The Virtual Construction Enterprise

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The construction industry, especially in Europe, is very fragmented. Therefore the impact of information technology hasn't been strong as in automobile or aircraft industry. Consider, for instance, an aspect such as design (CAD, graphics, visualization), analysis (numerical methods, simulation), production (computer-aided manufacturing, CNC, robotics) and management (PDM). The various parties in the construction trade have they own computer systems, but there is a lack of integration, which significantly reduces the capability to communicate and share information among them.

Our thesis is that innovation in *Information Networking* (IN) is producing a higher level of integration between applications, which can result in a number of competitive advantages for the construction business. The thesis is supported by the results of recently concluded or still ongoing European research projects. None of these projects produces the overall integration we are describing, but all together they outline an effective scenario, which we expect to evolve further. We are considering the computer tools traditionally used in the construction trade, and presenting some IN tools and the degree of integration already achieved by these European projects.

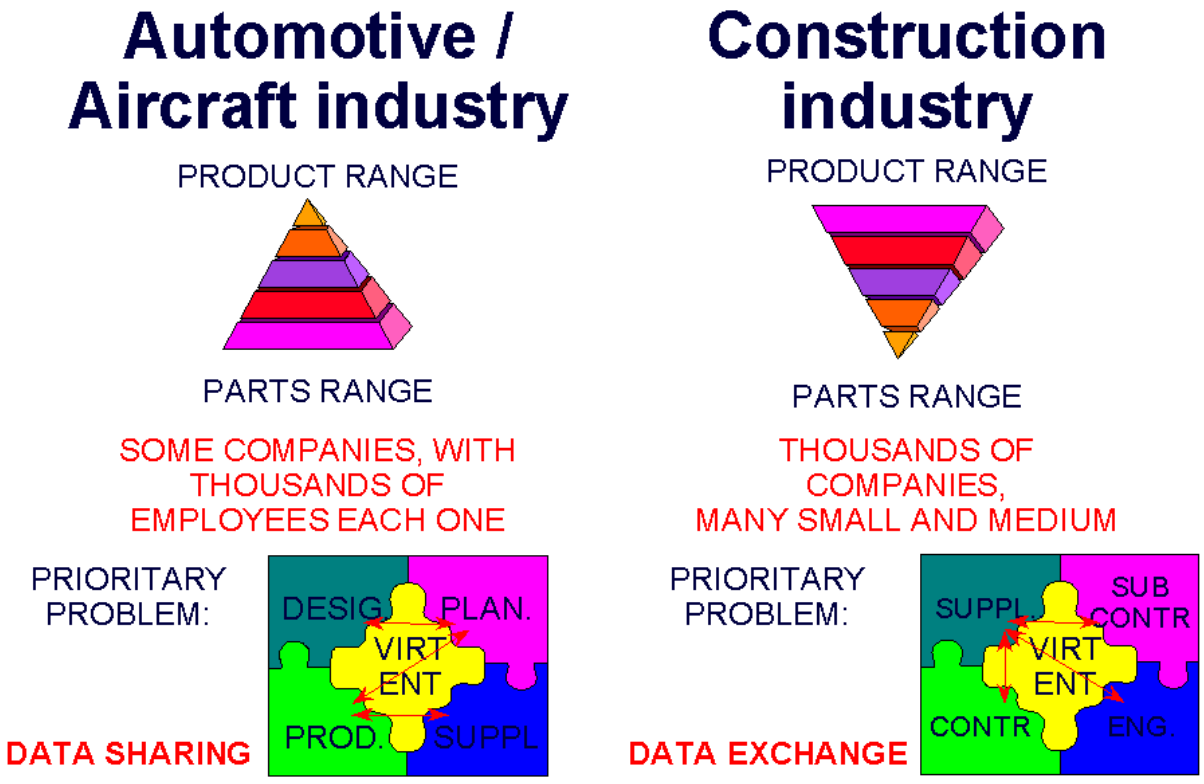


Fig. 1.Comparison of the automotive and aircraft industry with the construction industry.

Leading Information Networking

Historically, if an inception point has to be defined, we would set it in the representational shift from geometry-oriented to object-oriented systems. This point symbolically marks when the IN took the lead of innovation and started to consider not separated aspects of construction but the process as a whole.

Object-oriented representation embodies information on genuine building elements, describing aspects such as material, loading, physical properties, manufacturer, cost, life-cycle, geometry, etc. This approach evolved continuously until now, and some of the noteworthy steps are:

STEP – IFC. To optimize the effort in describing objects an international (ISO10303 – STEP) and an industrial (Industry Foundation Classes) standard has been defined. Despite the differences between the two standards, they both use the EXPRESS data specification language (ISO10303-11) to formalize the structure of the attribute pattern of objects [1, 2, 3].

OMG CORBA – DCOM. The Object Management Group (OMG) developed a standard (CORBA) for connecting and integrating object applications running in a heterogeneous, distributed environment. An application in the CORBA environment is a set of objects and associated operators. The Interface Definition Language (IDL) defines the object boundaries and the interfaces with the possible clients [4].

WfMC. The Workflow Management Coalition (WfMC) works to the definition of standards for the modeling and interoperability between workflow systems, e.g. the Workflow Process Definition Language (WPDL) [5].

The Virtual Construction Enterprise

The goal of the virtual construction enterprise is to create agile partnerships, linking the most competitive companies in project oriented ventures.

The keys to success of the virtual construction enterprises are *close*, *dynamic* and *wide* integration among the partners.

Close Integration

Effective integration of partners into a unitary virtual construction enterprise relies on network integration to share project information. Architectural and engineering firms/dept., consultants, companies, suppliers, contractors and sub-contractors through networks are able to work on a common project and co-operate as a unitary entity. But this issue is particularly severe for the construction trade, which is still extensively based on paper and voice communication.

The goal of the already concluded European Esprit project 2040 [6] is to implement the information infrastructure to form virtual construction enterprises. The information should be available even to geographically scattered partners throughout the entire project life.

The project must balance two conflicting requirements: the punctual and shared access to the data vs. their propriety and security. The current approach based on central server-vault contrasts with ownership issues raised by the open and flexible partnerships in the virtual enterprise. The Esprit project implements a true distributed information infrastructure compliant with the OMG standard, which grants access to the data according to the rights associated with each object or instance.

The distributed nature of the system is an important aspect of the virtual enterprise. Because no central repository exists, every company holds the rights and the management capability of its objects-parts of the project, on its own server, deciding who can access what and for which purpose. This way, one company can participate in different virtual construction enterprises, even competing

on the same market. On the other hand, virtual enterprise can benefit from the collaboration of most innovative and competitive companies on the market.

Dynamic Integration

The virtual construction enterprise is required to be more flexible than a traditional construction company, because its commitment is project oriented. Every project can require reorganization of the whole structure of the virtual enterprise: managerial, administrative, technical, architectural, engineering, productive. Moreover, the processes are required to be in parallel rather than sequentially: they are elaborated and managed concurrently.

The information system should be flexible and dynamic to fit with the ever-changing organization of the virtual construction enterprise. We can compare the information system to an orchestra: each company-firm acts as a player, the Express, OMG-IDL and Web offer the instruments, the STEP and WPDL the score.

A key issue of the system implementation, partially financed by the Esprit project, is the dynamic definition of the model of the virtual construction enterprise. The model is defined as:

- *Instances*, the entities constituting the model.
- *Patterns*, the properties of the instances, they can be attributes, methods or part of an association.
- *Methods*, they describe the behavior of pattern instances, i.e. the changes to the value, attribute or association to an object.
- *Filters*, they implement users' search criteria to the model.

The dynamic nature of the implementation relies on the Express, WPDL and IDL language bindings. They make it possible to modify and update at runtime the model of the virtual construction enterprise.

Wide Integration, E-Commerce

As the construction market globalizes and the competitive pressure increases, success relies more on the capability to increase outsourcing, linking best-of-breed suppliers, defined on a geographically distributed scale, according to the enterprise globalization of business.

The scenario we are defining, based on the European Esprit project 2205 [6], uses the Internet - XML [7] to implement business-to-business electronic commerce among small and medium sized companies. The implementation is sector oriented, considering data structures and graphics support capability, including 3D data product representation. The exchange of data structures and messages is designed following the STEP methodologies, and modeled with the EXPRESS language. As in the case of OMG-IDL and WPDL, There is an ongoing work to interface EXPRESS to XML, so that EXPRESS language can be used to define the structure of XML messages.

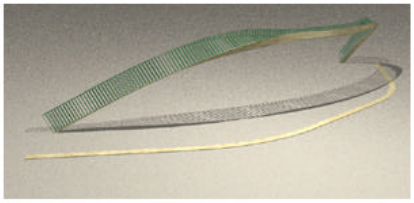
In the current implementation the engineer or purchasing dept. can choose among pieces and parts from a digital catalogue. The system interactively defines the details of the items and then transfers the digital order to the manufacturer's computer. The designer can choose among on-line catalogues of several suppliers, and integrate the product data of the item in the product model s/he is working on.

In the future we expect information networking to integrate a broader range of building-manufacturing support services, respectively:

- Object Oriented CAD,
- Simulation of building-manufacturing process,

- Item building-manufacturing,
- Testing the item.

Fig. 2 exemplifies some of these services for the construction of a timber part, e.g. dimension and CNC simulation, assemblage and testing.



Dimension and CNC simulation

Assemblage

Testing

The virtual construction enterprise demands more flexible paradigms, behind the catalogue of products, even digital. The integration of building-manufacturing services across the net opens the deployment of "search engines" based on item properties and features. While the engineer defines the instances and patterns of an item-object, in the background the search engine browses the Internet looking for parts satisfying the designer's criteria. In so far as the design process often goes through initial conceptual ideas and representations towards more defined and precise stages; the engine is able to present her or him a number of more closely defined choices. At a certain moment, the engineer can decide to move from feature design to product based design, integrating the product model provided on-line by the supplier.

Education and Training

We have still much to consider about the impact of the virtual enterprise on the construction trade, e.g. lifecycle, maintenance, quality. However, we are certain that human factor issues are crucial aspects for the success of the virtual construction enterprise.

The education and training process cannot be confined to specialists in information networking: the construction trade is a real multidisciplinary endeavor. To be successful it must permeate the companies vertically. Methods and tools of teaching must be considered to retrain experienced people at every level -not just the newcomers.

To address these issues, we have formulated a European project, which largely exploits IN technologies to create an ICAI environment for training, revisiting the concept of apprenticeship as a way of learning by examples. This computer system advocates the coaching role without the need of one-on-one personal interaction.

Authors' Background

Mario De Grassi is Professor of Construction management, Building estimating, Building technology and Building construction. He has founded and directs the Building Technology Research Laboratory, as well as the Artificial Intelligence in Design Laboratory. He has coordinated research programs related to the development of Artificial Intelligence Tools for Architecture

Design, Intelligent Tutorial Systems. Board member of public administrations and of the University of Ancona. He is the author of more than 80 scientific publications.

Anna Maria Zorgno is Professor of Technology of Architecture, former Head of the Department of Architectural Design. She co-ordinates the PhD Doctorate in "Architecture and Building Design". She was a member of the Administration Council of the Consortium for the Research and Continuous Training of the Politecnico di Torino and of the Board of Directors of the Architects and Engineers Society of Torino. She has co-ordinate various research project of the Ministry of University and Scientific and Technological and the Italian Research Council.

Alberto Giretti is Research Scientist, MS in Electronic Engineering and PhD in Artificial Intelligent Systems. He is conducting research at the Artificial Intelligence in Design Laboratory. He has participated in the Project for Building, and is developing the Architectural Symbolic Assistant (ASA) system. He has participated in a number of international conferences and published many international reviews.

Luca Caneparo is responsible for the technical aspects of the Design Network Lab, and is contractor of European ESPRIT and LEONARDO projects. He is CEO of the Archimedia Inc. He has published more than 20 papers in international journals and proceedings.

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