International Journal of Design Sciences & Technology

Volume 18 Number 1

ISSN 1630 - 7267

Caroline Lecourtois (2011). Architecturo-logical and epistemo-logical research on collaborative design, International Journal of Design Sciences and Technology, 18:1, 31-45

Europia Productions

ISSN 1630 - 7267

15, avenue de Ségur,
75007 Paris, France.
Tel (Fr) 01 45 51 26 07 - (Int.) +33 1 45 51 26 07
Fax (Fr) 01 45 51 26 32- (Int.) +33 1 45 51 26 32
E-mail: ijdst@europia.org
http://www.europia.org/ijdst

Architecturological and epistemological research on collaborative design

Caroline Lecourtois*

* Ecole Nationale Supérieure d'Architecture de Paris-la-Villette, PARIS, France. Email: caroline.lecourtois@ariam-larea.archi.fr

This paper presents an architecturological and epistemological research on collaborative design as well as scientific methodologies comparing the viewpoints of Cognitive Ergonomics and Architecturology on collaborative design. Architecturological research endeavours describing the cognitive activity of design through applied methodologies confronting an a priori scientific language with empirical cases. Cognitive Ergonomics builds knowledge from experimentations by observing the reality from which concepts are constituted.

In a French research called CoCrea (Creative Collaboration) and financed by ANR (French National agency of Research), the two scientific fields are confronted to better know the complex mechanisms of collaboration in architectural design made with a digital collaborative space.

Keywords: architectural conception, collaborative design, applied architecturology, epistemology

1 Introduction

This paper presents an architecturological and epistemological research on collaboration in architectural design. It compares Cognitive Ergonomics and Applied Architecturology as two scientific methodologies studying architectural design.

These two scientific fields meet together to describe and clarify the cognitive mechanisms of architectural collaborative design, in a French research called CoCrea, financed by the French Agency of National Research (ANR).[1] From questioning contemporary architectural habits and practices relatively to sharing tools, CoCrea aims to explain in the presence or remote creative collaboration in architecture. It implies three different research paradigms and three different laboratories: Cognitive Ergonomics developed at LIMSI-CNRS, Applied Architecturology developed at ARIAM-LAREA and knowledge engineering and design developed at LUCID-ULg.

From precedent researches on collaboration showing the need of support for remote working meetings, a Distributed Collaborative Digital Studio (DCDS) has been created by the team of LUCID-ULg.[2] This DCDS is an IT support that recreates at distant, the situation of in the presence meeting works. It has been used in CoCrea to experiment different situations of collaboration, in the presence and at distant, and to observe architectural productions made by two hands. The experimentations constitute the raw material of Cognitive Ergonomics and Architecturology to approach architectural collaborative design. The respective analysis methods of these two viewpoints permit to explain the specificity of each and to build epistemological knowledge on design sciences.

The first part of this paper presents the CoCrea research and the experimenta-

1 CoCrea is an acronym for COllaborative CREAtion, project # ANR-08-CREA-030-02

2 Safin, S. & **Leclercq, P.** (2009). Studio Digital Collaboratif : un environnement de conception collaborative à distance, IHM09 [ihm09.imag.fr/actes_informels/Informels/06/Safin.pdf]

tions made with DCDS and, introduces the explanation of the two scientific fields they implicate: Cognitive Ergonomics and Architecturology (part two). The third part focuses on methodologies of architecturological researches and opens on the architecturological results of CoCrea (part four) discussed in part five. In conclusion, the paper explains the limits and potentials of such architecturological research on design education and IT development.

2 CoCrea and experimentations with DCDS

CoCrea (COllaborative CREAtion) is a multidisciplinary research approaching collaboration in the early stages of architectural design.[3] Approaching collaboration in the early stages of architectural design has been possible thanks to a new digital tool specifically designed by Lucid-ULg to assist collaborators at these stages, the DCDS, Distributed Collaborative Digital Studio.

DCDS is an original new IT environment that aims to permit to synchronously interact at distant as if collaborators were side by side to work. The development of this tool is based on a design theory which states that to assist designers, IT support must to be not constraining. In other words, the computer-aided design could exist if computer disappeared from users' consciousness. From this design theory and the main role of freehand sketching in creativity, DCDS was thought as a freehand sketch-based tabletop environment allowing to design at two or more. Its main goal is to facilitate the sharing and the exchange in real-time.

It's a multimodal IT environment that facilitates the communication at distant by sketching or writing, the view and the voice. It's composed of a large digital drawing tablet associated with software of synchronous sharing documents and, of a system of video-conference. It allows to exchange and to communicate remotely and synchronously by speech, gesture and freehand sketch.

The synchronous graphical communication is permitted by the software SketSha that allows to import digital documents and to share in real time the annotations of each designer.[4] Figure 1 presents the DCDS used in collaboration at distant by two architects. Each architect has the same device and can see his partner through the screen of the computer. On their tabletop they have the same document that they can annotate and on which they see appear on real-time the annotations of the other. The video-conference system permits also to ear the partner. The freehand sketch-based tabletop seems to allow assisting the creativity at several in the early stages of design.

Figure 1 Distributed Collaborative Digital Studio (Cocrea / ARIAM-LARE-A)

3 Mayeur, A. et al (2010). Concevoir à plusieurs et à distance en architecture : vers de nouvelles pratiques professionnelles ? In: Actes du Séminaire Globalisation et Territorialisation: questions de travail, Université Paris 1 Sorbonne, Paris

4 Kubicki, S. et al (2008). Digital Cooperative Studio, ICE 2008, 14th International Conference on Concurrent Enterprising, Special session ICT-supported Cooperative Design in Education, Lisboa

The DCDS is the exclusive IT environment used in Cocrea. It has been used to realise different kinds of experimentation focusing on architectural collaborative design and creativity. In other words, CoCrea studies collaborative creativity as cognitive activities of freehand sketching and more specifically the ones done in the early stages of design of one architectural project.

These kinds of experimentation present themselves as three complementary methods to collect data on architectural collaborative design and, also, as three different ways to use the DCDS. These three methods are called *in situ* observations, longitudinal observations and experimentations in laboratory.

In situ observations consist in installing two DCDS in remote locations of an architectural agency for observing at distant design meetings made with them. Longitudinal observations consist in observing the customary use of DCDS during the design process of a specific project. In this case, the same architects of an agency use DCDS of the laboratories implicated in CoCrea, when they need. At last, experimentations in laboratory consist in inviting pairs of architects that are accustomed to work together, to experiment DCDS on short exercises of conception. In this case, each pair has done a shot exercise of design at distant and another one in the presence. The two exercises were the same for each pair, a rural school and a hotel, and were clearly defined by a specific program already tested in precedent researches.

front their DCDS. The picture below each shows their tabletop and what they can see on it. When one of them draws, the second sees the stroke appear on his tabletop. They can also sketch together, at the same time, on the same document.

Figure 2 extract from video record of an experiment with SDC support (Cocrea / ARIAM-LAREA)

Figure 2 presents a screen capture of the quadri-film recorded from one of the experimentations in laboratory. The two top pictures show the pair architects in

CoCrea gathers ergonomists-cogniticians, architecturologists and IT engineers to question architectural collaborative design differently than the habits of each scientific field. Comparing our methodologies and others experimentations related in the book "Accolade. Architecture, collaboration design"[5] for example, CoCrea corresponds with:

- the theme 8: "User interfaces and modes of operation and communication should be as natural and effective as possible" and its task 8: "Design a human-computer interface for the early phase of design",
- the theme 14: "Applicability Collaboration factors -- Hardware -- Social" – and its task 14: " Testing and evaluating of different media configurations for a successful social interaction in collaborative design".[6]

In other words, the main hypothesis of Cocrea is to think that computer environment is became intermingled with daily life, "with our way of doing and thinking"[7] and investigates its effects on architectural design. Furthermore, from the goals of DCDS explained above, CoCrea tests the "invisibility" of DCDS – not be constraining, disappearing from consciousness - in situations of collaborative design and tries to point some of its aided collaborative design functionalities.

More precisely, CoCrea asks two main cognitive objects: collaboration and designing. Concerning collaboration, the questions are to know: - how architects collaborate at distant and in the presence meetings for designing, - how the DCDS helps to collaborate or implies manners to collaborate in design, - the time collaboration at distant or in the presence relatively to the synchrony of trade, ie the time (real or not) of reaction of collaborators. Concerning designing, the questions are to know: - if collaboration in design exists, - how approaching the share of designing, - how architects share their cognitive activities of designing.

In other words, the issues raised in CoCrea are in relationship with those of Achten, David, Kvan, Gero and others, concerning the explanation of design activity, exchange mechanisms and digital support tools.[8 to 11]

Practically, these questions have been raised and studied through the three methods of use of DCDS or of collecting data: *in situ* observations, longitudinal observations and experimentations in laboratory. Each of them has been recorded and was analyzed through the viewpoints of Cognitive Ergonomics and Architecturology. The subpart below explains the specificity of each of these scientific fields: Cognitive Ergonomics and Architecturology.

3 Cognitive ergonomics and architecturology

Cognitive Ergonomics is a subfield of Ergonomics which studies the relationships between products or situations of work and, mental activities like perception, representation, reasoning, memorising, the language, decision, designing … The goals of such a subfield of Ergonomics is to enlighten the influences of new products or of situations of work on mental activities in order to orientate their adaptation. They are also to describe the mechanisms of the mental activities in order to take awareness of them in the development of new products or of new situations of work. In other words, Cognitive Ergonomics studies the situations

5 Stellingwerff, M. & **Verbeke, J.** eds (2001). Accolade. Architecture. Collaboration. Design, Delft University Press
6 op cit pp 19-20
7 op cit pp 27
8 Achten, H.H. (2002). Requirements for Collaborative Design in Architecture. In: Timmermans, H. ed, Sixth Design and Decision Support Systems in Architecture and Urban Planning - Part one: Architecture Proceedings Avegoor, Netherlands
9 David, B. (2001). IHM pour les collecticiels, In Réseaux et Systèmes Répartis, Hermès, 13, pp 169-206
10 Kvan, T. (2000). Collaborative design: What is it ? Automation in construction, 9, pp 409-415
11 Gero, J.S. ed (2010) Studying Design Creativity, Springer

of work, the uses of products and the mental activities in order to explain the relationships of them and the influences each other.

The human-computer interaction is became one of the most studying subject of Cognitive Ergonomics. The research work of the ergonomists-cogniticians implicated in CoCrea aims to model the cognitive activities implemented in design process, to enlighten the use of IT devices and, to specify the ways in which they assist these cognitive activities.

The Cognitive Ergonomics approach of CoCrea aims at first to clarify impacts of the use of DCDS on mechanisms of exchange in architectural collaborative design. It is secondly to evaluate the functionalities of DCDS and its handling as a necessary condition for it to be an aided collaboration computer in design. In other words, the Cognitive Ergonomics approach permits more to answer the questions concerning collaboration than those concerning designing. Its results help to make a list of new specifications to orientate the future development of DCDS and its improvements.

Furthermore, CoCrea offers to ergonomist-cognitician mean to question the difference between collaboration in the presence and remote collaboration in design. It's the reason of our double experimentations in laboratory. The hypothesis of the ergonomist-cognitician is that it's possible to describe the consequences of the distance on the project designed by comparing the mechanism of collaboration in these two situations of collaborative design. For them, collaborative design in the presence is a referential situation they are already able to explain. In CoCrea, they have mainly studied collaboration at distant from their knowledge about collaboration in the presence and the new observations realised in the presence with the DCDS. So collaboration in the presence with DCDS was a referential situation to approach the collaboration at distant with DCDS.

Practically, their analyses were orientated to understand the activities of building a common needed referential for sharing work. Their scientific paradigm is thinking collaboration as multimodal interactions implemented for co-production. The multimodal interactions are combinations of looks, gestures, words and sketches. So, the ergonomist-cognitician have analysed each modality of communication of the CoCrea's data in order to describe the ways that collaboration was implemented in the design of a sketch i.e. the project.

To describe the specificities of remote collaborative design from the situation of collaborative design in presence, they have analysed the experimentations in terms of social, economics and cognitive performances.[12] They have counted time and occurrences of:

- looks at the collaborator
- sketching or writing
- not sketching or writing
- kinds of gesture (deictic-kinetic, deictic-graphic, scansion, kinemimic, pictomimic, quasi-linguistic, and so on)
- words about problems solving and/or external resources

The results of the Cognitive Ergonomics studies enlighten the ways that interactions are conducted in terms of percentages of type of interaction (looks, writing, kinds of gesture and kinds of words) and difference of percentages in-between the referential situation and remote collaborative design.[13]

Architecturology is a relatively recent French scientific field initiated by Boudon

12 Mayeur A. et al (2011a). Expérimentations en coprésence et à distance, Situations de production architecturale collaborative outillée en co-présence vs. à distance, Lot 3.1 / Livrable T24, Projet ANR Cocrea

13 ibid

in the 70's and coming from Architecture.[14] It has been created to build specific knowledge on architecture that academic's sciences as psychology, sociology, linguistic, history, geography and, so on, are not able to get up. In other words, Architecturology has been developed from an epistemological study about academic sciences, in order to build new means to approach architecture and, to constitute theoretical architectural knowledge understandable by them.

From the question knowing how the designer gives measurements to his object or project, Architecturology examines cognitive activities implicated in what it calls Conception in contrast with design. Its scientific paradigm is specific and constructed from own scientific developments radically in opposition with those of Cognitive Ergonomics.

While Cognitive Ergonomics can be considered as an empirical science, Architecturology is originally a formal science. Unlike the formal sciences, the empirical sciences maintain close relationships with sensory experiences.[15] In other words, Cognitive Ergonomics is built on observations of realities and from empirical or clinical cases analyzed with variables inspired by these realities.

As a formal science, Architecturology abstracts itself from matter or content to focus on the form i.e. the form of knowledge it constitutes on a scientific object. Architecturology ignores the project or the architecture produced by design but is interested in describing the mechanisms of awarding measurements to a designed object. Independently of material realities or of sensible experimentations, it aims to explain the reasoning of what it conceptualizes with the term conception: cognitive activities of awarding measurements to a designed object regardless the designed object. It has then constituted a scientific language with concepts representing ideal cognitive mechanisms of design (an *a priori* scientific language system), never observed like that in realities.

As a formal science, Architecturology has based its scientific paradigm on the Bachelard's "epistemological break" and the Canguilhem's distinction of "natural object" and "scientific object".[16] [17] It has distinguished its "scientific object" from Architecture taken as a "natural object". This "scientific object" takes the form of a question which is: how the conceiver gives measurements to his designed object? by posing that it's possible to differentiate the cognitive activity of design from the design in its whole.[18] Calling this cognitive activity of design, conception and, posing it as its "scientific object", Architecturology has built concepts for enlightening it. Nowadays, these scientific concepts form a scientific language system, independent of specific architectural realities and, allowing speaking of conception, in general, in terms of operations of conception implemented for attributing measurements to a non-yet-existing object. In other words, the architecturological scientific language system is a knowledge model of conception, a representative idealized and open frame, which can be used as a scheme to question realities and to build new knowledge to adjust it or, to understand object from the viewpoint of conception.

So, Architecturology offers a particular point of view and its own reading grid to consider phenomena by focusing on its scientific object. One of the main phenomena developed in architectural design is the producing of sketches, drawings and models of the non-yet-existing object i.e. the object in conception. These phenomena of sketching, drawing and modelling into conception have been studied by Boudon and his research's team at the Laboratory of Architecturology and

14 Boudon, Ph. (1971). Sur l'espace architectural, Essai d'épistémologie de l'architecture, Dunod

15 Soler, L. (2000). Introduction à l'épistémologie, Ellipses

16 Bachelard, G. (1934-2000). La formation de l'esprit scientifique, Vrin

17 Canguilhem, G. (1975). Etudes d'histoire et de philosophie des sciences, Vrin

18 Boudon, Ph. (2004). Conception, éditions de la villette

Epistemological Research on Architecture (LAREA).[19] [20] [21] It has also been studied by the ergonomist-cognitician implicated in CoCrea.[22] The sharing of this studying object and the specific complementary knowledge built by ergonomists-cogniticians on one hand and, architecturologists on the other hand, led us to come together in CoCrea.

CoCrea is an empirical research and not a formal one. It is naturally suitable to apply Cognitive Ergonomics but not Architecturology in its original state. It's the reason why CoCrea is not a real Architecturological research but is an Applied Architecturological research. Applied Architecturology is a branch of architecturology which has been developed from the *a priori* scientific language system built by Architecturology to explore specific architectural design through conception. It is empirical methodologies using the architecturological concepts as schematic representations of mechanisms of conception and, as analysis tools for approaching real cases.

4 Methods of Applied Architecturology

The principle of Applied Architecturology is to confront the theoretical Architecturological model of knowledge to empirical realities. This principle proceeds from a scientific method aiming to validate or not theoretical propositions which constitute a formal science. The theoretical propositions are, in this case, all the architecturological concepts created as what E. Kant calls empty concepts and that take values by experiences.[23] The scientific methodology implemented in Applied Architecturology is recognized by epistemologists. It is called the probation and consists in testing *a priori* concepts on realities. That's using the formal language system as a reading grid to interpret realities.

Consequently, Applied Architecturology is a branch of Architecturology that takes the form of an interpretive science. Interpreting, in opposition with explaining, consists in general in deciphering and giving meaning to something by posing that the deciphering or the meaning is different from the something itself. An interpretive science gives tools to interpret realities through its scientific object that is to say, to build on them, focused knowledge.

So Applied Architecturology consists in testing *a priori* architecturological concepts on realities to build interpretive knowledge on their conception. The ways of testing, i.e. of confrontation between architecturological concepts and realities, can be diverse and, depend on the representations of the explored empirical cases and on the aims of the interpretations.

The representations of the explored empirical cases can be composed with verbal descriptions, press papers, physical or virtual models, sketches or different kinds of texts (critical, historical, technical, theoretical, etc.).

The aims of the interpretations are in general to describe the conceived part of an object. This object is what varies. It can be conception itself,[24] perception,[25] architectural style,[26] Computer aided conception,[27] collaborative conception,[28] and so on.

Applied Architecturology regroups therefore different methods that permit to enlighten conception, perception, architectural style, computer aids and collaboration as conceived objects or mental mechanisms describable in terms of operations of conception. It gives tools to analyze and interpret cases from the reading grid composed with the architecturological language system. Practically, it con-

19 Boudon, Ph. & **Decq, O.** (1976). Figuration graphique en architecture. Fascicule 3b: Architecturologie des sigles, AREA, COPEDITH

20 Lecourtois, C. (2005). Architecturologie appliquée à une sémiotique de l'esquisse architecturale, in Actes du Colloque SCAN05, Rôle de l'esquisse architecturale dans le monde numérique, Paris

21 Lecourtois, C. & **Guéna, F.** (2009). Eco-conception et Esquisse assistée, Conception architecturale numérique et approches environnementales, in Actes de SCAN09, PU Nancy

22 Elsen, C. et al (2010). Evolution des pratiques en conception: une approche ergonomique compréhensive des objets médiateurs, in Conférence Ergo'IA 2010, Innovations, Interactions, Qualité de vie

23 Kant, E. (1781-2006). Critique de la raison pure, Flammarion

24 Lecourtois, C. (2006). Conception de l'espace et espace de conception, in TIGR, Nouvelles approches de l'espace dans les sciences de l'homme et de la société, Institut de Géographie Reims

25 Lecourtois, C. (2007). Architectural qualities and local identity, in CSAAR 2007, Tunis

26 Delaveau, A.S. et al (2009). Digital as tool/ reference for architectural conception, Proceedings of the 27th eCAADe, Istanbul

27 Boissieu, A. de et al (2010). Modélisation paramétrique partagée, Le cas de l'utilisation de Digital Project lors de la conception du Pavillon de la Fondation Louis Vuit-

sists in postulating that all the representations of the explored cases are composed with "indicial signs" of operations of conception.
The term of "indicial signs" comes from Ch. S. Peirce and designates the kind of signs that having meanings depending to a precedent object. It's the case of footprints in the snow that designates that someone has gone.[29] Ch. S. Peirce distinguishes different kinds of signs from a triadic semiotic model that links three elements of the sign: object, representamen and interpretant (context). From the relationships between these three elements, he has built a typology of signs in which there are "indicial signs".
Consequently, Applied Architecturology is based on the Peirce's semiotics paradigm and consists in deciphering the representations of cases through the lens of architecturology, in order to interpret the cases in terms of operations of conception. In other words, it has built scientific methods of reading the underneath of the representations that can, for the ones, be called semiotics graphic and, for the others, semiology.[30] These methods have been imagined by Lecourtois and are currently used, in thesis works, to question and explain computer aided conception,[31] collaborative conception[32] and architectural digital conceived style,[33] through physical representations of project.
In fact, five methods of Applied Architecturology have already been built as architecturology semiotic and two others as pragmatic usage of architecturological knowledge.

4.1 The first method of Applied Architecturology

The first method of Applied Architecturology proceeds from the specific role of sketching in architectural conception. Sketching is, for designer, instrumentation by which physically conceiving architecture i.e. giving shapes and measurements to a project.[34 35 36] It is a manual and cognitive activity by which the operations of conception are involved into the project through its graphical representations.
Consequently, all sketches or graphical representations as also 3D models, designed during the design process of an object for conceiving it are, manifestations of the cognitive activity of conception. They can then all be observed as compositions of "indicial signs" of cognitive operations of conception.
The cognitive operations of conception that Applied Architecturology allows to interpret from the representations of the project consist in linking the new object with references to give it, by different ways, shapes and measurements. These references can be various and depend on the implicit spaces of reference of the conceiver. The cognitive operations of conception are set by Architecturology as five different ways to involve references into conception:
- referring the project or one element of it to a field of reference
- segmenting the project or one element of it (into elements to conceive)
- dimensioning the project or one element of it (by giving measures)
- orientating the project or one element of it
- positioning the project or one element of it

This method consists in reading the representations of the project through these operations of conception by using the principle of Architecturology called game between models and scales.
This principle consists in thinking the conception process as the transformation of an architectural model by the successive applications of cognitive operations

ton pour la Création (Gehry Partners) sous l'angle des opérations de découpage, Scan'10 Espaces collaboratifs, Marseille
28 Ben Rajeb, S. et al (2010). Operations of conception in Architectural Collaborative Design, In Proceedings eCAADe. Future cities
29 Peirce Ch.S. (1978). Écrits sur le signe, rassemblés traduits et commentés par G. Deledalle, Paris, Le Seuil (coll. L'ordre philosophique)
30 Lecourtois, C. (2005). ibid
31 Boissieu, A. de et al (2010). ibid
32 Ben Rajeb, S. et al (2010). ibid
33 Delaveau, A.S. et al (2009). ibid
34 Boudon, Ph. & **Decq, O.** (1976). ibid
35 Lebahar, J.C. (1983). Le dessin d'architecte, Parenthèses
36 Conan, M. (2000). Concevoir un projet d'architecture, L'Harmattan

of conception (called scales). Within this principle (or scientific modelling of conception process), each model used or produced by a conceiver (sketches, conventional graphical representations, texts of presentation, models and so on) is a mental representation of a precedent or, of a future objet in conception. This principle consists then in thinking that the transition from one model to another is due to the implementation of cognitive operations of conception.
Therefore, this method consists in comparing two consecutive sketches or models, to identify graphical or models entities readable as "indicial signs" of cognitive operations of conception.

4.2 The second method of Applied Architecturology

The second method of Applied Architecturology has been developed to enlighten architectural perception as an individual conceived cognitive activity.[37] From theories on perception of Reuchlin,[38] Austin,[39] Bouveresse,[40] Cléro[41] and using the words of Sansot,[42] architectural perception is thought as an activity aiming to "qualify the reality".[43] Consequently, users of architecture would build their architectural perception by expressing their opinion on it. The surveys realized to understand the mechanisms of architectural perception[44] show that users build their opinion on architecture relatively to their "horizon of expectation".[45] In other words, for building their opinion, they compare what they understand and feel about the conception of the architecture with what they would have done if they were architect and, they give values relatively to the correspondences of each other.
Studying architectural perception with Applied Architecturology consists therefore in describing operations of conception implemented by users for expressing their opinion on architecture. It is possible to do so by analysing verbal or textual expressions of perception as data for architecturology semiotic and scientific interpretation.

4.3 The third method of Applied Architecturology

The third method of Applied Architecturology has been produced for a thesis work on architectural style.[46] It consists in using the first method of Applied Architecturology (presented above) on doctrinal discourses and models of projects in order to enlighten the recurrent operations of conception. The method thesis tries to explicit the ways that conceivers develop own architectural styles, usually not perceptible. It suggests approaching architectural style through the concept of "act of style" built in opposition with the concept of "fact of style".[47]
Practically, it consists in reading, with the architecturological language system, contemporary projects and presentation texts of their architects in order to express the ways that architectural style is conceived and, how IT influences the conception of an architectural style.

4.4 The fourth method of Applied Architecturology

The fourth method is used to question IT support and computer aids in cognitive activity of conception.[48] It is currently used to question the possibility for architectural conception to be parametric i.e. to be instrumented by parametric modelling (IT specific method). To enlighten this question, two kinds of cognitive operation have been theoretically distinguished: cognitive operations of conception

37 Lecourtois, C. (2007). ibid
38 Reuchlin M. (1998), Psychologie, Puf
39 Austin, J.L. (1971). Le langage de la perception, Armand Colin
40 Bouveresse, J. (1995). Langage, perception et réalité, Jaqueline Chambon
41 Cléro, J.P. (2000). Théorie de la perception, de l'espace à l'émotion, PUF
42 Sansot, P. (1973). Poétique de la ville, Klincksieck
43 Lecourtois, C. (2007). ibid
44 ibid
45 Jauss, H.R. (1978). Toward an Aesthetic of Reception.: University of Minnesota, Minneapolis
46 Thesis of A.S. Delaveau, directed by F. Guéna and C. Lecourtois at ARIAM-LAREA
47 Delaveau, A.S. et al (2009). ibid
48 Thesis of A. de Boissieu, directed by F. Guéna and C. Lecourtois at ARIAM-LAREA

and, cognitive operations of modelling. The cognitive operations of conception are those presented above while cognitive operations of modelling are those that the thesis work must discover. The aim is to question this distinction between the cognitive activity of conception and the cognitive activity of modelling and to point the ways hat they are intermingled in design or the ways that they would be intermingled in design.

In other words, this fourth method aims to understand the ways that operations of modelling influence or can influence the cognitive activity of architectural conception.[49] It consists in applying the first method on the representations of a project and, on digital models realized for it. It is also to question the practices developed in agencies to understand the ways that architectural conception and digital modelling are led correlatively or independently.

4.5 The fifth method of Applied Architecturology

The fifth method of Applied Architecturology is pragmatic. It consists in using the scientific language of Architecturology for creating new software. The software imagined from Architecturology aims at assisting the architectural designer in the 3D modelling.

From the specific role, explained above, of freehand sketching in architectural conception, graphical software called ESQUAAS (Architecturologically assisted sketching) has been developed at ARIAM-LAREA. The development of this software is not finished yet but, its theoretical base is to offer an IT graphical platform not constraining and allowing sketching as usual with a pen on paper. The action of ESQUAAS will to interpret the running strokes with the scientific language system in order to construct a 3D model underneath the freehand sketch. The interaction between ESQUAAS and the designer will be limited to not disturb the creativity. ESQUAAS will therefore build quasi-independently the 3D model of the project.

This independency of ESQUAAS is possible due to its environment that works with a multi-agents system. This multi-agents system has been designed from a re-constitution of the architecturological language. The re-constitution consists in turning each architecturological concept into a determined context made with properties, operations of conception and, meanings of relations between strokes, in order to make it an interpreting tool able to understand what the designer is sketching.[50] [51]

4.6 The sixth method of Applied Architecturology

The sixth method of Applied Architecturology is also a pragmatic usage of architecturological language. It consists in participating in a process of design as expert of conception by providing a theoretical point of view on the project. This method has been experimented for designing a courthouse. From a published research about the symbolism of justice, a French architectural agency has commissioned me for participating to the design of a new courthouse.[52]

The role of Architecturology was to guide the work of design in order to organize the process around a theoretical development of the project. The architecturological knowledge about the courthouse has helped to develop an original architectural new concept of the courthouse architecture representing the French actual mechanisms of justice. All the process was organised around the develop-

49 Boissieu, A. de et al (2010). ibid

50 Guéna, F. & Lecourtois, C. [www.ariam-larea.archi.fr]

51 Lecourtois, C. & **Guéna, F.** (2009). ibid

52 Lecourtois, C. (2008). "Espace de conception" d'une architecture judiciaire: les nouveaux palais de justice, in Diagonale Φ n°4- n°5, Inscriptions spatiales – travaux de l'école doctorale, Université Jean Moulin, Lyon 2008-2009

ment of a theoretical architecturological text of presentation of the project.
The collaboration between the designers and the architecturologist has taken the form of weekly meetings. Between these meetings, designers were working on the project from the text presented in the precedent meeting and collaboratively worked during the meeting and, the architecturologist was working on the text to adapt it to the project presented in the precedent meeting and collaboratively worked during the meeting and, to develop new theoretical idea of the project.

4.7 The seventh method of Applied Architecturology

The seventh method of Applied Architecturology is the one created for CoCrea. It is one of the architecturology semiotic methods. It aims to question and describe collaborative conception in architecture. It has been used to analyse the CoCrea data: *in situ* observations, longitudinal observations and experimentations in laboratory.
On the postulate that architecture is a cooperative work, Applied Architecturology has helped to question the ways that conception is concerned by cooperation and a multiplicity of actors. CoCrea is the first research in which Architecturology investigates the nature of the architectural conceiver and the possibility for him to be multiple. The main question of Applied Architectuology in CoCrea is to know if architectural conception can be led by a multiple-author or a not individual conceiver.[53] [54]
In other words, the main question of Architecturology is to know if architectural conception with DCDS can be collaborative. To enlighten this question, Applied Architecturology has distinguished the two objects concerned by it: collaboration and collaborative conception.
Collaboration is considered as a conceived mechanism that can be enlightened in terms of operations of conception. To collaborate, conceivers need to share a concrete space and also abstract spaces of reference. DCDS offers the sharing concrete space and its theoretical base about collaborative work. Applied Architecturology has therefore been used to question the functionalities offered by it to assist collaboration. Practically, it has consisted in studying the operations of conception implemented in architectural conception by using determined functions of DCDS. Concerning the sharing abstract spaces of reference, the Applied Architecturological method used was the first one described above. Each representations of the project, produced during the observations and experimentations, i.e. sketches and verbal exchanges, have been read through the lens of Architecturology to interpret them in terms of shared spaces of reference and shared operations of conception. It has allowed enlightening collaboration and also the second object of Applied Architecturology in CoCrea, i.e. collaborative conception.
The question relatively to collaborative conception concerns the possibility for the cognitive activity of architectural conception to be collaborative or shared. The postulate of Applied Architecturology is, if collaborative conception in architecture exists then it is possible to find shared cognitive operations of conception. Therefore, the existence of the sharing of the cognitive activity of conception in architecture depends on the possibility of explaining the sharing of some operations of conception.
With the first method of Applied Architecturology, sketches made with two

53 Lecourtois, C. et al (2010). Interpretations Collaboratives: Usages et implications du Studio Digital Collaboratif en situation de conception architecturale, SCAN10
54 Ben Rajeb, S. et al (2010). ibid

hands and common spaces of reference discussed by the two conceivers have been identified. The shared operations of conception were identified from entities of sketches and entities of verbal exchanges worked together and supposing new architectural decisions.

5 Architecturological results of CoCrea

Consequently of the distinction of the two knowledge objects of Applied Architecturology in CoCrea –collaboration and collaborative conception -, two different kinds of operations of conception have been identified to explain collaborative conception in architecture:

- the ones explain collaboration as a conceived mechanism, i.e. operations to conceive collaboration called pragmatics operations of collaboration[55 56]
- the others explain collaborative conception in architecture and are called operations of collaborative conception or shared architectural operations of conception.

Concerning the pragmatics operations of collaboration, eight classes of operations have been detected from the experimentations in laboratory led at distant: prescription, interpretation, evaluation, segmentation, empowerment, pooling, referring and normalization.[57] Each of these classes of pragmatics operations of collaboration explains some mechanisms of the exchanges of the two distant conceivers. Two groups of them can be distinguished: The ones relate to actions implemented by one of the conceiver in response to the work of the other (prescription, interpretation and evaluation), the others are common actions done synchronously by the two conceivers (segmentation, empowerment, pooling, referring and normalization). In other words the ones describe cognitive operations made by a conceiver while the others describe the organisation of the collaboration. In fact, the ones are operations of the logical or formal operations that are not pragmatics but are inevitably implicated in the others.

Concerning the shared operations of conception, two levels have been distinguished. The level of the elementary operations of conception, i.e. the five described above – referring, segmenting, dimensioning, orientating, positioning – and the level of the classes of operations of conception, called architecturological scales. Twenty one architecturological scales have been explained by Architecturology as specific environments of designing – human scale, scale of model, geographical scale, technical scale, etc.-. Each of them designates a complexity between spaces of reference implemented in conception and one or much more elementary operations of conception.

Relatively to these two levels, Applied Architecturology in CoCrea shows that architecturological scales can be shared by the two conceivers. The sharing of architecturological scales constitutes in fact the sharing of a common referential and the sharing of the entities of project to work. Pooling and referring are the main pragmatics operations of collaboration implicated in the construction of this sharing. The pragmatics operation of segmentation can proceed from the sharing of one or several architecturological scales by choosing to separate the conception relatively to each of them and the competences of each conceiver.

Concerning the elementary operations of conception, their sharing depends on the medium implicated in their implementation in design. They can be shared when they are worked in the verbal exchanges. The idea of implementing an

55 ibid
56 **Lecourtois, C.** et al (2010). I
57 **Mayeur A.** et al (2011b). Résultats des analyses en ergonomie-cognitive et architecturologie des expérimentations en coprésence et à distance outillée, Lot 3.2 / Livrable T32, Projet ANR Cocrea
58 CoCrea, project # ANR-08-CREA-030-02

elementary operation of conception is then shared. The physical action of implementing the elementary operation of conception in design is more difficult to share. In spite of referring that remains an abstract operation of conception detached from any physical action of implementation, the others, segmenting, dimensioning, orientating and positioning, need to be inscribed in the physical representations of the project to be really effective. Generally, this inscription in physical representation is made by one of the conceiver and not by the two in the same time.

Even so, segmentation and dimensioning have, in two different cases, been done collaboratively, i.e. at two, synchronously. In one case, each conceiver has sketched his own graphical representation of the project to work relatively to the same architecturological scale. They have, in fact, operated on two different elements of the project by thinking of the same architecturological scale. In the other case, the conceivers have worked synchronously on the same element of the project relatively to different architecturological scales. They have sketched on the same time, on the same graphical representation.

These cases have been possible due to the specific potentiality of DCDS to enable synchronous multi-hand sketching. DCDS allows to remotely sketching synchronously with two hands and, this functionality is for the developers of DCDS a condition of collaborative design. CoCrea shows that this functionality is not fully exploits by the conceivers because they are not used to draw at two. But, when they discover the functionality, they game with it and really sketch at two rather at the end of the process.

The study of the classes of pragmatics operations of collaboration shows that use of DCDS implicates as well collaborative conception that individual conception. Segmentation and empowerment were systematically implemented with different ways even so DCDS has not been designed to facilitate individual conception.

Some pairs of architects have physically cut their collaborative design space, i.e. the digital graphical table, in two different parts for each conceiver. Others have sketched in a little part of the whole table as they were alone on a piece of paper. Others yet have asked for a piece of paper (not allowed in experimentations) to sketch independently in its corner and to not share his sketch. Others finally have suggested a new functionality for DCDS to allow working on personnel layers at the same time, i.e. one layer not systematically shared for each.

These architecturological results have been completed by Applied Architecturological analysis of the use of DCDS. These further analyses have allowed discovering others pragmatics operations specifically attached to the functionalities of DCDS. All these architecturological results have orientated the future development of DCDS by adapting some functionality to the needs of conceivers. However, they proceed from at distant use of a unique IT Support for collaboration. They are then limited to the theoretical background and the functionalities of this tool and are not generalized to the whole collaborative conception. In other words, this study has to be more exhaustive by pursuing the analysis of data of others experimentations as, in the presence collaborative conception made with DCDS or with another support or, at distant collaborative conception made with other IT Supports.

Furthermore, the comparison or the study of the relationships between the classes of pragmatics operations of collaboration and operations of conception is

in progress in the thesis of S. Ben Rajeb, directed by F. Guéna and C. Lecourtois at ARIAM-LAREA. It should inform about the operations of the logic implementing in collaborative conception and, should enlighten the implications of the situations of collaboration on cognitive mechanisms of conception.

58 CoCrea, project # ANR-08-CREA-030-02

6 Conclusions and discussion

This paper presents a comparison between the two different scientific viewpoints of Cognitive Ergonomics and Architecturology. It points their scientific methodologies for approaching and analyzing design and collaborative design. The construction of their scientific paradigm has also been described as two opposite developments relatively to reality and abstraction.

From a research in which these two scientific fields are gathered, this paper explains the object of knowledge enlightened by each: mechanism of collaboration in design and collaborative conception.[58]

Cognitive Ergonomics and Applied Architecturology do not have the same viewpoint on collaborative design. While collaboration in design exists for the ergonomist-cognitician, it's still a question for the architecturologists. Furthermore, while the research methods of ergonomist-cognitician suppose the possibility to compare two different situations of architectural conception, methods of Applied Architecturology avoids the comparison by posing that each situation of architectural conception is unique.

By distinguishing the conception of the design, Applied Architecturology is here particularly described through its different research methods allowing to approach and to enlighten objects concerned by conception. In CoCrea, it has questioned the possibility for cognitive operations of conception to be shared at distant, due to the use of a specific IT support called DCDS (Distributed Collaborative Digital Studio). By posing collaborative conception as a cognitive mechanism of sharing spaces of reference, architecturological scales and operations of conception, it has also helped to evaluate the impact of DCDS' functionalities on the cognitive mechanism of collaborative design.

The result of this work is limited to the research situation of CoCrea and has to be pursued to build more general knowledge on the mechanisms of conception of collaboration and the mechanisms of collaborative conception.

Bibliography

Achten, H.H. (2002). Requirements for Collaborative Design in Architecture. In: Timmermans H. ed, Sixth Design and Decision Support Systems in Architecture and Urban Planning - Part one: Architecture Proceedings Avegoor, Netherlands

Austin, J.L. (1971). Le langage de la perception, Armand Colin

Bachelard, G. (1934-2000). La formation de l'esprit scientifique, Vrin

Ben Rajeb, S., Lecourtois, C. and **Guéna, F.** (2010). Operations of conception in Architectural Collaborative Design, In Proceedings eCAADe. Future cities

Boudon, Ph. (1971). Sur l'espace architectural, Essai d'épistémologie de l'architecture, Dunod

Boudon, Ph. and Decq, O. (1976). Figuration graphique en architecture. Fascicule 3b : Architecturologie des sigles, AREA, COPEDITH

Boudon, Ph., Deshayes, Ph., Pousin, F. and **Schatz, F.** (1994). Enseigner la conception architecturale, cours d'Architecturologie, Editions de la Villette

Boudon, Ph. (2004). Conception, éditions de la villette

Bouveresse, J. (1995). Langage, perception et réalité, Jaqueline Chambon

Canguilhem, G. (1975). Etudes d'histoire et de philosophie des sciences, Vrin

Cléro, J.P. (2000). Théorie de la perception, de l'espace à l'émotion, PUF

Conan, M. (2000). Concevoir un projet d'architecture, L'Harmattan
David, B. (2001). IHM pour les collecticiels, In Réseaux et Systèmes Répartis, Hermès, 13, pp 169-206
Boissieu, A. de, Lecourtois, C. and **Guéna, F.** (2010). Modélisation paramétrique partagée, Le cas de l'utilisation de Digital Project lors de la conception du Pavillon de la Fondation Louis Vuitton pour la Création (Gehry Partners) sous l'angle des opérations de découpage, Scan'10 Espaces collaboratifs, Marseille
Delaveau, A.S., Guéna, F. and **Lecourtois, C.** (2009). Digital as tool/reference for architectural conception, Proceedings of the 27th eCAADe, Istanbul
Elsen, C., Darses, F. and **Leclercq, P.** (2010). Evolution des pratiques en conception: une approche ergonomique compréhensive des objets médiateurs, in Conférence Ergo'IA 2010, Innovations, Interactions, Qualité de vie
Gero, J.S. ed (2010) Studying Design Creativity, Springer
Kant, E. (1781-2006). Critique de la raison pure, Flammarion
Kubicki, S., Bignon, J-C., Lotz, J., Halin, G., Elsen, C. and **Leclercq, P.** (2008). Digital Cooperative Studio, ICE 2008, 14th International Conference on Concurrent Enterprising, Special session ICT-supported Cooperative Design in Education, Lisboa
Kvan, T. (2000). Collaborative design: What is it ? Automation in construction, 9, pp 409-415
Lebahar, J. C. (1983). Le dessin d'architecte, Parenthèses
Reuchlin M. (1998), Psychologie, Puf
Lecourtois, C. (2005). Architecturologie appliquée à une sémiotique de l'esquisse architecturale, in Actes du Colloque SCAN05, Rôle de l'esquisse architecturale dans le monde numérique, Paris
Lecourtois, C. (2006). Conception de l'espace et espace de conception, in TIGR, Nouvelles approches de l'espace dans les sciences de l'homme et de la société, Institut de Géographie Reims
Lecourtois, C. (2007). Architectural qualities and local identity, in CSAAR 2007, Tunis
Lecourtois, C. (2008). "Espace de conception" d'une architecture judiciaire: les nouveaux palais de justice, in Diagonale Φ n°4- n°5, Inscriptions spatiales – travaux de l'école doctorale, Université Jean Moulin, Lyon 2008-2009
Lecourtois, C. and **Guéna, F.** (2009). Eco-conception et Esquisse assistée, Conception architecturale numérique et approches environnementales, in Actes de SCAN09, PU Nancy
Lecourtois, C., Ben Rajeb, S., Guéna, F., Mayeur, A., Darses, F., Leclercq, P. and **Safin, S.** (2010). Interpretations Collaboratives: Usages et implications du Studio Digital Collaboratif en situation de conception architecturale, SCAN10
Lecourtois, C. (2011). Sudying collaborative design. Epistemology and research methodology. In: Carrara, G, Fioravanti, A. and Trento, A. eds, *Connecting Brains shaping the world =>collaborative design spaces*, Europia productions, pp. 25-37
Mayeur, A., Ben Rajeb, S., Darses, F., Lecourtois, C., Caillou, S., Guéna, F., Honigman, A., Leclercq, P. and **Safin, S.** (2010). Concevoir à plusieurs et à distance en architecture : vers de nouvelles pratiques professionnelles ? In: Actes du Séminaire Globalisation et Territorialisation: questions de travail, Université Paris 1 Sorbonne, Paris
Mayeur A., Darses F., Lecourtois C., Guéna F., Ben Rajeb S., Safin S. and **Leclercq P.** (2011). Expérimentations en coprésence et à distance, Situations de production architecturale collaborative outillée en co-présence vs. à distance, Lot 3.1 / Livrable T24, Projet ANR Cocrea
Mayeur A., Darses F., Ben Rajeb S., Lecourtois C., Guéna F., Safin S. and **Leclercq P.** (2011b). Résultats des analyses en ergonomie-cognitive et architecturologie des expérimentations en coprésence et à distance outillée, Lot 3.2 / Livrable T32, Projet ANR Cocrea
Peirce Ch.S. (1978). Écrits sur le signe, rassemblés traduits et commentés par G. Deledalle, Paris, Le Seuil (coll. L'ordre philosophique)
Safin, S. and **Leclercq, P.** (2009). Studio Digital Collaboratif : un environnement de conception collaborative à distance, IHM09 [ihm09.imag.fr/actes_informels/Informels/06/Safin.pdf]
Sansot, P. (1973). Poétique de la ville, Klincksieck
Stellingwerff, M. and **Verbeke, J.** eds (2001). Accolade. Architecture. Collaboration. Design, Delft University Press
Soler, L. (2000). Introduction à l'épistémologie, Ellipses

Instructions for Authors

All papers are reviewed by at least two reviewers. All reviewed and accepted papers have to be resubmitted, implementing reviewers and editors comments or suggestions. Only accepted papers conforming to instructions will be considered for publication in the *International Journal of Design Sciences and Technology*.

The first page of the paper must contain the full title of the paper as well as the name, affiliation, address, telephone, fax and email of the main author and co-authors (if applicable). Also mention the name, postal address, telephone, fax and email of the author to whom all correspondence to be directed.

The second page should contain the full title of the paper, the sub-title (if any), an abstract of 100 to 150 words summarising the content of the paper and 3-5 keywords for the purpose of indexing (the use of references in the abstract is discouraged). Maximum length of a long paper is 7000 words (4000 words for short papers). Please note that the use of Footnotes and endnotes are discouraged. The layout of the journal allows the use of 'side notes' (see a sample issue of the journal). Where appropriate give information for the 'side notes' (maximum length 60 words) between double square brackets (such as full bibliographic reference, page numbers, remarks and notes). All side notes should be numbered consecutively. For instance: [[17 A 'side note' reflects additional information, a reference or the URL of a website]]

The paper will be written in (UK) English. It will be single-spaced with 30 mm margins on all sides (paper size A4). Use Times New Roman for the main body of text (size 10), figures (size 8) or tables (size 8). The use of **Bold**, *Italics*, ALL CAPS, SMALL CAPS, etc. is discouraged. All chapters should be numbered consecutively (more than one level sub-headings are discouraged). All Figures and Tables with their respective captions should be numbered consecutively. They should each, be placed on a separate page, at the end of the paper. All figures, tables and equations should be mentioned in the body of text. Give an approximate insertion point for figures and tables, between double square brackets. For instance: [[insert Figure 5]]. You will be asked to resubmit your drawings if necessary. **Do not layout your paper**. *Do not use any styles or any automatic layout system.* Please do not use 'Track Changes'.

All Tables should be referred to in the text as Table 1, Table 2, etc. All Figures should be referred to in the text as Figure 1, Figure 2, etc. Line drawings should be of good quality. Use light background if possible (white is preferred). Photographs and screen-shots should also be submitted separately as JPEG files (use high resolution for better results). Authors should prepare high quality figures and drawings. Avoid the use of colours in your illustrations, as the journal is not published in colour. Maximum width and height of a figure are respectively 115 (150 mm if absolutely necessary) mm and 190 mm. Maximum width and height of a table are respectively 115 mm (150 mm if absolutely necessary) and 170 mm. All Equations will be numbered consecutively and should be mentioned in the text.

Use 'Harvard System of Reference'. Bibliography (references) is collected at the end of the paper, arranged in alphabetical order by the first author's surname, followed by initials. All authors should be mentioned. Dates will appear between brackets after the authors' name(s). This is followed by the title of the book, name of the publisher, place of publication and page numbers (if applicable). To refer to a journal paper, add the full title of the journal followed by Volume:Issue Number

and page(s). Examples of references to a book, a journal or a website are shown below:

> **Dixon, N.M.** (2000). Common Knowledge: how companies thrive by sharing what they know, Harvard Business School Press, Boston, MA
> **Buxton, W.** (1997). Living in Augmented Reality: Ubiquitous Media and Reflective Environments. In: Finne K., Sellen A. and Wilber S. eds, Video Mediated Communication, Erlbaum, Hillsdale N.J., pp. 363-384
> **Beckett K.L.** and **Shaffer D.W.** (2004). Augmented by Reality: The Pedagogical Praxis of Urban Planning as a Pathway to Ecological Thinking, University of Wisconsin, Madison
> **Djenidi H., Ramdane-Cherif A., Tadj C.** and **Levy N.** (2004). Generic Pipelined Multi-Agents Architecture for Multimedia Multimodal Software Environment, Journal of Object Technology, 3:8, pp. 147-169
> **Gorard, S.** and **Selwynn, N.** (1999). Switching on to the learning society? Questioning the role of technology in widening participation in lifelong learning, Journal of Education Policy, 14:5, 523-534
> **Blackman, D.A.** (2001). Does a Learning Organisation Facilitate Knowledge Acquisition and Transfer? Electronic Journal of Radical Organization Theory, 7:2 [www.mngt.waikato.ac.nz/Research/ ejrot/Vol7_1/Vol7_1articles/blackman.asp]
> **World Bank** (2002). Social assessment as a method for social analysis, World Bank Group [www.worldbank.org/gender/resources/assessment/samethod.htm]

Papers in their definitive version will be submitted as a MS Word file for the PC (MS Word RTF format for Macintosh). In addition, a formatted version of the paper (including images and tables) will be submitted in PDF format and all figures must be submitted in high resolution jpg or tiff format. Submit your paper as an email attachment to the Editor-in-Chief [beheshti@ planet.nl]. You can also send your paper and images on a CD-ROM by an International Courier to:

Editor-in-Chief
International Journal of ***Design Sciences and Technology***
Europia Productions
15, avenue de Ségur
75007 Paris, France

Author(s) have to complete, sign and return a *Copyrights Transfer Form* to the publisher. This copyrights transfer assignment will ensure the widest possible dissemination of information. Papers published in the International Journal of *Design Sciences and Technology* cannot be published elsewhere, in any form (digital, paper-based or otherwise) without a prior written permission from the publisher.

The author(s) are responsible for obtaining permission to utilise any copyrighted material. For more details about this subject, please contact the publisher at an early stage.

The decision of the Editor-in-Chief on all matters related to the International Journal of Design Sciences and Technology including the review process, publication of papers, etc. is final and cannot be disputed.

The leading author of a paper published in the International Journal of *Design Sciences and Technology* will receive a digital copy of the author's paper free of charge. Printed copies of any individual paper (minimum 50), any issue (minimum order 10 copies) and the Journal Year Book (one or more copies) can be purchased from the publisher (ask for an invoice from the address above or IJDST@europia.org).

How to Order

International Journal of *Design Sciences & Technology*

IJDST-online

You can view and download a digital version of individual papers free of charge from the journal's website.

IJDST Hardcopies

Hardcopies of any individual paper (minimum order 50 copies), any issue (minimum order 10 copies) and volumes (minimum order is one single copy of the book containing 2 issues) can be ordered directly from Europia Productions. You need to send your **Request for an Invoice** (preferably by email, Fax or letter) indicating details of your order and the quantities. Please provide your full name and initials, postal address, email and telephone number. An invoice will be sent to you indicating the total amount of your order, the cost of packing/postage and method of payment.

Individual Subscription IJDST Hardcopies

Individuals can subscribe to receive a hardcopy of the book containing 2 issues for € 150.00 (incl. 5.5 % VAT, packing and postage). You need to send your **Request for a Subscription Invoice** (preferably by email, Fax or letter) indicating the IJDST Volume. Please provide your full name and initials, postal address, email and telephone number. An invoice will be sent to you indicating the method of payment.

Institutional Subscription IJDST Hardcopies

Libraries and organisations can subscribe to receive a hardcopy of the book containing 2 issues for € 150.00 (incl. 5.5 % VAT, packing and postage). You need to send your **Request for a Subscription Invoice** (preferably by email, Fax or letter) indicating the IJDST Volume. Please provide details of the library or organisation, name contact person, postal address, email, telephone number and Fax number. An invoice will be sent to you indicating the method of payment.

Other Publications

Other Europia Productions publications can be ordered from the address below. You always need to send your **Request for an Invoice** (preferably by email, Fax or letter) indicating details of your order and the quantities. Please provide your full name and initials, postal address, email and telephone number. An invoice will be sent to you indicating the total amount of your order, the cost of packing/postage and method of payment.

Europia Productions
15, avenue de Ségur, 75007 Paris, France
Telephone +33 1 45512607
Fax +33 1 45512632
E-mail: dst@europia.fr
URL: Europia.fr/DST

International Journal of
Design Sciences and Technology

Editor-in-Chief: **Reza Beheshti** and **Khaldoun Zreik**

Volume 18 Number 1

Issue Editor: **Gianfranco Carrara**

Table of Contents

1630-7267