χ-House – a Game to Improve Collaboration in Architectural Design

How to Distill a CD Based Model into an E-learning Tool

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The current research we are conducting refers to a general model of architectural design. The complexity of the present-day design process is such that new ICT tools are required to consciously and appropriately govern the design choices. In particular, the tools that involve the early phases of the design process, when the choices crucial to the entire building process are made.
In this perspective we are developing, together with a general model of architectural design based on Collaborative Design (CD), a simplified version of it – the χ-House game – that can be used to help university students appreciate the complexity of doing architecture and building.
This "simplified version" of the general model is therefore a useful 'design training tool' in the case of complex problems that can be solved by means of iterations, trade-offs, creativity, and group work; and at the same time makes it possible to highlight, define and link relatively little known aspects of design, such as scheduling, relations among operators, decision-making mechanisms, and process and design priorities.

Keywords: *Collaborative design, game; research and education, web based design.*

Design and collaboration

The research we have been conducting refers to a general model of architectural design process. The general approach followed is focused on the centrality of design. Ever since ancient times it has reflected characteristic features: physically, socially and culturally rooted in the local territory, collective work of the human mind. Other features derive from these, such as the uniqueness of the artifacts produced and the more or less intensive collaboration among design process operators.

The intrinsic nature of design in architecture is embodied in its multidisciplinary and interdisciplinary nature and the consequent complexity of the design problems, regardless of the project dimensions and the disciplinary areas involved. As far as the project is concerned, we take into consideration the specific aspects of the Technology of Architecture, of Building Production, Procedures and Codes.

The successful outcome of architectural design and its correct translation in terms of consistent and adequate implementation is linked to numerous factors, all of which dependent on the more general problem of governing the complexity of the design process.

It is worth reflecting on the ultimate significance of 'design' activity.

Different attributions [in the sense of attribution = "meanings prevalently associated" with the design of an architectural work], have been made to design activity. According to Cross (Cross, 1985, pp. 170-171) it may be subdivided into three large categories: *methodological* and managerial – activity aimed at problem solving (Archer, 1965); *systemic* – conscious attempt at imposing a significant order (Papanek, 1972); *fideistic* – performance of a complex act of faith (Jones, 1966).

Without doubt, in actual fact, these and other attributions are always copresent to different degrees. According to this classification (with all the reservations and arbitrariness that accompany each type of classification) for example, we might imagine that in King Mausolos' mausoleum the methodological aspect accounts for 15%, the systemic aspect 25%, and the fideistic aspect 60%; in Beaubourg 50%, 30% and 20%, respectively. Other classifications and consequent attributions might be made if we took into consideration the type of actor called upon to operate, his role, in the design phase being examined, the economic and cultural situation in which the activity is carried on, etc.

Here we intend to examine the *operating* aspect. Having ascertained that it is in practice "a decision-making activity aimed and directed towards the satisfaction of certain human desires or needs" (Asimov, 1962), how does this activity develop materially?

As a matter of fact we note that design is the *capacity to choose from among various hypotheses*. What are needed, therefore, are:

- solution *hypotheses*, i.e. physical and behavioural prefiguration of the building by means of models of reality;
- the possibility of *selectively choosing* (i.e. choosing from among a narrow group) various solutions that belong to an equivalence class;
- *comparison* versus the aims pursued, so that hypotheses are rendered comparable whenever they are not already;
- the *ability* to speed up the process through the conscious choice of solutions, corresponding more closely to the aims.

It is therefore not enough to produce a myriad of hypothetical undifferentiated solutions provided by the actors involved or by programs [as happened with the "Automatic Design" programs developed in the 1970s and the early 1980s], but it is necessary to 'skim off' the more promising ones. To do this it is necessary to have criteria and methods of assessment and therefore, even earlier, to make them homogeneous (or at least quasi-homogeneous) in a "space of comparison". This is the heart of Design.

Clearly in the "space of comparison", this is a recursive process, i.e. it passes through a series of intermediate solutions that are progressively adapted to the aims, which are also gradually outlined as the process continues and both (solutions and intermediate aims) become new starting points for exploring the goals-solutions "space of comparison" (Carrara and Kalay, 1994, pp. 149-150).

This operating aspect of design activity, has been spreading in industry, research and professional offices, namely architectural offices.

It actually satisfies the demands of a working environment that facilitates information exchange, the dissemination of knowledge, comparison of different hypotheses, the creative urge, and the choice of more shared, conscious and participatory solutions.

However, while the methodology is widely shared, there are severe shortcomings in the support tools.

As outlined above with regard to the *operating* aspect of design, we currently possess tools referring to the partial and specific aspects of this process because the models of reality from which they are derived only rarely refer to the consideration of the *Collaboration in Design* as a whole.

In this connection the concept of *design* needs to be clarified more.

Architectural, and other design, takes on two distinct meanings:

- to elaborate, develop and verify a basic idea in detail;
- to explore and extend the range of solutions by proposing new ideas.

These correspond to two phases that alternate in the course of design and, although dependent on the actor's greater or lesser capacity, in any case follow relatively recurrent rules and timing (Maher, 2002) .

Hence the basic idea of research in this field concerning the second meaning has been to develop new ICT tools capable of facilitating collaboration among the actors involved. Over time these (design) problems have lost their narrower, highly specialized and sectorial scientific scope, passing from the CSCW (Computer Supported Cooperative Work) studies to those of CWE (Collaborative Working Environment) and those of CE (Collaborative Environment. They now investigate the entire organization of the work from a multidisciplinary point of view (van de Broek and Stewing, 2007).

Collaborative Design

The paradigm of the working environment CE regarding design, where actors can share knowledge, design solutions and goals in a collaborative way is called Collaborative Design – CD – (Kvan, 2000; Kolarevič, 2000). The CD may be defined as an environment where actors work at the same level of importance, exchange knowledge with each other, are aware of each others' problems, feel other actors' problems to be their own and that the overall design solution is shared. So that CD, within the assigned time frame, allows the field of exploration to be extended, the choices to be made explicit and their technical-scientific aspects to be examined in greater detail already in the early phases of the design process, as well as the operational efficiency of the design development in the concluding phases to be enhanced also thanks to the most advanced ICT tools and resources.

All actors (designers) in a project have their own workspace characterized by a time period, a field of action that they can manage, by choices they can propose to other experts, by decisions they may take, by a hierarchy of authority, by a degree of autonomy vis-à-vis the other operators, by limited allocated resources: we have called all this 'Personal Workspace for Design Solution', Personal Design Workspace (PeDW), for short.

Each actor in his own PeDW develops his own design solution on the basis of his own experience and specific knowledge of his own specialist field; the instance deemed the most satisfactory is then transferred to the Overall Desogn Workspace (ODW). This instance is incorporated into the overall design being developed, thus it is becoming available to all the other actors (designers) in other disciplinary sectors who can themselves import it into their own PeDW and modify it, according to their specific skills.

At every stage, each actor's solution hypothesis is the 'actor's design solution'(an instance) proposed by him in the 'space of the design solutions of his own PeDW'.

Since the 'space of the actor's design solution' is the intersection set in the PeDW of his Specialistic Knowledge Base – SpKB – with that of the operating context and with that of the procedural rules, it is a subset of the PeDW.

However, the actor can propose 'actor's design solutions' that do not respect the truth of the intersection set temporarily suspending the application of constraints and requirements so as to extend the exploration of his new solutions in the PeDW (Hofstadter, 1988).

By expanding his knowledge in the PeDW he may find 'actor's design solutions' that are indeed 'new' solutions as they show up the inconsistency or the non applicability of those constraints that initially seemed to deny the possibility of having a non empty intersection set.

This is what has happened in design reality in all periods and is another fundamental aspect of design that must be taken into account in the model we are developing: the possibility of exploring and then proposing design solutions that are incoherent towards some SpKBs and inconsistent towards data.

Furthermore, as there are several 'actors', who modify their PeDW, we can claim that also the set of the sets of 'design actor's solutions space' varies over time.

Likewise in the ODW, the 'space of overall design solution' is given by the intersection set of the Common Knowledge Base – CKB – of those deriving from the overall operating context and with that of those proposed by the overall procedural rules. In the ODW the CKB is a KB that makes it possible to become part of this work environment and facilitates interactions among actors having fundamental rules, main object-concept characteristics and the essential requirements (Fioravanti and Rustico, 2006; Carrara and Fioravanti 2006; Carrara et al., 2004; Carrara and Fioravanti, 2002).

This intersection may prove to be an empty set, in the case of conditions that are too rigorous as often happens in reality, and so no overall building design will exist, or else, in the ODW, the solutions defined above are partially overlapping and so a set of more or less agreed sets of solutions exists.

In this sense, the project is the outcome of collective decisions and hierarchically managed by one or more of the 'actors'.

Collaboration in preliminary design phases

Our research deals with the early phases of the project when, within a short space of time, the operators involved, from now on "actors"[1] (Wix, 1997) have to choose among different options that will have a crucial impact on the outcome of the entire building process. These phases are usually denoted as Conceptual and Preliminary design.

Indeed, although most of the overall building cost is situated in the construction phase, its definition is practically made at the very beginning of the process, along with conceptual and preliminary design choices (Penttilä, 2006).

The subsequent two phases of the design process, denoted as detailed and constructive ones, find powerful aids to design, to assessment and to verification in the shape of CAD tools and software in all their forms: CADDrawing, CAM, CAE etc.

Conversely, the first two phases are difficult to formalize as they demand a relationship that is:

- highly direct among the operators involved, in order to reduce the intermediate decision-making levels, eliminate red tape and "flatten" the hierarchical pyramid (Cross, 1985, pp. 144-145);
- explicit, in order to be immediately comprehensible to many actors and avoid misunderstanding it is necessary that the information transmitted includes the cultural and scientific context from which it is drawn, clearly expressed and attached to the information itself. It is important, in other words, to avoid implicit, uncontextualized, jargonized information comprehensible only to "experts";

1 "Actor: a functional participant in building construction". Its object oriented representation is:

```
ENTITY BC_Actor
 SUPERTYPE OF        (ONE OF ( Principal, Manufacturer, Supplier));
actor_name:          STRING;
postal_address:      OPTIONAL SET [1:?] OF STRING;
office_address:      OPTIONAL SET [1:?] OF STRING;
postal_code:         OPTIONAL SET [1:?] OF STRING;
telephone_number:    OPTIONAL SET [1:?] OF STRING;
fax_number:          OPTIONAL SET [1:?] OF STRING;
email_address:       OPTIONAL SET [1:?] OF STRING;
 END_ENTITY
```

- highly interaction (almost simultaneous), in order to speed up the taking of decisions that are conscious and as shared as widely as possible, having a prompt feedback for the hypothesized decisions with possible observations, counter-deductions, proposals;
- de-hierarchized, so that actors can intervene freely (and responsibly) in the design process, since the more “equal” the work environment, the greater the extent to which the full involvement of the actors is obtained, who become proactive, and at the same time, also stimulated and receptive.

Indeed, still today in the early phases of the collaborative design process, the instruments and the procedures most frequently used are working meetings attended by a small number of experts in different disciplines which are held both periodically and when unexpected problems arise. In order to establish remote interactivity, in addition to the conventional tools such as e-mail and the telephone, also videoconferencing or Internet messaging systems are used (Dakros and Knox, 2004).

This working method, which often translates into actual procedures, inside design and production organizations, aims at viewing “with an open mind” the design challenges of our times, which are always new, unexpected, and at the same time to take account of possible resources: new materials, technologies, procedures and verifications proposed by the building industry and regulatory techniques. Awareness of the problems and the new resources is then disseminated by the various actors.

It should however be pointed out that these procedures do not have any support tools to ensure effective collaboration. Those available do not achieve what was previously analyzed point by point because, for example, they do not allow asynchronous collaboration with a coherent and contextualized explanation of requirements that are not respected.

Beginning from this starting point we have been developing a general architectural design model based on CD, on the one hand, and on the other a more simplified version.

This ‘simplified version’ of the general model will prove useful both in defining and correlating little known aspects of design, such as its timing, the relations among the actors, decision-making mechanisms, design and process priorities, and as a ‘training tool’ for complex problems that can be solved through interactions, trade-offs, creativity and group work.

χ-House game

For this purpose we have been designing a ‘game’ – χ-House – (Fioravanti and Rustico, 2006) to study the above-mentioned problems in a more restricted (but significant) field: a simplified design process system in an architectural design course will be a powerful e-learning tool (Kalay and Jeong, 2003; Moloney, 2005; Moloney, 2002; Brown and Berridge, 2001; Woodbury et al., 2001; Woodbury et al., 2001a).

It that can be of assistance to university students in allowing them to appreciate the complexity of doing architecture and building. In the present paper we shall be examining this second model.

The differences between the two models are more quantitative than qualitative so as not to reduce the universality of the CD model.

They refer to:

- the actors, who are numerous, here are 5 (**C**lient, **Ar**chitect, **S**tructural **E**ngineer, **E**nergy-plant **E**ngineer, **Bu**ilder- quantity surveyor) (fig. 1);
- the actors, who are variable and are active only in given phases, become fixed;
- the actors, who may have different hierarchies in the various design phases, now have only two hierarchical orders: the superior order of the Client and the lower one of the other four actors, considered as equals;
- the scheduling, in which “event-activities” pre-scheduled in time become random (each actor can intervene by proposing new design solutions at will);

- the geometry of the spaces, from free now becomes constrained to orthogonality and modularity;
- the building components which from continuous dimensions with even complex forms now take on modular dimensions with the form of a parallelepiped;
- the type of component that from ever-increasing numerosity due to continuous innovation is now limited from the outset;
- the characteristics of the components, which from a high number dependent on a complex context, now become only position, geometry, orientation, time and the actor(s) related to the component;
- the quality, which is not evaluated using complex functions, but by means of a conventional point score assigned by each actor.

There are no salient differences between the two models regarding:

- innovation, the possibility of adding new components (albeit in a limited number in the second model);
- the application and removal of constraints, referring both to the PeDW and the ODW;
- the variability of the component characteristics, although limited to a few simple aspects of the second model (such as wall thickness of walls);
- predefined values – the defaults – already present in each building component and in each Space Unit or Building Unit;
- the ontology of the Building Object – BO – defined as a unitary system of the Space System and of the Technological System;
- the possibility of varying the required properties and thus the expected performance of the entire BO by the *client* and like the specialistic aspects of the BO by the *other actors*;
- the transmission of information and knowledge among the various actors;
- the shareability of part of the knowledge between one actor and the others;
- the responsibility and traceability of the choices made and the design solutions proposed by each actor for each BO part and component;
- the interactive and simultaneous design space – ODW;
- the specificity of the PeDWs, their representations, interfaces and the working tools of the individual actors.
- quality, which is globally assessed through the joint assessment of the proposed design solutions (in the simple model is given as the sum of the assessments of all the project aspects, including those for which they are not strictly responsible).

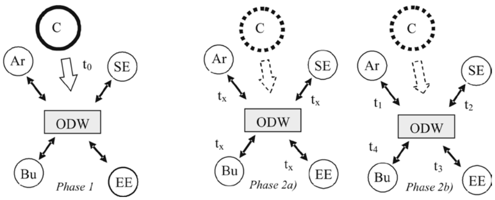


Figure 1
Actors in χ-House game and ODW

Game procedures

The actor-client C determines the needs of the desired type of building by setting a series of requirements. On the basis of this the other actors develop their own design hypotheses in their PeDW. Two process rules may be observed for the actor's intervention:

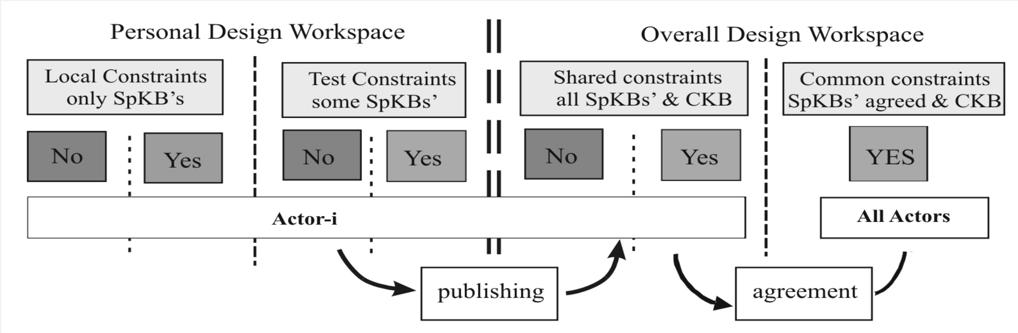
a. he publishes his own design solutions freely in any time $\forall t_x$;
b. he can publish only according to a set time schedule t_1, t_2, t_3, t_4.

In actual fact the two modes alternate as they have both set times, in which everyone must release their own design solutions or else approve the overall design solution, and also free times within the former.

χ-House achieves CD among the actors through the design solutions present in the ODW in two different modes: asynchronous and synchronous.

In the first (fig. 2) the actor works collaboratively

Figure 2
Off-line collaboration



with the others in a 'mediated' fashion: through a partial knowledge one's own proposed design solutions are evaluated immediately (by the SpKBs), or else, through an overall knowledge one's own design solutions are evaluated in partial time (by the actors).

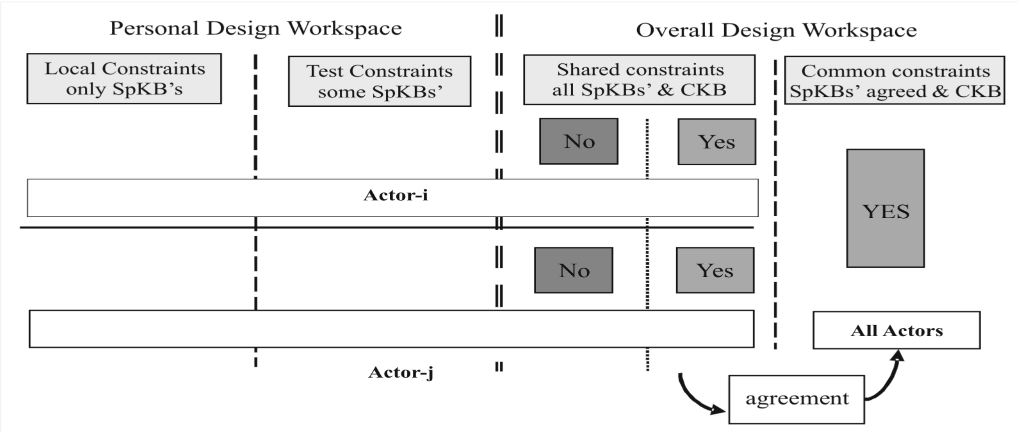
To do this the actor works in his PeDW where he is able to activate only the local requirements of his SpKB, or else activate also a few (ultimately all) the requirements of the SpKBs of the other actors.

This is achieved through an instantiation of one's own design solution in the ODW such as to trigger the mechanism for propagating constraints, the properties of the BO, the checks and thus the warnings and the explanations of how to overcome them.

This second phase may be a 'Test' phase in that it is concealed from the others, or else a 'Public' one, in the sense of being made visible. Usually each design solution may be released as having respected the requirements (Yes) or not (No) in the PeDW as in the ODW.

In the second, synchronous, mode (fig. 3), the actor works collaboratively with the others (not necessarily all of them simultaneously) in a 'non-mediated' fashion: his own design solutions are evaluated instantaneously and in detail (by the SpKBs and by the actors). The actors work in the ODW on the same design solutions (or rather on the author's 'personal instances' – the "valencies" – of the same design solutions.

Figure 3
On-line collaboration between Actor-i and Actor-j



The graphic objects of the game are Architectural Desktop ones, the data base is a MySQL and the KBs are implemented in CLOS.

The simplified CD model - Χ-House – allows architectural and building problems to emerge, gets students accustomed to working together and complies with the specific nature and role of each actor/student in the design process. As any conflict can be flagged, combined with an immediate explanation thereof, actors/students may understand others' constraints and goals and can propose new creative ideas.

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