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PROPERTIES OF THE VIRTUAL BUILDING
VB

P. Christiansson
IT in Civil Engineering Institute, Dept. of Building Technology and Structural Engineering, Aalborg University, Aalborg, Denmark

Abstract

The paper discusses properties of the future digital Virtual Buildings from client, design, construction and operation&maintenance perspectives. In this context we define 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".

We focus on requirements formulations on the future Virtual Building models, the necessity and possibilities to build redundant overlapping descriptions of buildings and why and how formal temporal building process properties may be included in the descriptions. We believe that it is not possible nor desirable to create a single non-redundant model to represent a building from idea to demolition. In the discussion account is also taken to 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

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/maintenance activities and documentation within and between projects, to enhance team collaboration, to facilitate partnership and virtual organization formations, etc. We have seen during the last decades how 'programming languages' have developed into new generations, 1st, 2nd, 3rd, 4th, 5th with the main purpose of bringing the end user closer to direct manipulation of the application models and to make systems easier to build and maintain. The ultimate goal is a virtual reality environment where we create, directly manipulate, and test the end building products in their 'real' contexts. A supplementary historic recapitulation of building modelling trends and intelligent buildings are given below.

2 Climbing the abstraction ladder

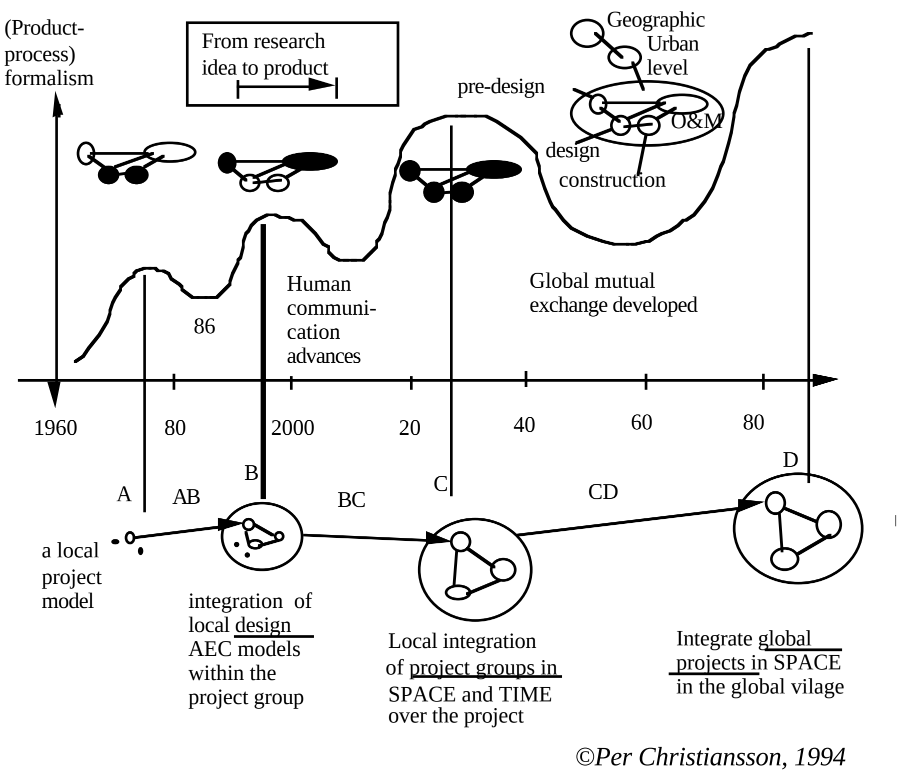

Fig. 1: The formalized descriptions of the building process oscillates to higher formalism levels. From (Christiansson 1994)

We have now for 40 years been engaged in building formalized digital descriptions (models) of the process and particularly of the building itself. Figure 1 outlines the development so far and also tries to do a forecast.

From (Christiansson 1994)

"- Integration to a Product Model, PRM, (1970)
- Disintegrate, tools perspective (75)
- Integrate logically. PRM (80), disintegrate physically in networks(80)
- Integrate mixed representations. PRM (90). Integrate networks on services level ISDN (90), INTERNET accelerates, .
- ?Connectionist models for PRM (00), everywhere accessible DKN [Dynamic Knowledge Net today World Wide Web] (00) What next?
- Unlearn, virtual agents, pattern communication, (XX)..

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') standardization has made progress. We have got 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).

We 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) and (Christiansson 1998). See also (Wahtis 1999).

3 What's new?

3.1 The Virtual Building Concept

Information technology will have a great impact on how design construct and use of new and existing buildings in the times to come. The enabling technologies have made great progress in several fields which. 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*.

We here introduce a definition, (Christiansson 1993), 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". 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)

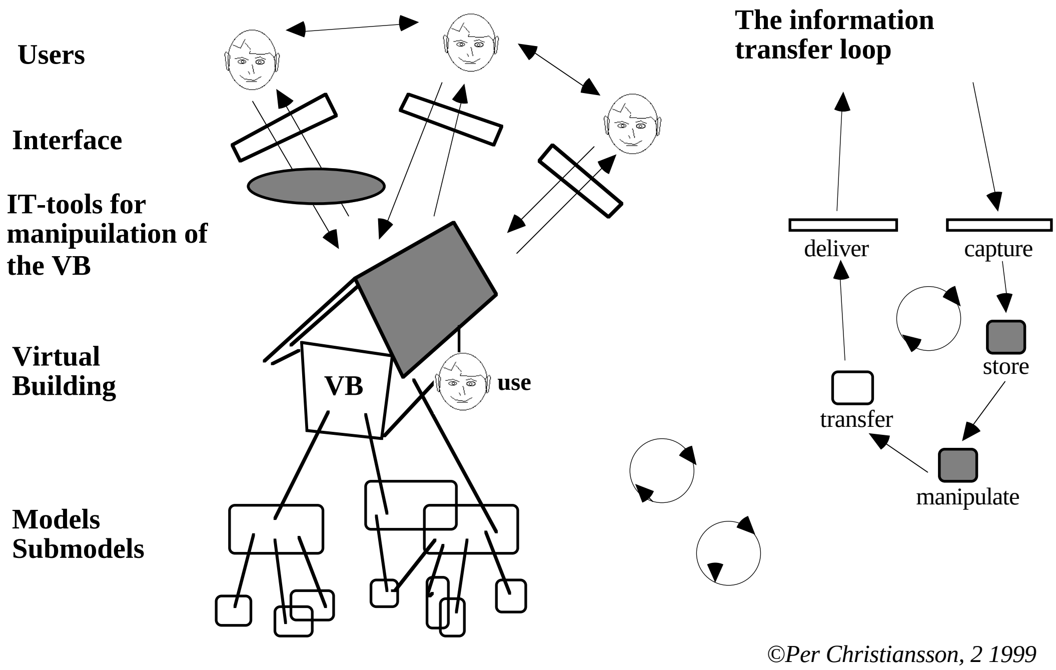

Fig. 2: The virtual building and its sub models are accessed through multimedia interfaces with different degree of realism and provisions for collaboration.

3.2 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 (weather, fire, energy requirement variations, change of use, protection, communication etc.). Today we talk 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 I arranged a national Intelligent Building Workshop at Lund University where we listed some problem areas; 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 ten years after the mid 80s not so much happened in practice. R&D projects where undertaken which lead to development of communication standards. Some of the standards are the LonTalk Communications Protocol (http://www.echelon.com), European Installation Bus (EIB), European Home Bus (EHB) and new standards for wireless networking. Now we can await an accelerated interest in utilizing the benefits of intelligent and responsive buildings for user services, building operation & maintenance, and interaction with services in the digital city. The VB will be of great importance to facilitate design and to simulate the behavior of the intelligent and responsive buildings.

3.3 The design process

The Virtual Building, VB, will at different time points during design be generated, 'tgen', and contain information about the final building product on certain detail levels, 'level', and for alternative solutions, 'alt'. As design progresses the instantiated solutions may be studied with respect to time during erection, use and demolition of the design artifact i.e. VB(time, tgen, level, alt)=performance, See figure 3.

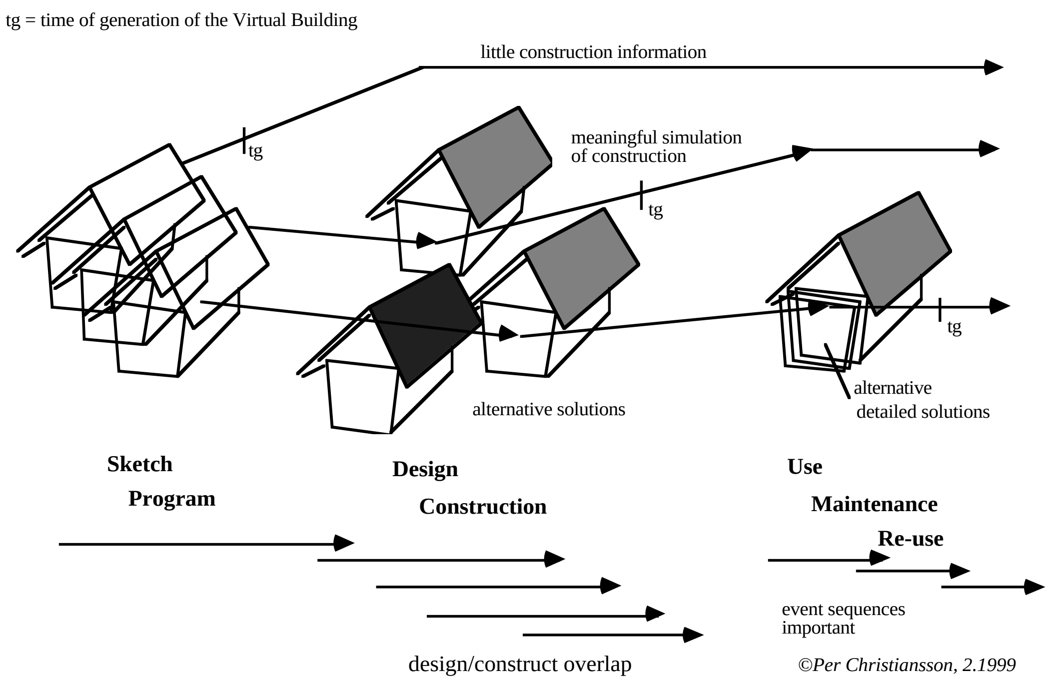

Fig 3: The Virtual Building can be used to simulate all phases of the life time of a building as well as give input values to new projects.

Figure 4 outlines the complex situation during instantiation of the Virtual Building model. The functional requirements will influence the design of the different systems in the final building and how these are related and coupled. We must design systems to ensure load carrying, space separation, supply systems (water, electricity, information, heating, communication control, etc.), transportation systems, security systems, systems to guarantee comfort , facility and property management systems, etc. 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).

3.4 Handling redundancy in the Virtual Building.

The degree and type of redundancy in the Virtual Building model depends on type of project, organizational environments, design culture, stage of development of the VB model etc. In case of a very formalized type of product there will be less needs to handle redundant information.

In (Merriam 1993) we find the following definitions

- *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

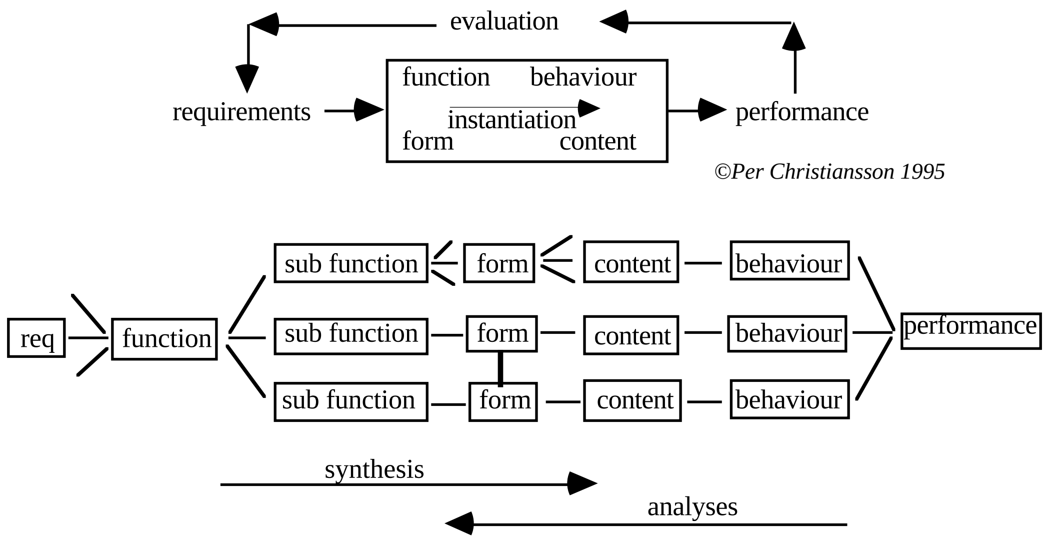

Fig 4: The design process cycle. Requirements are translated to functional requirements which in the design process leads to instantiated design parameters which leads to new functional requirements etc. Complex time dependent functional couplings will arise.

The VB gives us opportunities to handle redundant information which may be very beneficial. We will be able store alternative solutions if we ensure that inconsistency not will arise between forms/contents during fulfillment of functional requirements (e.g. installation clashes, steel and wooden door)

Powerful computers will allow us to *rebuild* the building on the fly *as many times as we want.* During this simulated building process we check for inconsistency in the derived solutions and the solutions development processes . In order to narrow the solution space we must introduce time points after which solutions are fixed.

Warnings could be given for manual interaction if for example the solutions are under-determined (no ventilation ducts sketched which causes the fire protection system to be undefined, prompt the responsible persons to check buildabilty with regard to disturbances on the environment, etc.). Helpers in the form of software agents which could prompt the building process participants during consistency checks may be developed and introduced in the VB.

In (Christiansson 1998) is described how hypertext (with redundant information) can be meta structured using RDF (RDF 1998) enabling efficient indexed meta level cross search in documents contents.

In (Rezgui, Y., Cooper. G. 1998) efforts in the European Esprit Condor project to model semantic linking between different Electronic Document Management, EDM, systems are described.

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 building environment will pose external loads of different kinds on the VB (loads from weather, city resources supply systems, sunlight access etc.), the usage of the building (change in utilization, user comfort profiles, user services and maintenance demands, etc.). One external load, 'access load', seldom thought of is derived from the fact that digital data has a limited access life time. See figure 5.

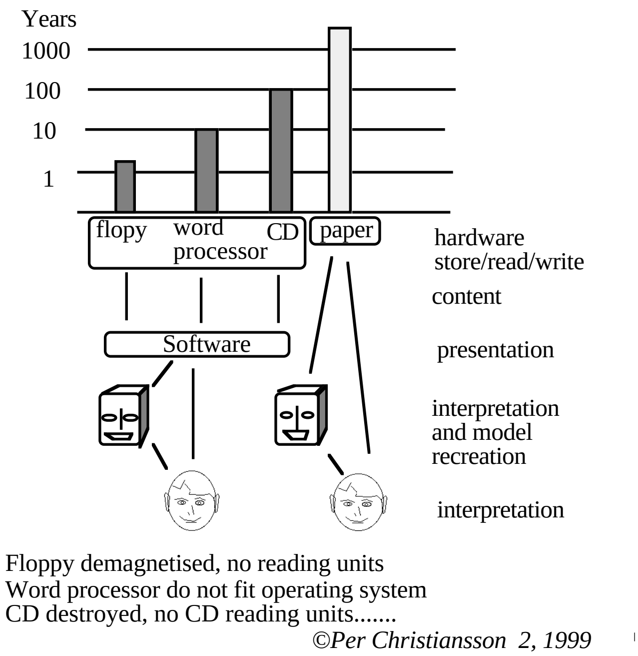

Fig 5: Digital data media has limited access life time and must continuously be renewed. We will though also develop support systems to interpret digital data (pattern recognition IT).

The Building Process is composed by sub processes which may be well formalized (in production lines) in the case of manufacturing of supply or building components. We may in the future in connection with 'industrialized individual building' see a closer interaction between the more unique once-for-all building project and linked supply processes (information and products on demand).

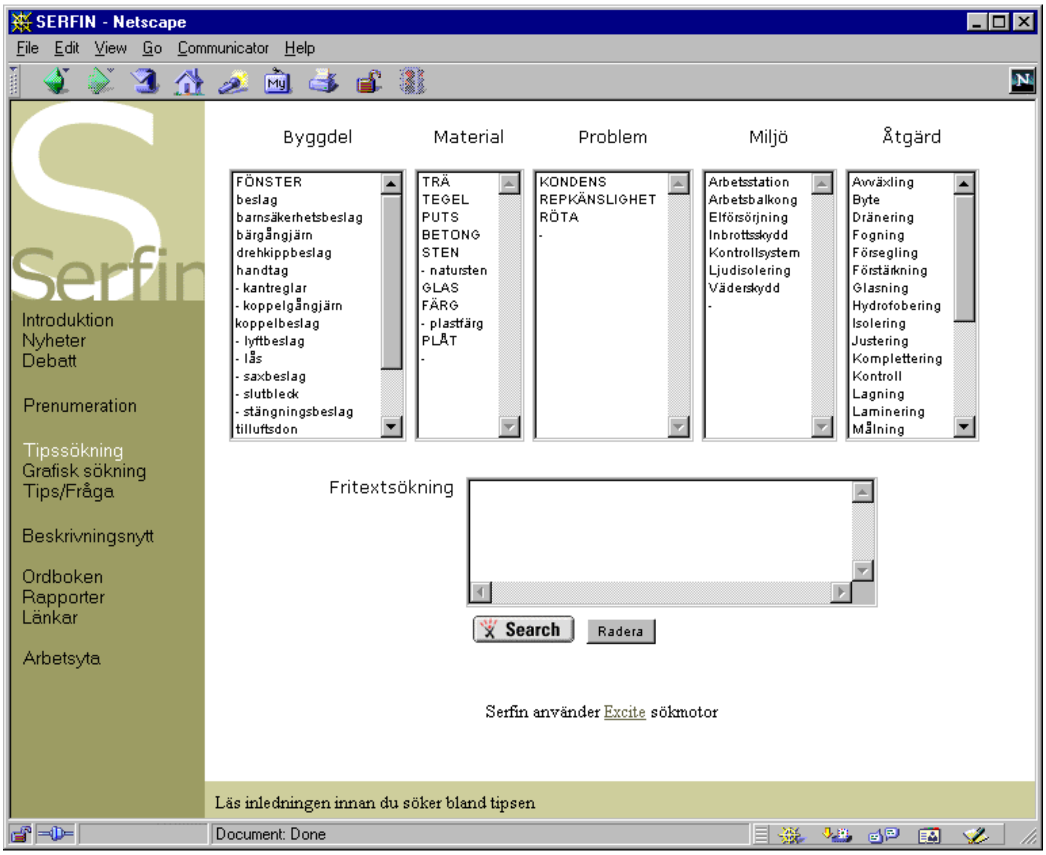

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Fig. 6: The digital VB information environment has to be documented. In the SERFIN system (Technical Building Maintenance on the Internet) meta structured information can be searched through Building Part, Material, Problem type, Environment and Action vocabularies and/or pure free text. (Christiansson 1997).

4.2 Temporal Aspects

We will in the future have greater possibilities to handle temporal data in the databases since e.g. temporal extensions to SQL (Structured Query Language for relational databases) which now after 25 years of evolution are beginning to be implemented, (Snodgrass 1994). This means that we can add time dependent data to our databases and do searches where we can handle both point-based and interval-based temporal data. A temporal SQL is proposed which have 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,
- 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

4.3 Virtual Building Universe of Discourse

We will get more powerful IT-tools to store and handle the Virtual Building. How much shall we store? If we do a reference to a regulation should we then also store that part of the regulation, unless we can guarantee that it will be easily available in the future? Shall we store the terms/classification and definitions/dictionaries used? See also figure 5 and (Burns and Cole 1998).

How much of the context shall be stored in the VB itself? It is not easy questions to answer as they are highly related to the cost of building a self contained VB.

In general we will see new services develop which will act as *secure information containers* for long term digital information on *project level* below the more secure global library information storage with its long (centuries) validity. (A project is in this context *all* organized undertakings). My suggestion is that we should store more rather than little 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 which have different working styles, competencies and personalities.

The VB users interfaces the 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 will here lead too far to further elaborate on the influence of assumed and implemented user models that the VB will support. It will though be of great importance to take into account different building process participants background, competencies, modes of intelligence etc. In addition to Howard Gardners 7 or more modes of Intelligence, (Gardner 1993) the emotional intelligence, (Coleman 1997), will play a more vital role in the design of the future 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 refine the Virtual Building and we will constantly make re-assessments. It is though time to do some creative bold holistic inceptions at universities and industries and as collaboration between them both to construct and evaluate models of Virtual Buildings to the benefit of the end-users of the buildings and the building industry itself.

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