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# Thoughts and Tools of Collaborative Architectural Design Process

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## Abstract

The needs of collaboration among design participants spread in different locations is emphasized in the early design stage in order to not only save time and provide places to meet and talk, but also to save cost for those events as well: This is being realized by the Internet, which helps support a networked, integrated real-time multi-user environment. As the base for collaboration activities moves from physical places to cyberspace, the methods of connecting every participant by means of a computer technology have been desired and considered. This study aims at investigating today's collaboration technology in the architectural design process, especially focused on the early stages, in terms of tem poral dimensions. In addition, major concepts for and previous efforts and tools of collaborative design have been examined, and a specific recommendation has been proposed for future development of collaborative architectural design systems: That is distributed collaboration, which is accessible and comprehensible to all the professionals in the building design team, which not only allows the sharing of information but also the sharing of understanding, and which facilitates the development of design tools for different aspects of the envisioned collaborative design environment.

*Keywords: collaborative design, collaborative fabrication, design process, integration, distributed technology, Internet*

## 1. INTRODUCTION

Pearson has quoted Lewis Goetz's statement in his article, *How to Succeed with Expanded Services*: "Our job is to understand all of the issues facing a user and come up with a process and a plan to solve them. For large corporate users, the issues often include human resources, technology, and coping with change, in addition to design consideration. The key is convincing the user to let us put together the package of services and consultants" (Pearson 1998). Applying this to architectural fields, it is assumed that downward cost pressures, coupled with more specialized building trades and the increasing technical complexity of projects, will create a demand for the integration of computer-aided architecture tasks.

It is also projected that there will be a great need for visualization interfaces of complex architectural design components of a building model and for resources as a product model that will help standardize architectural objects, such as the actual doors and walls.

On the other hand, the growth of the Internet is assumed to foster electronic commerce in market places and as a result, to generate new needs for database systems on the Web. The enhancement of Web technology in database management will also provide new ways of communication and collaboration, not only for business enterprises, but also for academic institutions.

Internet is becoming the optimal tool for collaboration among participants in architectural design and construction projects because of the low connection costs and wide availability. Such collaborations will include the exchange of project drawings and various forms of project materials and general distribution of project information through the Internet. One way or another, the existence of the Internet and the wealth of related technology will change the way architectural design and construction are practiced today.

Distributed object computing, for instance, has the potential to change the information landscape of a broad range of business practices. As integrated computer systems offer the capability to improve the effectiveness and efficiency of management processes in practice, their use is likely to increase the information flow and the quality of communication among project participants in the collaborative design process.

This study will investigate how architects can use today's collaboration technology, especially in the early design stages which mainly involve their cognitive work, and aims to gain insight into the advantages and shortcomings of such an approach. From this insight, it is envisioned that specific recommendations will be made for future development of collaborative architectural design systems.

## 2. THOUGHTS OF COLLABORATION IN THE ARCHITECTURAL FIELD

In 1963, Steven Coons wrote a visionary paper titled "*An Outline of the Requirements for a Computer-Aided Design System*" which suggested two main trends that a CAD application would face in order to support various design tasks, and set the research agenda in CAD for the next generation.

Currently, Computer-Aided Architectural Design (CAAD) systems have adequately satisfied several demands. They have dramatically improved the accuracy and consistency of working drawings, enabled designers to visualize their design ideas in three-dimensions, allowed the analysis of designs through data exchange and integrated databases, and even allowed the designers to evaluate designs based on comparisons to previous cases and/or the formalization of grammars.

There is, however, a consensus that CAAD systems have not yet achieved their full potential. First, most systems employ a single-user approach to solving architectural problems which fails to grapple with the fact that most design work is done through teamwork. Second, current systems still cannot support early design stages which involve client briefing, data collection, building program formulation, and schematic design generation (Jabi 1996).

Coons predicted this need for computer-aided collaborative design through his paper:

> The Computer-Aided Design System should be capable of carrying on conversations with, and performing computations for several designers at several consoles substantially all at once. In this way each designer can be immediately aware of what the other designers are doing, and thus avoid one of the truly severe problems of intercommunication that designers face today (Coons 1963).

Up until recently, the use of computers in the profession of architecture has grown with the power of easy data management, updates, use of standard library and tools for communication and collaboration. The computing resources of an organization or project team are spread across many different platforms in different locations. Boyer and Mitgang argued about the importance of ending the isolation of the architectural discipline, and have suggested that "We needed to make working connections with others - engineers, planners, landscape architects, and an array of non-designers - who participate in the making of the built environment" (Boyer and Mitgang 1996). This state of affairs is creating a growing interest in distributed CAAD integration due to the needs of direct collaboration among project participants spread in different locations. The potential for the integration of information is expected to have a tremendous impact on architecture and construction industry.

In *Challenges to architecture*, Gutman has reported that "Various career paths and types of practice have been advocated as solutions to the motivational and organizational problems of principals and employed architects," and "The combination of diversity and fragmentation are major factors that help explain why so many firms are badly managed and why when offices are managed efficiently, they achieve work of dubious architectural quality" (Gutman 1986). A typical large-scale architectural project, normally, involves participants in various disciplines, generating large volumes of data and decisions. Centralizing such large amounts of data in a single database poses technical difficulties. Distribution technology, however, can solve these problems by accomplishing the concept of network transparency, for example, data physically stored in many different locations can be seen as a single data repository.

Haviland has also emphasized that "Building requires collaboration among many different entities who bring their individual talents, motivations, styles, and biases to a temporary multi-organization created to execute a project or a program of projects" (Haviland 1996). Researchers have addressed information integration in computer-aided architectural fields in a variety of ways: communication between applications, interfaces linking multiple applications and multiple databases, and integration through central databases according to a common conceptual model.

Duerk's book, *Architectural programming: Information Management for Design*, proposes "an algorithm for organizing design information by issue so that information is gathered efficiently and is available to the designer at the right time in the process" (Duerk 1993). It indicates that information itself can be useless unless it is successfully organized and presented. As a visual presentation is easier to comprehend than a textual description or a spoken report, an efficient way of visualizing information needs to be developed to lighten the cognitive burden on users. This aspect becomes more important especially when systems present a massive amount of data retrieved from a database, or a complex data type such as architectural data.

The focus on collaboration is due to recent technological advances, both on the hardware and software sides, which, coupled with a maturity in the knowledge-base of group behavior and dynamics, have made it possible to support and enhance collaborative processes through technological interventions (Jabi 1996).

Coons, first of all, emphasized the role of Human-Computer Interaction (HCI) with which the future CAAD systems would be pursued:

> Man and machine in an intimate cooperative complex, a combination that would use the creative and imaginative powers of the man and the analytical and computational powers of the machine each with the greatest possible economy and efficiency. … It is becoming increasingly clear that the combined intellectual potential of man and machine is greater than the sum of its parts (Coons 1963).

Lawson has also suggested that "The designers of system involving both men and machines have attempted to combine the attributes of people and machines to the best overall effect," and "It seems reasonable to view the design of a CAAD system as a man-machine decision making system," through his book, *How Designers Think* (Lawson 1990). Although there have been many research projects in HCI to improve communication between human and systems like CAAD systems, one of the current issues in interface design is how to manipulate interaction with non-geometric data. Also, the rapid growth of the Web and its business and academy-oriented opportunities portend a new need for information interaction and visualization.

An architect uses non-geometric data in making design decisions both for administrative purposes and to manage the design process. In practice, a design is produced with synthesis and analysis of information. Such information can range from site data to legislation, standards and product information. Because most of this architectural information pertains to a building model, information about architectural design needs to be related to the building model as a core model. Additionally, these building model data need to follow commonly accepted exchange standards to be adapted to systems in other firms as well as to be reused in future projects with flexibility and generality that Coons emphasized in his paper: "The computer should also be able to furnish information about standard processes" (Coons 1963).

Coons also mentioned the importance of graphical facility which must be a computational facility for unraveling and performing all of the mathematical analyses and computations that pertain to the design process (Coons 1963). A three-dimensional (3D) interface can provide a challenging visualization information method as well as effective retrieving and searching methods, minimizing the cognitive load for users. A three-dimensional interface can provide a challenging visualization information method as well as effective retrieving and searching methods, minimizing the cognitive load for users.

Novitski has agreed, as quoted from Scott Berry's words that "Languages of 2D abstractions and professional jargon often fails to communicate its intended message," and "3D animation, when used as a process tool, affords more opportunities for exploration and helps users make more informed decisions" (Novitski 1994). Some virtual-environment researchers have sought to present information in 3D structures, and this area is still open to further research. While users must cope with their position and orientation when viewing the objects, 3D interfaces provide a rich and efficient data visualization method.

As technology advanced to support multiple designers using heterogeneous applications, many issues were raised in the realization of an effective collaborative design environment. These issues include: supporting visibility of the conversion logic going to an application; allowing updates from multiple sources; supporting incremental updates; facilitating extensions of the building model to support new applications, and support for collaboration (Eastman, Jeng and Chowdbury 1997).

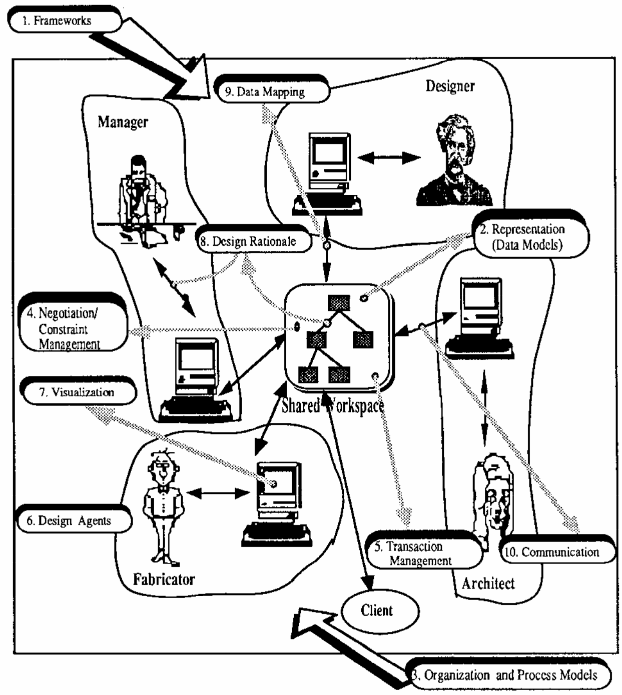


Figure 1. Design as a Collaborative Process (Source: Sriram 1994)

## 3. COLLABORATION IN THE DESIGN PROCESS

The architectural design process can normally be divided into the following phases: pre-design, schematic design, decision-making and design optimization, design development, construction documents, bidding, and administration of the construction (McGinty 1979). Information used for the design optimization and development is collected from various sources, organized and conceptualized in stage of the pre-design. In the schematic design phase, the overall characteristics of the building are established. Significant issues are identified, and initial design decisions are made. The decision-making and design optimization phase is an iterative process during which design proposals are presented for review by client, project participants, review board composed of experts from various fields or design jury, and, through communications and collaborations among them, design decisions are finalized. During the design development phase, following the approval of the design, the specific character and intent of the entire project are described, details are developed and construction documents are produced. These may be a combination of working drawings and written specifications which serve as a legal description of what is to be built. As the construction documents near completion, they are released for bidding, and a contractor is selected. The final phase of the design process is the one in which the architect administers the construction, interpreting changes and judging performance.

Throughout all of these phases, architects are involved in a variety of tasks, ranging from the most creative to the relatively pedestrian. The use of CAAD has grown over the decades, and it has been involved in the automation of tasks and in the management of information, especially in the later phases of the design process. CAAD has, however, had comparatively little impact on the earlier phases of design; there is a point in the design process when architects and designers must make a cognitive leap from pre-design sketches and study models to CAAD representations in two or three dimensions (Lansdown 1994).

Efforts have been made to encourage the development of CAAD systems to enable their use in the early design phases. A prerequisite for the increased communication and use of CAAD in this stage is an interface that will allow architects to create and interact more intuitively with their schematic designs in digital format. For instance, Virtual Reality (VR), perhaps one of the most advanced 3D presentation interfaces, has much potential for enhancing the way all participants interact with their digital models. The Internet is a solution to allow models to be linked and used simultaneously with various interactions.

The needs of direct collaboration among project participants spread in different locations is also emphasized in the early design stage in order to not only save time and provide places to meet and talk, but also to save cost for those events as well: This is being realized by the Internet, which helps support a networked real-time multi-user environment. As the base for collaboration activities moves from physical places to cyberspace, the methods of connecting every participant by means of a computer application and sharing pre-owned software through standardization on the network have been desired and considered. This issue is creating a growing interest in distributed CAAD application integration, since computer resources used by many different agencies or project teams have been spread across many platforms in different locations for specific uses. It is, furthermore, hard to build a huge, single application to include all necessary functions and support all project participants.

(1) Time Dimensions in the Design Process

All of the steps relating to the design process using CAAD applications can be examined based on temporal dimensions. It seems clear that time in the design process applying various computer technologies is measured along at least two separate dimensions. One is a valid time dimension which is also called an event or real-world time when the events occur in the application domain of the design process. The other is a transaction time dimension; for instance, when transactions take place within a CAAD application. This is also called database or system time (Worboys 1995). It is meaningful to distinguish between different time dimensions in the pointed design process because structural paths for each of the temporal dimensions may be measured with similar discrete or continuous variables.

The architectural design process, investigated relative to a valid time dimension, tends to be shaped with more divided, additional steps while aspects of sharing information among diverse project teams and of finalizing design agendas are considered. This new design process formed to help ensure all design issues will be addressed by all collaborating team members in search of solutions (Mendler and Odell 2000). There are ten key steps in the collaborative design process where considerable care and deliberation are called for:

1. Team formation
2. Education and goal setting
3. Pre-design and information gathering
4. Schematic design
5. Decision-making and design optimization
6. Design development
7. Documentation and specification
8. Bidding and negotiation
9. Construction and commissioning
10. Operations and maintenance

Collaboration can happen in nearly all steps of the design process, but the collaborative design issues investigated in this paper are to be applied in the early stages; especially pre-design through design optimization, before detailed design development. Each specific step has been investigated with relevant transactions which are processed in parallel, but in a different time dimension: the system time.

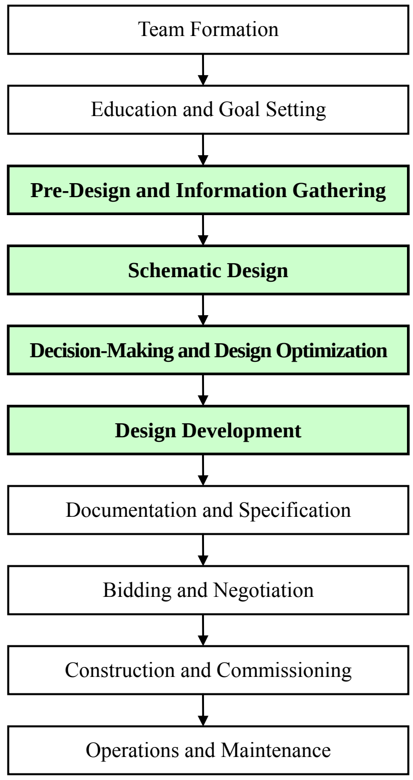


Figure 2. Ten Key Steps in the Collaborative Design Process

In the pre-design stage, information is stored and organized in the system using multiple databases and presented by an information visualization system based on Graphical User Interface (GUI), which helps users lighten the cognitive burden during preliminary design. A well-planned cohesive, visual presentation is more important especially when systems present a massive amount of data retrieved from a database, or when there is complex architectural data.

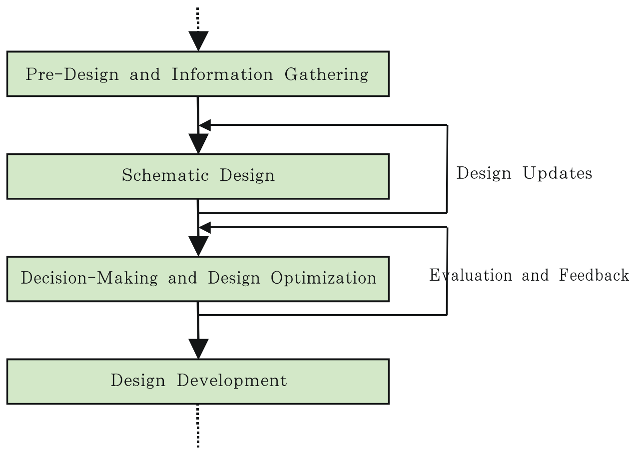


Figure 3. Collaboration in the Early Design Stages

The demonstration of a design concept is necessarily attempted while the design is in early schematic development. During this earliest phase of an architectural design, there are only rudimentary ideas and information to be represented. An abstract, massing model of the design, one in which only the basic forms of a design are represented without detail, is usually created with 3D objects, translated from non-geometric data, or extracted from and transformed to a core model; VR can play a role as the 3D visualization interface and as the standard, abstract model on the Web.

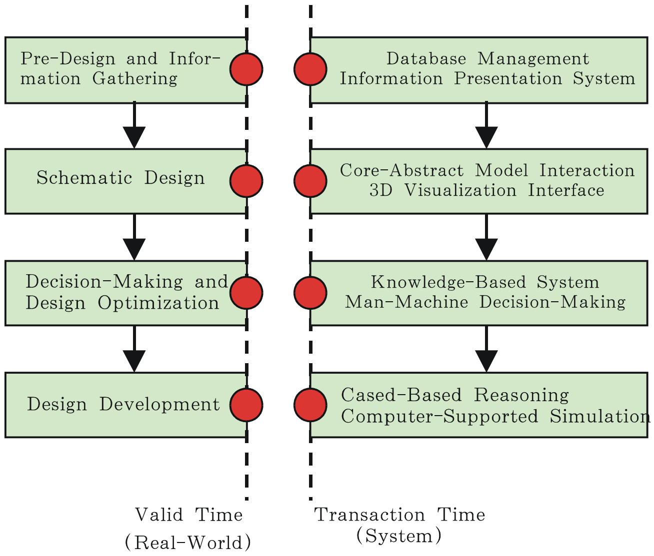


Figure 4. Time Dimensions in the Early Design Process

The design process requires not only an architectural representation of design components, but a presentation for decision-making towards design optimization as well. The VR system itself introduced above may not be available for an evaluation of the schematic design; accordingly, the tools of real-time communication and feedback are needed for periodic review by clients, design critics and other participants. Distributed computing can support linking various expertise for better communication, bounding different knowledge-based applications and finalizing design agendas and decisions through collaboration. When the collaborative design system consists of user-friendly interfaces for both representation and presentation, the critics, including clients, will then be able to successfully evaluate design ideas.

The gaps between the conception and visualization of design ideas tend to hinder direct or immediate feedback in the collaborative design process. However, the simulations on the network will provide a method to examine the CAAD model during design development, to detect flaws which may occur in future construction, and give an opportunity to evaluate design elements such as proportion, scale, and order; things that were hardly apparent to designers using traditional CAAD models alone. Object-Oriented (OO) programming and methodology can be modeled after real world objects to reduce the cognitive burden. The use of VR associated with OO programming for simulation early in the design process will force the detailed development of the design idea to proceed more easily and effectively.

(2) Scenario and User Groups

The need for an improvement in the overall quality of our built environments is felt in all sections of our community, and a proportional increase in the complexity of the building is inevitable. The increasing complexity of the built environment requires more knowledge and experience to be carried on the design process, and undeniably, contemporary buildings incorporate many disciplines - aesthetic, technical, social, financial, and so on. The growth of knowledge in the participating disciplines tends to diversify each into many sub-specializations (Khemlani, Kalay and Choi 1998).

Multi-specializations in the AEC (Architecture, Engineering and Construction) industries make the process of building design more time-consuming and complicated. It is also difficult that architects and other specialists work together effectively on a design, because they are not only physically located in different places, but are also usually working on different design models. There can certainly be many scenarios while design activities are in process, yet it is meaningful to investigate a typical case of collaboration in the early design stage. The design specialists, for instance, may perform a preliminary design and send it over to the other AEC experts, such as structural engineers and environmental engineers, HVAC experts, playing an important role as design participants and critics as well. The structural engineers may demand certain changes on the design, but during this time the environmental engineers may have performed revisions on their own. This lack of collaboration may cause a trouble that they inevitably have to repeat some or all parts of their work because of the unannounced changes. Meanwhile, the architects would communicate with their clients and make some additional changes which are posted to all the concerned participants and might result in much useless work. Because every project has a financial burden, and consequently, a limited time for optimizing the design, such delays in communication tend to exacerbate the process taint. Furthermore, there are also gross errors in transmitting and interpreting information; these can lead to costly mistakes which cannot be recovered. Naturally, it may be determined to abandon compromising the quality of the design itself.

There is yet another serious problem other than the communication issue: it is very difficult to have a clear vision of the overall goodness of the project among participating specialists. Due to their limited points of view, each specialist tries to optimize the design for his/her own discipline, which quite conceivably may come at the expense of other disciplines. For example, eliminating windows on a side of a building to save energy might also deprive the residents of a good view, and a balanced façade.

What is really needed to bring the various specializations together into a coherent whole is an effective system of collaboration. This calls for the development of an environment within which all the building design professionals can work together, so that there are no delays, inconsistencies, miscommunications, and other errors. This environment also has to provide a means to negotiate partial solutions, to trade them off against each other so the overall result is improved. Essentially, the environment has to specially recognize the significance of collaboration in enhancing the quality of building design, and be geared towards actively fostering and providing for that.

It is in the development of such an environment for collaborative, multi-disciplinary building design that computers may play their most important role in the professions. Efforts to use computers in enhancing the quality of building design and the efficiency of the design process have met with remarkable success in some areas: A wide variety of sophisticated computer tools are available for design visualization in the form of drafting, 3D modeling, rendering, and animation applications, such as AutoCAD, form·Z, and other. These have become an inseparable part of the toolkit of the professionals involved in the design process. In contrast to the availability and usability of visualization software, computer tools that can provide intelligent assistance in the actual design process in the form of analyses, criticism, evaluation, prediction or generation, are noticeably absent. This statement expresses the need for multi-disciplinary applications for the collaborative design process, and such computer aids require a virtually unified environment or platform which integrates all distributed applications helping support intelligent functions mentioned above in one. In fact, in today's design scenario, a collaborative design environment could be made possible to be created only by computers that are the medium both common and powerful to serve as the communication channel (Khemlani, Kalay and Choi 1998).

## 4. TOOLS OF COLLABORATIVE DESIGN

The building design process has changed significantly in the last years. Generally, it is a matter of fact that the technological developments in every field of science have an influence on the society and therefore on the design and the design process itself. Architectural specialists are considering especially for the influence of the rapid developments of ICT in architectural design (Sariyildiz, Volker and Schwenck 1997).

The main characteristic of the examined collaborative system in this paper is to give support during the early design process. "Support" means that the tools should provide functions to free the architects of routine tasks, to avoid faulty actions and to detect errors as early as possible, to support the architect by increasing the amount of available information, to support the exchange of information between different partners and user groups participating in the design process, etc.

The term "collaboration" can be described by distinguishing integration with respect to the following three dimensions (Schefström and Broek 1997):

1. Data (Information)
2. Control (Communication)
3. User Interface (Presentation)

The data integration aspect of tools determines the degree to which data generated by one tool is made accessible and is understood by other tools. The control integration aspect of a tool determines its communication ability, i.e. the degree to which it communicates its findings and actions to other tools and the degree to which it provides means to other tools to communicate with it. The user interface integration aspect is the degree to which different tools present a similar external look-and-feel and behave in a similar way in similar situations.

Collaboration has to be realized in all three dimensions. This avoids situations where limitations occur because of incompatible file formats, incompatible communication protocols or because of user interfaces that are not suited for the people working in the field of architectural design.

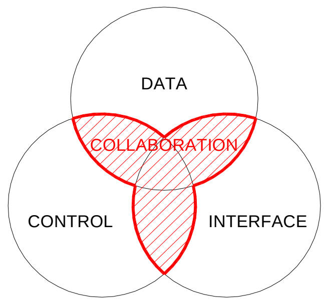


Figure 5. Dimensions of Collaboration

In order to use technologies for collaborative architectural design effectively in an integrated way, the following scenarios/concepts can be considered:

1. The process is based on an integrated manner of designing. Decisions are made as a result of discussion in a design team, where possible alternatives have been carefully evaluated.
2. The design process is executed on the basis of 3D models which are handled by means of computers.
3. The availability of support software corresponding to the need of the architect is one of the key features determining the success of the idea.
4. In the design process, there are different types of models. These models contain all relevant information generated in the design process. This includes the possibility to deal with several alternatives. Because of their availability in early stages of the design process, definitive decisions can be made better (Sariyildiz, Volker and Schwenck 1997).

The use of computer technologies in enhancing the quality of building design, as well as the efficiency of the design process itself, has been the subject of much research for more than three decades, and the importance of a collaborative design environment for the effective application of computer aids in enhancing the quality of building design has currently become well established within the CAAD research community (Khemlani, Kalay and Choi 1998). Two general directions have emerged: one which provides a low-level, shared information exchange platform, augmented by separate disciplinary models; the other which provides a comprehensive common database that can be used by all the participating disciplines.

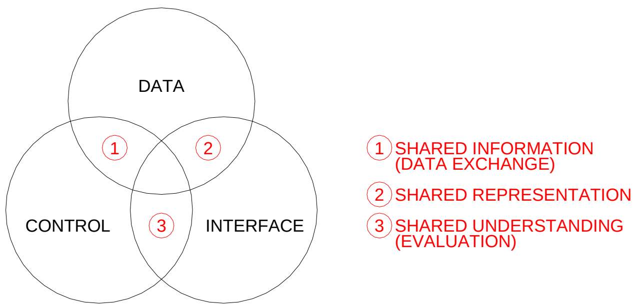


Figure 6. Major Directions of Collaboration

The first direction has been suggested by efforts such as STEP (the STandard for the Exchange of Product Model Data) and COMBINE (COmputer Models for the Building INdustry in Europe), and is predicated on the belief that each discipline knows best what it needs, hence should be entrusted with developing its own disciplinary model. The other path has attempted to develop more comprehensive design databases, demonstrated by efforts like IBDE (Integrated Building Design Environment), OXSYS, and EDM (Electronic Document/Drawing Management), and recognized these potential deficiencies. While these solutions are more practical and easier to accomplish, it suffers from a lack of shared understanding, and from a reduced level of semantic communication. ICADS (Intelligent Computer-Aided Design System), BDA (Building Design Advisor), and many recent methodologies provide for shared understanding with the design evaluating system.

The focus of STEP is on data exchange, rather than the actual representation of the building, which is concerned with defining a standard for the representation and exchange of product information in general, not just building data. STEP seems to be too general purpose to provide an efficient and workable solution to the problem of building representation, and too shallow as far as semantic content is concerned.

The COMBINE project, working with the STEP standard, deals with a neutral file exchange of data among various application programs, which has "an integrated data model" for the building description, which gets translated to the applications; however, this data model was developed by synthesizing the individual data schemas of the various design tools and requires integration procedure of new data models to be updated, so it is not a complete model and has to be re-worked, when a new tool is to be integrated into the system (Kalay 1992).

The use of XML, ASP, PHP, and smart objects in databases, online services, plug-ins, and CAAD software technologies are also bringing forth the next revolution in the business industries in aspects of data exchange. Likewise, seamless computing is envisioned and has been attainable in the CAAD industry (Han 2004).

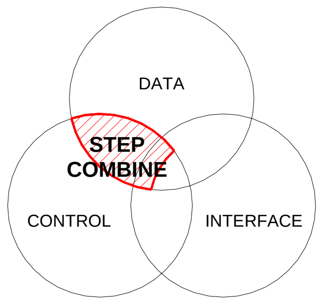


Figure 7. Realm of Shared Information: Data Exchange

Both the OXSYS and the IBDE systems are too specialized to provide the solution to a generic building representation. The OXSYS system was developed for the design of hospitals and ancillary buildings in accordance with a particular style of construction and relies on predefined "kit of parts" to cover a large portion of the design and construction process (Richens and Trinder 1999). The IBDE system consists of seven stand-alone, knowledge-based design tools, each dealing with a specific aspect of high-rise office building design, integrated into one system (Fenves et al 1994).

The EDM system was developed to address issues in the design of buildings with a wide range of design abstractions, construction technologies, and variations in building use. EDM is open-ended, so that additional descriptions can be added, and thus aims to be general-purpose as well as complete. Charles Eastman and the EDM group have suggested the product model that is the standardized data model with the input/output methodologies; the product model, however, has not supported design evaluation which is to be integrated into the main system.

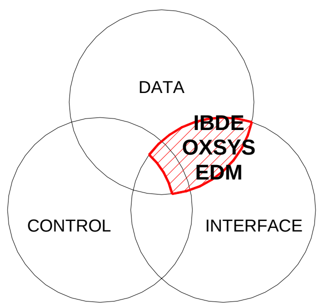


Figure 8. Realm of Shared Representation

The focus of the ICADS system is not on the detailed representation of a building, but on developing a controller for multiple rule-based expert systems that it brings together to collaborate in evaluating a design (Pohl and Myers 1994). Only a limited number of architectural objects are recognized by this system, so it is not very versatile.

BDA is an integrator of a host of existing evaluation systems, which provides a unified interface and a common data representation and exchange format. It is in the area of distribution, however, that BDA differs most from the recent distributed technology. BDA uses not a dynamically updatable repository of objects, but a passive one; BDA recognizes the need for a common database, which is the repository of the values that are produced and are required by the various applications.

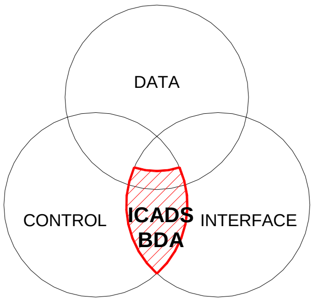


Figure 9. Realm of Shared Understanding: Evaluation

## 5. CONCLUSION AND DISCUSSION

The Internet has evolved as an excellent resource for the AEC disciplines, as it allows quick, efficient, and widespread communication to those who can access it, sharing everything from design information to project participant communication. Companies who previously marketed and sold CAAD products are now diversifying and offering services and other resources related to all aspects of the design industry.

Just as the earliest CAAD applications were relatively unsophisticated in their capabilities of making the drafting process of designers easier, these online services are currently in an early, formative period. The CAAD and AEC industries are relatively beginner on the Internet and so such services have strong as well as weak points. Already established CAAD companies enhanced the features of their offerings with innovation coupled with know-how, while newly joined enterprises to the industry realize of the needs of the industry viewed from new perspectives. Considering the consummate growth and widespread utilization by the AEC industry, the Internet and these Web-based services will be the greatest area of growth and development in the CAAD industry (Park 2001).

A specific example concerning online CAAD services would be new technologies allowing their transaction and data transfer over the Internet **[Data]** via GUI and their manipulation [**Interface**]. Such innovations facilitate the sharing of objects online by creating easily in the transfer and communicating between content provider and client; in order to stay competitive, the AEC industries must rely on an effective communication [**Control**]. These components need to be integrated, as emphasized previously, in order for design to come to achievement by way of the unified collaborative design environment either virtually or physically. Allowing the user to concentrate more on the design of the project itself and not technical issues, these components ease the procedures in design.

Another new strategy for collaboration is proposed to empower designers in the architectural field with an innovative process, which comes from the utilization of distributed computing based on the Object-Oriented approach. OO design applied to CAAD development lends favorably to the expected nature of distributed objects, which can considerably cut down decision-making procedures by providing cooperation between them; developments in CAAD technology has led to modular objects and eventually to their distribution. Distributed technology allows the designer to extract valuable information associated with the objects distributed online, not only values such as simple dimensions, but also other user-defined values from which reasonable updates and modification can be made.

Web services are appearing that cater to the AEC industry's need to collaborate efficiently and methods of implementing Web-enabled collaboration are arising. Recent peer-to-peer, distributed approaches are becoming a major trend of collaboration, although they have not been commercialized in the architectural profession yet. This approach provides a basis for all work to be done, concerning everything from project information to application without having to worry about obsolete or non-common hardware, software or unneeded personnel.

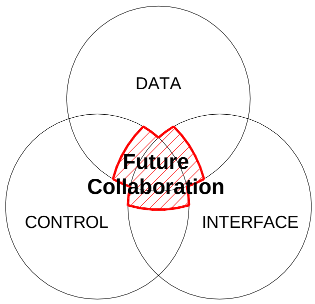


Figure 10. Collaboration in the Future

The current Web related programming technology, including Virtual Reality Modeling Language (VRML), ColdFusion, Java and Java Database Connectivity (JDBC), makes it now possible to implement a successful three-dimensional information presentation system, which can be tested as a prototype model on the Web. With the understanding of architectural tasks and the specific nature of architectural data and communication, a three-dimensional interface using VRML and Java can be designed to meet architectural design demands.

Concepts and tools such as HCI, Data Exchange Standards, OO Programming and Web technology have all emerged from work on conceptual data models and network computing, and are apt to foster the development of a new paradigm that will enable researchers to take a new approach to CAAD. Indeed, the development of CAAD software applications, the development of new modeling methodologies and the definition of standards for information exchange create opportunities for achieving distributed system integration.

Therefore, the opportunity is seen to implement a solution which will provide both objects of basic usability to designers and the ready accessibility of those objects in the form of programmed applications over the Web, and will thus be manifested in the CAAD-enabled distributed system.

This paper proposes that what is needed for effective computer-aided collaborative design is an integrated application environment, using distributed collaboration technology, which is accessible and comprehensible to all the professionals in the building design team, which not only allows the sharing of information but also the sharing of understanding, and which facilitates the development of design tools for different aspects that can be plugged into it, and details the additional solution to a shared building representation for the envisioned collaborative design environment.

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