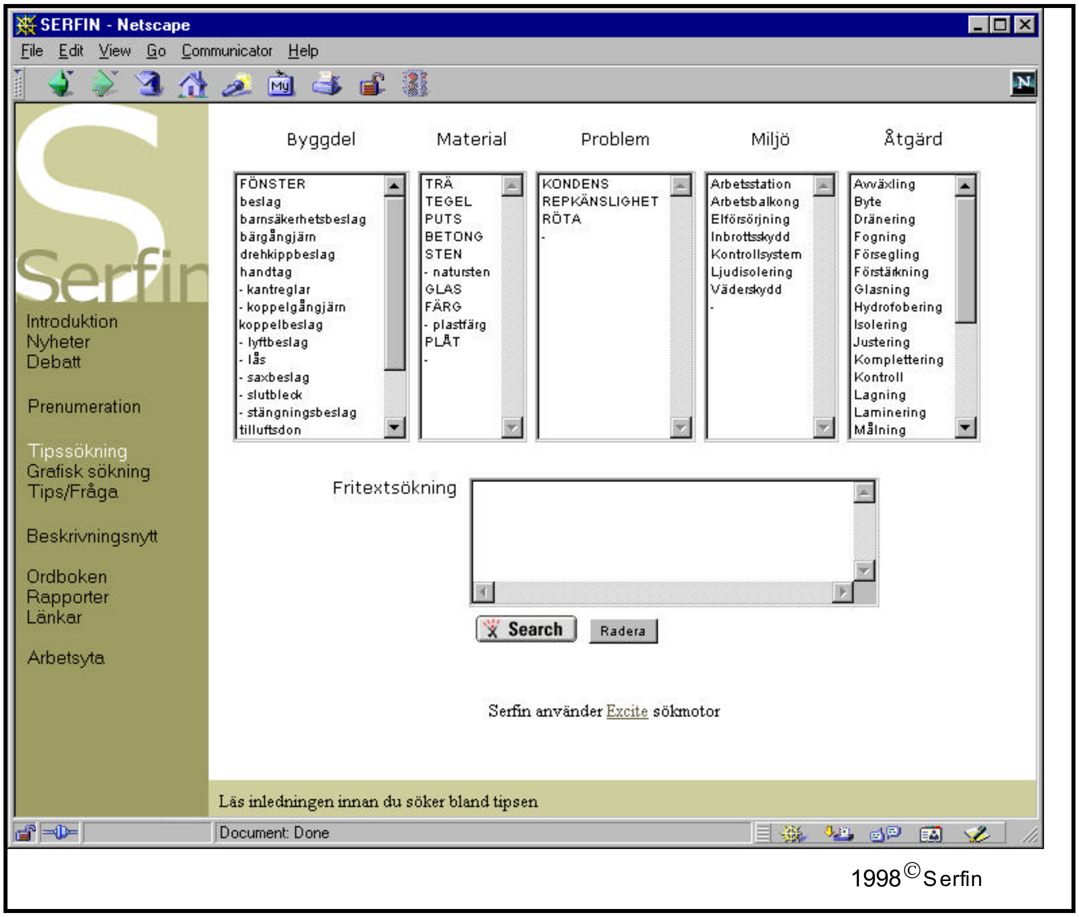

Fig. 6: The digital VB information environment has to be documented

4.3 Virtual building universe of discourse

The industry will be receiving more powerful IT-tools to store and handle the Virtual Building. How much shall be stored? For example, if one makes a reference to a regulation should the system store that part of the regulation? Can we guarantee that it will be easily available in the future? Shall one also store the terms/classification and definitions/dictionaries used? Please refer to Figure 5 and (Burns and Cole, 1998).

How much of the context shall be stored in the VB itself? These are not easy questions to answer, as they are highly related to the cost of building a self contained VB; i.e. who invests in, owns and will benefit by a comprehensive VB?

In general building practitioners will see new services develop which will act as *secure information containers* for long term digital information on *project level* that lies below the more secure global library information storage with its long (centuries) validity. (A project in this context contains *all* organized undertakings). The author's suggestion is that practitioners should store more rather than less information, until the knowledge communication society has stabilized (50-100 years).

4.4 The virtual building as a shared workspace

The VB and its multimedia interfaces will greatly enhance and influence the communication and collaboration support among the involved building process participants who have different working styles, competencies and personalities.

The VB users' interfaces have a crucial influence on:

- degree of *realism* in access of the Virtual Building
- *efficiency* in navigation, search and manipulation of the VB
- how well *collaborative* work on the VB will be supported

It would be, at this time, too premature to further elaborate on the influence of assumed and implemented user models which the VB will support. To determine this, it will be of great importance to take into account many factors such as different building process participants background, competencies, and modes of intelligence. In addition to Howard Gardners seven or more modes of Intelligence, (Gardner, 1993), the emotional intelligence, (Coleman, 1997), will play a more vital role in the design of the user models contained in the versatile future VB.

5 Conclusions

The paper discusses the future properties of the virtual building, here defined as "a formalized digital description of an existing or planned building which can be used to fully simulate and communicate the behavior of the real building in its expected contexts". It is a continuos endeavor to develop end and refine the Virtual Building and the industry will constantly have to make re-assessments. It is now time to do some creative, bold, and holistic inceptions at both universities and industries and as well as collaboration between them, both to construct and evaluate models of Virtual Buildings for the benefit of the end-users of the buildings and the building industry itself.

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