How to Construct an Audience in Collaborative Design

The Relationship Among which Actors in the Design Process

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The features of complexity in architectural design have now been clarified. Complexity, intrinsic in architectural work, has increased in recent years as in all other fields of human endeavour – social, economic and cultural.
In the specific case of architectural design, the most significant factors in this regard consist of the large number of actors, the numerous disciplines involved, technological innovation, regulations and rules governing the design process and the various different design aims.
In order to address this complex of problems, long-term research based on the Collaborative Design paradigm, CD, is now being carried out.
In it, thanks to the reciprocal exchange of information, the complementary nature of the knowledge possessed by the various actors, and the contemporary nature of the design action by the various actors on the same components, positive effects are exerted on the design as a whole. The latter thus gains in coherence and in improved integration among the design solutions proposed by the various actors.
In CD all the actors are involved from the outset of the design work and are helped by distributed Knowledge Bases (KBs) and Intelligent Assistants (IAs). In this case it may happen that information and knowledge automatically exchanged among KBs (through the IAs) are excessive and/or not addressed to the right actors.
How can information redundancy be avoided, and how can the flow of information sent over the network be controlled? The present paper introduces and defines the concept of „Audience", that is, the group of actors to which it is permitted to send information concerning non respected requirements and the „reduced Audience" to which to send the knowledge needed to overcome the difficulties encountered.

Keywords: *Collaborative Architectural Design, Complexity, Intelligent Assistant, Context, Audience.*

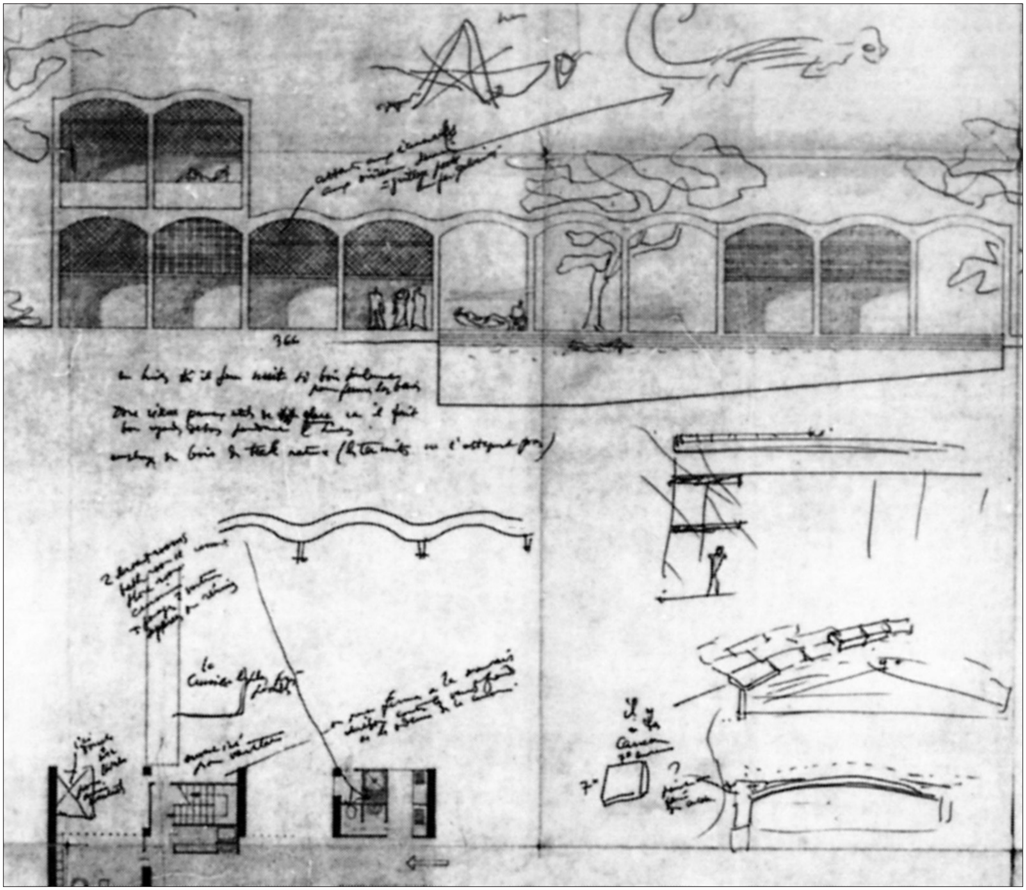

Figure 1
Sarabhai's villa and its roofing at Chandigarh 1957, Le Corbusier.

Complexity and Collaborative Architectural Design

Projects of Architecture, from the outset a collective work, for reasons of new environmental, energy and productive challenges, consist on the one hand of a strong specialization directed towards the analysis of increasingly complex problems and, on the other, a profoundly interdisciplinary approach to ensure an effective design synthesis.
The problems that have to be addressed today are, in a word, linked to the „complexity" of the phenomena. In these cases it is extremely reductive to use nineteenth-twentieth century paradigms that are limited to breaking down the phenomenon into smaller parts and more limited in time: reductionism, superimposition of effects and consequentiality.
Indeed, for the first of these, as indicated by Simon (1996 pp. 197-200, 206-207), several aspects of the phenomenon that in the first instance are considered negligible and thus to have little effect on it, the „weak forces", over a longer period of time are

those that are decisive for the development of the phenomenon itself. Furthermore, when the scientific disciplines are considered separately the results may prove unsatisfactory.

Also as far as the law of superimposition of effects is concerned, or in general for all the phenomena described through first order functions, in which the outcome depends solely on the initial state and not also on the modifications of the initial state due to the quantities involved, it has been largely replaced by both „Second Order Theory“ and „Catastrophe Theory“ (Woodcock and Davids, 1978). Here it is seen that small variations in given contexts can give rise to large modifications in the observed phenomenon.

Lastly, as far as consequentiality is concerned, crisis resulted from Systems Theory through the observation of the feedback from the phenomena and the fact that the result of a project is the unrepeatable result of its specific history.

In order to avoid a rigorously sequential design process following a reductionist approach leading to unsatisfactory outcomes[1] the Collaborative Design paradigm was proposed in which all the actors[2] are involved from the outset in every Design Process phase: from the Planning phase to the Feasibility Study, from the Preliminary phase to that of Recovery and Demolition.

Not only, but at each phase, for example, that of the Preliminary Design phase which is both procedural, regulatory and bureaucratic, from the outset not only large-scale problems are copresent, as is commonly believed, but also small scale problems. It may happen, indeed, that the actor-architect in architectural design, already in the early phases, introduces a certain type of roofing which becomes a key element to which the entire project will conform, fig.1.

Collaborative Computer Aided Architectural Design

We believe that the correct method for solving the above problems lies in the discussion and sharing at the right time of the specific knowledge possessed by each actor in the design process.

This may come about either conventionally, among the actors, or through the intervention of IAs.

In the first case, for the dialogue and communication of knowledge among actors, consolidated tools are available, which include the telephone, e-mail, videoconferencing, web meetings. All these tools refer to „tacit“ [3] (Drakos and Knox, 2004), or non self-explicit knowledge. The latter requires either the synchronous presence of the author of the document or the association of detailed explanations with the document itself.

Indeed in both these modalities, in order to render their otherwise „tacit“ knowledge „explicit“, direct interpersonal relations are necessary as well as the history of previous documents in order to make the documents „meaningful“.

In the second case, the exchange of knowledge takes place through the IAs. Knowledge may be „explicit“ (or self-explanatory). One requirement is that it can also be asynchronous and not demand the presence of the actor that defined it and then shared it with the other actors. This second type of shared knowledge is the one that will be pursued through the Collaborative Design paradigm.

In it the actors – who are experts in their many separate disciplines – helped by expert systems (the IAs) – collaborate among themselves by sharing their knowledge and experience, retaining their intellectual property and maintaining their own MetaKnowledge confidential (Carrara et al., 2004).

While it is actually hard to envisage architectural design nowadays without the aid of CAD tools, as well as for specific applications, these tools are useful and productive owing to their capacity to afford information exchange among all the actors (at least at the lower level – simple data), but with practically no exchange of knowledge.

These problems, together with those linked to delocation and competition among the choices made by the actors, concurrent from a conceptual and procedural, and not necessarily temporal, point of view, in the design process, are the salient aspects of the paradigm of Collaborative Computer Aided Architectural Design, ColCAAD. This is intended to set up expertise among actors leading to integrated design from the outset by means of potentialities of ICT systems and exploring new possibilities of Cognitive science.

This paradigm is of great interest to the international scientific community, as is shown by the works of Eastman et al., 1997, Kvan, 2000, Kolarevi, 2000, etc.

The research is based on experience acquired in several researches (Carrara and Fioravanti, 2002; Gero and Reffat, 2001; Kalay, 2001; Reffat and Gero 2000, Rosenman and Gero, 1996).

Knowledge engineering and ColCAAD

The knowledge gap in the network of relations involving all the actors participating in the design process, often representing profoundly different disciplines, gives rise to incoherences between values and/or behaviours of the objects (in the wide sense, agents also) and often leads to conflicts among operators.

In order to ensure a systematic approach to these problems, it is necessary:

- both to increase (and formalize) knowledge in one's specific field;
- to point out and manage incoherence:
- to facilitate the exchange of diverse knowledge among the actors.

These three factors have a strong influence on the design process.

The first is still performed in a rough and ready fashion between the actor and his Knowledge Base. Indeed at the present state of research, there are still no sufficiently effective software algorithms to ensure „knowledge acquisition“ from free-text or XML formatted documents, either as files or over the Internet. One other problem in this field, but subsequent to the former, is that of „knowledge acquisition“ aimed at a particular „actor“; this is the field of Aspect Oriented Programming (AOP). This is a frontier topic that is still not sufficiently mature, which we start investigating for its possible application in our system.

The second factor, the identification and management of incoherence, refers both to the constitution of the object-agents and to the mechanisms for identifying it among the IAs and distributed Knowledge Bases (Carrara and Fioravanti, 2003).

The third factor involves two main problems: from an IT point of view, how to exchange knowledge among different IAs, and assigning a semantics to the object-agents treated by Carrara et al. (2004), and from a logical point of view, what information must be exchanged and with whom. The latter problem is the subject of the present article.

ColCAAD, actors and knowledge

Acting on these three factors reduces the gap between the large quantity of available knowledge and that is needed to operate properly. Nevertheless it is necessary for exchanged knowledge not to be plethoric, and that it should not be addressed to actors extraneous to specific problems in a given phase of the design process, which could lead to knowledge-spamming.

In order to illustrate the above claims it is necessary to give a very brief outline of the systemic framework in which the article represents the progress that has been made in research over a large number of years.

We propose a MetaSystem for Collaborative design, an environment in which various expert systems are present, the IAs, at various conceptual levels with different models, structures, conceptual representations and coding forms; they may be interfaced using the 'Esperanto language' XML at different levels of knowledge complexity (Carrara and Fioravanti, 2004).

In the MetaSystem it is defined a set of specific distributed Intelligent Assistants (IAs), of different kinds, specific and personalized by the various actors, which aid the design work. The IAs are constituted not only by KBs in the strict sense (the knowledge of the building components) but also by objectives, design constraints, procedures, and inference engines. The MetaSystem models the design process as a sequence of operations performed on the project by the various actors, separating a „Private“ Design Workspace (PDW) for which the actor is competent, from the „Shared“ one (SDW), on which several actors can act simultaneously (Carrara and Fioravanti, 2002).

This is made possible:

- by the System's capacity to allow the constraints to be removed by both the actor both in the PDW, and in the SDW during the Test phase, and in the SDW during the publication phase, so as in any case to be able to proceed with instantiation;
- by the composition of the IT objects that allow a high degree of polymorphism and a conceptual structure potentially open to infinite nesting, with the possibility of modifying their characteristics at will.

The objects constituting them are actual agents capable of interacting with the design context or Condicio , as it will be explained later.

The efficacy of this approach is expressed in the capacity to identify and manage incomplete information and the contradictory choices made by the various actors.

The present paper clarifies the latter aspect, identifying:

- the actors involved in a given design choice;
- the relations that exist among them;
- the pinpointing of those whose design choices give rise to conflict.

More precisely, after framing the field of interest, ColCAAD, the model for representing the building components will be shown, together with the relations among them and the design phases, between them and the actors, and between them and the outside world.

Subsequently conflicts due to unsatisfied requirements and needs will be analyzed.

The Condicio and the Audience

Each building object, process procedure or building project will be defined logically in terms of IT objects, each of which represented by characteristics - procedural attachments – having inheritance, etc. (Carrara et al., 2001; Carrara and Fioravanti, 2001).

It should be noted that all the characteristics of the object are not necessarily present in a single IA, but are usually present in many IAs.

Each object is influenced by Condicio of the design project. It depends on three factors: the status of the project instances, the status of the temporal instances, the status of the actors' instances. It is a superset of what Gero (2001) calls “situation”: the set of project instances and time.

Each agent-object is defined by many characteristics, including the one that refers to the actors involved: the Dominus, the one who in that particular instant has full control over the object; the Owner, who is the author of the Prototype; the other actors (Carrara and Fioravanti, 2002).

When a project is to be instantiated it may progressively be found that of the constraints that have been activated some may be unsatisfied. Concerning the latter a distinction must be made between those referring to the PDW, the resolution of which depends on the ability of the corresponding actor and those regarding the SDW. The latter case is the one typical of ColCAAD in which, except for the common case in which the values set by the various actors are found to be different in the respective PDWs, incoherent constraints may be produced. The matter may lead to design conflicts among actors with a consequent increase in the time required by the design and in the cost thereof.

When the MetaSystem fails to instantiate an IT object in the SDW it causes incoherence in several constraints among different PDWs, it runs a control procedure that find out the pervasiveness of the incoherence.

In the first place, as the IT object is a multiple object[4] of an equal number of IAs, the procedure identifies in which one of these it or one of its characteristics is present. It should be borne in mind that in our MetaSystem, with respect to an IT object, a constraint (characteristic) may be either included as a characteristic present in the object itself, or else in a parent object, or in an IT object in its own right that is nested in the first one. By so doing the actors that are in no way related to the object in question are excluded.

In the second place this procedure identifies which constraints of the IT object are not respected in the SDW. This means that the instance of an IT object has a certain value in the SDW that does not satisfy one or more constraints in one or more PDWs as a result of difformity among the IAs (that is, they may refer to procedures, components, verify methods, tolerances, etc.).

To give a concrete example, let us assume the IT prototype object is a „Type 1 ventilated external wall". In it there may be a (characteristic) constraint present in the object itself, e.g. the thickness of the plaster on the internal side; or a (characteristic) constraint present in the parent prototype object – the thickness of the cavity in the more general „ventilated external wall" prototype object, or else a (characteristic) constraint that is itself another object that is a function of several other prototype objects, e.g. a constraint on the internal surface that has different methods of calculation according to the actor, the design phase and the country in which the building is constructed.

In the third place, in the IAs involved that it has identified as incoherent, the procedure examines the actors that define the IT object, their field of responsibility, the range of applicability, the status of the design process and its phase (preliminary, detailed, constructive). In this way, the control procedure identifies the actors involved in the union set of the IAs (i.e. Common IA and the various Specialist IA) in the light of the Condicio object.

Lastly, for each of its objects, the procedure defines a correspondence Matrix to point all the actors involved that are critical to constraint satisfaction, the relations among them, the authority over the IT objects – building components on which they act.

This Matrix is constructed by placing the requirements of an IT object on the X axis, and the actors on the Y axis, and correlating their relations. Normally the subset of conflicting actors is a smaller

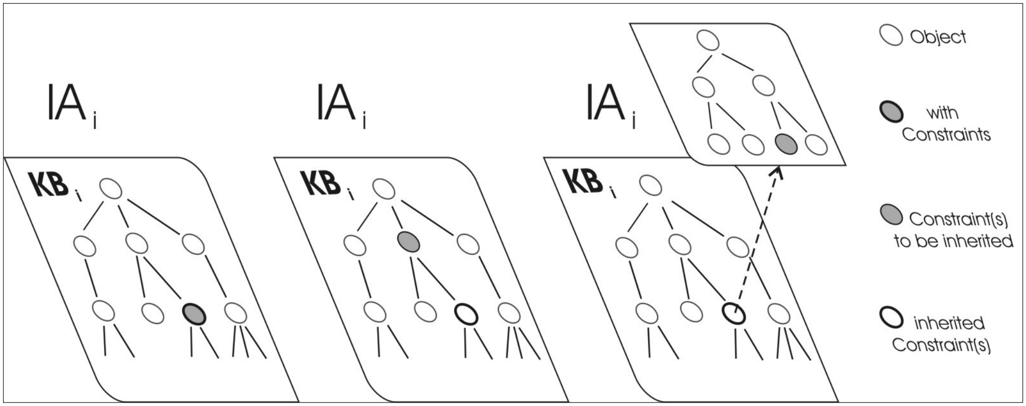

Figure 2.
The constraint and the structure of the object-prototype.

fraction of those involved at that stage, who in turn are fewer in numbers than all the actors participating in the design process.
This matrix resembles a sparse matrix which should be normalized. Once it has been normalized, the principal diagonal corresponds to the more deeply involved subjects, the set of which we define as Audience. The Audience is the set of actors involved in a decision process for a given object (prototype or instance), at a given time of design process.
At each instant, the actors that are part of the Audience can request explanations by querying the KBs through their own IA. Queries are made through the 'test' phase, that is, by proposing alternative design choices and activating the SDW constraints. In this way the MetaSystem transmits concise explanations of the ascertained constraints to the actor who made the alternative design choice and his knowledge is increased by being combined with concepts from disciplines with which he has little familiarity.
The case is different when the intention is to involve the other actors in one's own alternative design choice. In this case the actor proceeds to the phase of 'publication' in the SDW of his own alternative design choice; the new values of the object-instance characteristics are included in the SDW and are viewed from this by the various PDWs.
At this stage, unlike in the „test“ phase, the changes made, the notions associated with them and the list of actors in the Audience is sent to the Audience itself. It is proposed to send the modifications in the values and the associated knowledge to the entire Audience during the „publication“ phase; the modifications to the project can also affect aspects that the actor making the modification cannot predict. This is due to the symmetry of ignorance which is one of the basic premises of Collaborative Design.
On the other hand, in the case in which some activated constraints - referring to requirements that ought to be satisfied in a project instance under a given Condicio - have not satisfied as they are incoherent, the MetaSystem will have a different behaviour. Except for the distinction made between the "test" phase and that of "publication" which correspond to the fact that the knowledge is sent only to the actor who has made the modification or to the whole Audience, respectively, the concept of restricted Audience is introduced. This consists only of domini, owners, actors of the constraints that have not been respected. The notices sent by the MetaSystem are more detailed and refer to the list of unsatisfied constraints, their explanations, the procedures and the rules of the unsatisfied constraints, the list of actors that are part of the restricted Audience.
The larger the restricted Audience, the more invasive the design choice vis-à-vis the project, which is an indication of the importance of the correspond-

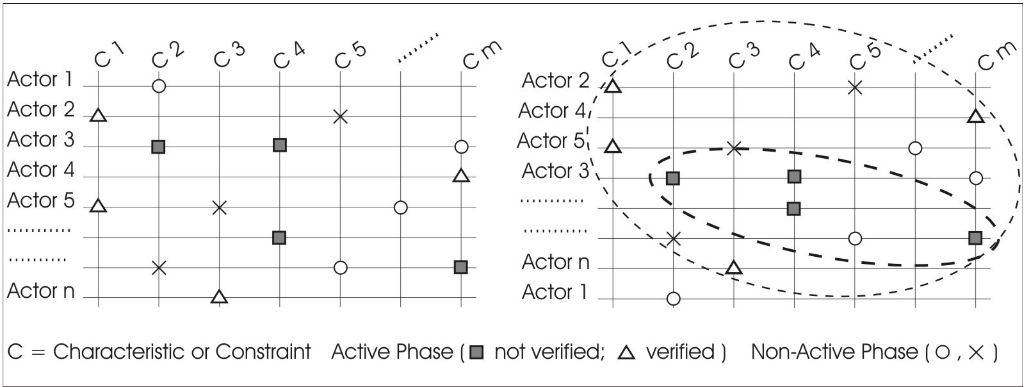

Figure 3
The Constraints and the actors - Audience and Restricted Audience matrixes.

ing characteristic, and is the same as assigning a different priority to several choices of the design process.

Conclusion

In present-day architectural design, but not only here, one of the difficulties encountered is on the one hand lack of information and of the knowledge required to make correct choices; on the other its excess, which can lead in practice to the un-decidibility of the design choices. Through the identification of the concepts of Audience and of restricted Audience we believe we have contributed to improving exchanges among actors of the knowledge required for greater awareness in design.

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Footnotes

[1] One large scale example is the construction of the great Assuan dam in Egypt. It increased the that country's electricity production, increased the area under irrigation but reduced the fertility and changed the ecosystem of the northern zones. Or else the Kansai airport, where the subsidence of the soil of the artificial island took place more rapidly than planned owing to a modest increase in the number of landings and take-offs, or the „popular success" (about 6 times greater than expected) of Beaubourg which caused the rapid wear of this facility.

[2] In the broad sense, the actors may be Architects, Civil Engineers, security managers, project directors, ecologists, clients, State Agencies, constructors (Wix, 1997).

[3] From Drakos and Knox: „E-mail has become the default application for knowledge exchange among employees. This can be inefficient and risky, so a variety of approaches must be considered.

An enterprise's competitiveness depends partly on how well its employees share tacit knowledge, but this can be difficult in a dispersed workforce. Tacit knowledge consists of people's experiences, expertise and personal best practices. Many enterprises use e-mail as the primary mechanism for making tacit knowledge explicit.

E-mail has its limitations, however, including the difficulty of reusing information, awkwardness when communicating with people outside a narrow circle of co-workers, and the large number of messages that people receive, which can obscure useful knowledge. Thus, enterprises will lose valuable intellectual capital if they rely solely on e-mail to share tacit knowledge".

[4] See definition of multiple object as an instance of the same object in different PDWs (Carrara and Fioravanti, 2002; Fioravanti, 2002)).