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REPRESENTATION OF AN ARCHITECTURAL DESIGN PROCESS; BETWEEN FORMAL AND FUNCTIONAL

Pierre P. Leclercq and Mariette E. Locus

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1. Introduction

What are the procedures carried out by a designer in drawing up the draft architectural project? What are the control conditions of such a process? What are the procedural specificities which lead to creativity?

As part of LEMA's research and teaching activities, these questions which underline our studies of the design process, continue the specification of information technology agents, which will be integrated into the next generation of computer-aided architectural design tools.

To implement such an aid environment, one must be able to identify the characteristics of the architect's design strategies, from the gestures which can be recorded in his work. Irrespective of the operational constraints of such computerised identification, which it would be premature to mention at present, there is a dual problem : what can we identify as the characteristics of a design strategy and, more importantly, how can they be represented?

2. Representation of a design process

With a view to following the dynamics of a design process, we have taken from Rasmussen (Rasmussen, 1990) the "diagram of the structure of a process" (figure 1). Although initially conceived to represent a diagnostic procedure, and despite the fact that we are using it in a simplified version, we feel it can suitably reflect the way a design evolves, in particular because this simplicity lends itself to practical implementation.

This diagram makes it possible to locate the stage the designer has reached in his work, step by step, by positioning it on two axes.

The ordinate reflects its levels of abstraction : the transition from one level of abstraction to another is induced by the operator's state of reflection, and is expressed in terms of deviation. Given the state of the system for which the designer is unable to make a decision directly, moving up to a larger level of abstraction widens the context of the reflection and renders the elements to be dealt with more symbolic. In other words, a movement towards the bottom of the diagram reveals the application of constraints, whereas a movement towards the top reveals the premises underlying the management of the goals desired.

The x-axis aligns the levels of decomposition, going from the complete system - seen in its entirety - to each one of its components. They are separated by intermediaries, whose titles vary according to the object of the observation. A movement to the right provides an account of a specialisation and is accompanied by a hierarchy of specifications; a movement to the left provides a generalisation.

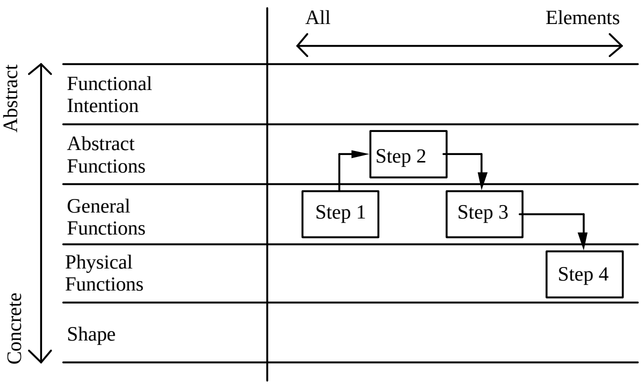

Figure 1. The simplified diagram of a design process follow-up

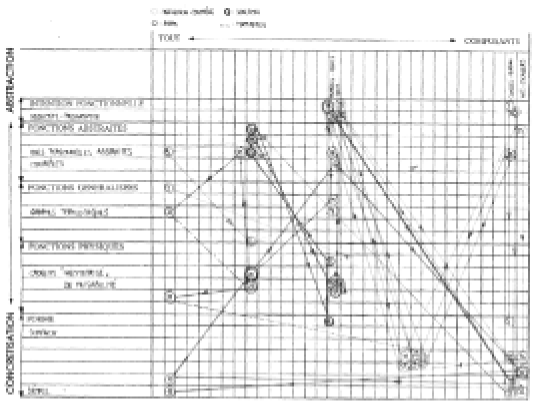

Figure 2. The complexity of following a real design process

3. The experiment and its protocol

We decided to monitor the design work of students in the 5th year of Technical Studies, Architect Civil Engineer (final year of university studies for this subject in Belgium). Given that they were now in the final year of their Architecture studies, we can assume that they were thoroughly grounded in design methods, they nevertheless have not yet developed a great deal of practical experience. As such, they will naturally tend to have no difficulty in developing their design method - sometimes even in a characteristic manner - and they tend to have scant resort to analogue techniques in resolving problems. With this particular sample of designers, we can thus circumvent the effects of pre-structured strategies, which are widely used by the professionals (Leclercq & Heyligen, 2002).

3.1 Adjusting the representation back-up

The observation exercise carried out in this course comprises an analysis of the design process for a small school, and its representation on the diagram of the structure outlined above. This task is carried out by the students, divided into groups of three (one designer, and two observers).

Despite the fact that the simplicity of the diagram enables it theoretically to be directly applicable, we noted that there was a difficulty in implementation : namely, most of the designers define their process as a series of steps whose representation often gives rise to problems. In most observations there are quite a large number of steps, which means that the results tend to be illegible, which in turn renders comparisons and analyses of the various processes impossible (see figure 2 hereafter).

With a view to clarifying the process to facilitate the identification of the characteristics of the design strategies, we would recommend a "phased" decomposition (we shall define this notion later in point 3.3), based on grouping together the various stages released by the designers themselves.

Each one of these stages is represented on the simplified version of Rasmussen's diagram : the levels of abstraction, as they have been defined, are no longer indicated. The axis of the ordinates, reduced to its simplest expression, now defines the degree of abstraction and/or concretisation. This modification involves a generalisation of the diagram in question, which will pave the way for an enhanced comparison between the design processes observed (see figure 2).

3.2 Expression of the exercise observed

The architectural programme involves the composition of a secondary school which must satisfy a various joint constraints linked to the space-functions : namely, six classes, a recreation area comprising four square metres per student, corridors with a minimal breadth which varies according to the type of natural lighting, etc, and the imposition of a topological organisation given by an adjacency matrix.

It should be noted that, although the circumstances in which the experiments are carried out mean that there is a limited time allowed, the designers decide themselves when they wish to stop working.

3.3 Definition of the concepts used

Before describing the observations, we shall define the four concepts which will be used in their analysis.

3.3.1 Step

A step, represented by a point on the simplified structure diagram, is the subject of a reflection or an action by the designer during the design process; for example, the evaluation of the surfaces of a functional sub-unit (a teaching unit, bursarship service, etc). This subject of reflection is depicted according by using two axes : according to a level of abstraction, on the one hand, and according to a level of decomposition, on the other (for example, the subject concerns a room, a zone, a wing of a building).

3.3.2 Relationship between steps

The relationships between steps concern the movement from one subject to the other (for example an adjacency graph rendered tangible by its geometrization). They are depicted by slanted arrows linking the points of the diagram according to the evolution of the subject.

3.3.3 Phase

A phase is generally defined as each of the changes or each of the successive aspects of a design phenomenon in evolution. On our diagram, it is possible, starting with the representation of successions of steps, to define a phase as a sub-unit of steps, whose finality is to locate itself either at the "entirely abstract" (emergence of a basic concept), or at the level of the "entirely concrete" (finished project). Reaching the end of a phase is conditioned by the sense of satisfaction of the designer.

3.3.4 Relationships between phases

The relationships between phases are links which describe the intervention of the result of one phase in the next one. We have essentially described two types of intervention. The first, generally encountered at the beginning of the process, takes place during the dynamic of the later phase and enables, in association with the ongoing work, a new solution to be created (link AIM, Associative Intervention Mode, in figure 3. The second mode, primarily encountered in the heart of the composition, involves commencing the dynamic of a phase by the result obtained in the previous phase (link CIM, Chained Intervention Mode, figure 3).

4. Observations and analysis

We have reproduced above the characteristic traits of two significant observations from our experimental programme. The following descriptions are based on figure 1 and contain, in brackets, the association of design actions to movements noted in each graph.

4.1 Phase 1

- Designer 1 : initially, there are a number of vertical movements towards the bottom (precision of the level of detail of the components), followed by a diagonal (work on a series of components), and finally by a horizontal movement which culminates in a system seen in its entirety (culmination of the first concept).
- Designer 2 : we notice an initial horizontal movement (transformation of the adjacency matrix into a graph), followed by a descending diagonal movement (establishing an initial concept) supported by a simultaneous movement derived from elementary components which are still vague.

Although the phases have a different dynamic - one might very well say an opposite dynamic (a vertical movement for the first designer, as opposed to a horizontal one for the second; an ascending diagonal movement against a descending one), they both make it possible to define an initial concept, despite its different localisation on the abstraction scale.

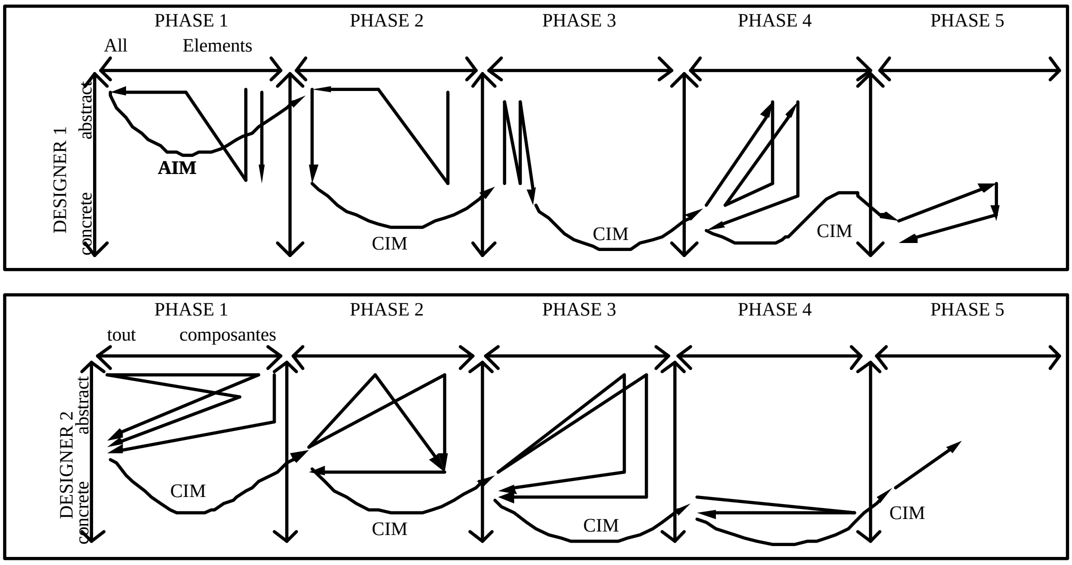

Figure 3. Observation of two characteristic Processes

4.2 Phase 2

- Designer 1 : we observe the same dynamic as in the first phase, because it involves working on other components which comprise another whole. Subsequently, this whole is inserted into the initial concept, which becomes more precise.
- Designer 2 : in the representation we first see a double ascending diagonal movement towards the components (control of the command of the concept resulting from the first phase), followed by a descending vertical movement (the designer is working on the components). Finally, the horizontal trajectory defines the concept more accurately.

It is important to note that if the dynamic is different, the spirit in which the designers approach this second phase is equally so. The first designer leaves aside, momentarily, the results obtained during the first phase, and concentrates on other constraints, which he will subsequently replace in their context. The second designer continues the development of his basic concept.

4.3 Phase 3

- Designer 1 : here we witness very characteristic displacements : these alternate vertical movements, situated at the level of the "entirety" on the x-axes, reflect the operations of verification of the concept with the expression and personal objectives of the designer.
- Designer 2 : a second cluster of ascending diagonals (an initial command control) precedes the characteristic vertical toeing and froing, located here at the level of the components (verification of detail), before returning to the "entirely-concrete" : the transformation of the verified concept into a concrete project.

Not only are the controls localised differently on the "all-components" axis, but they share a specific dynamic and are located, for the first time, in the same phase. It would be interesting to enlarge, at a later stage, the scope of the experiment to study this similitude.

4.4 Phase 4

- Designer 1 : the repetitive movement in this phase reflects the existence of a certain automatism in the designer's way of conceiving things. The aim of this triangular dynamic is to control and define each of the wholes considered in a precise manner. It ends at the level of the project which is the result of pooling these wholes.

- Designer 2 : Here we see a movement which is essentially horizontal. The designer works on the concept with a view to transforming it into an increasingly concrete project. Hitherto, this movement has never been observed; we can even state that it is one of the characteristics of process of this designer.

Although the aim of this phase is similar for the two designers (to achieve a concrete, therefore satisfactory, project), the same is not true of their dynamic. The first designer describes a triangulation movement, which contrasts with the very sober horizontal movement of the second designer.

4.5 Phase 5

- Designer 1 : this triangulation movement reflects a final modification, which culminates in an end-project.
- Designer 2 : here we note an ascending movement at the level of a group of components. The designer is aware at this stage that there is a major problem, and that, consequently, he is unable to define a final project.

The second designer is working exclusively at two levels of decomposition of "all-components", without making use of an intermediary sub-ensemble. This may explain the difficulty preventing the emergence of a valid solution. The use of the sub-ensembles represents a step and makes it possible to have a partial vision of the project. This makes it possible to highlight the related difficulties, as well as their resolution.

5. Results

Here we obtain two different design processes.

The first is considered as a primarily functional process : the designer composes his architecture by emphasising its functional aspects. He manages the organisation of spaces, works on the topological relations, and studies the accessibilities ... The second types of process is more formal : its designer attempts to integrate the architectural programme into a pre-established voluminal representation. Having predefined the form of his composition, even symbolically, he attempts to come up with a concrete response which will gradually satisfy the architectural programme in the context of his initial formal concept.

The process of the first designer may be defined as follows : the designer analyses the situation and determines an initial concept. Thereafter, he specifies the components, creates ensembles, which he then inserts into the concept and its context. Finally, this concept, little by little, transforms itself into an "all concrete" controlled by a series of verifications and successive readjustments. As such, the first two phases represent the work from different components. They are linked by the associative intervention mode (AIM), which makes it possible to create a new solution by assembly. Although they are carried out in a series, from a temporal point of view, each of the two phases comprises a parallel approach. The second type of intervention, the Chained Intervention Mode (CIM), comes about mainly in the following phases.

We note, therefore, that the functional approach would appear to be characterised by a process which reveals a two-sided dynamic : a parallel approach (phases 1 and 2), followed by an approach as part of a series (phases 3, 4 and 5), which illustrates work on the conditions in which the concept must be constructed.

For their part, the phases defined by the second designer reveal a similar aspect, their object being to give tangible form to the initial concept. However, we note a differentiation in the position of the final stage, according to the axis of concretisation throughout the process. Furthermore, the phases are linked only by a single intervention mode, in this case the Chained Intervention Mode (CIM) : the final step in each phase represents systematically the commencement of the following phase. As such, the formal approach would appear to draw on a more series-based process, through which the designer successively specifies his concept.

The two modes of design use the same specification technique for the project. Rather, they are distinguished by the use of very different ways of establishing the concept : one is constructed, while the other draws on other elements.

6. Discussion

Now let us develop some reflections induced by this experiment, by articulating them around a number of key questions which complete the analysis.

6.1 How can we exploit the established facts from this experiment in a professional context?

We would point out that we have voluntarily dispensed with one of the modes of thinking generally used by practicians, who generally use multiple design resolution pre-structures, probably drawing on more profitable approaches to resolving problems which are based on their intrinsic heuristics.
By erasing this technique from our observation sample, widely used in the profession, we are attempting to disregard the opportunistic aspect of analogy throughout the entire design process. Less capable of being grasped, and even less predictable, this analogical mode disrupts the reading of the "fundamental" processes which back them up, and which we would now like to better describe here.

6.2 Is this cutting into phases not contradictory with the continuity of all design processes?

The representation in phases is the only means which will allow us to achieve a legible mode of representation of the process observed. It is obvious that this cutting runs counter to the continuity of the process, as a result of the convergence sought in it. This cutting is based on the subjective proposals of the students (the designer and the two observers in each experimental group), which are harmonised by the simultaneous examination of the multiple observations compared.
We would stress that the differentiation between the formal/functional modes do not appear to have to be based on the articulation of the phases between them, but rather on the observation of the dynamic of the process observed within one or several phases, irrespective of the lack of accuracy of the limits of the latter.

6.3 What influences the conditions of the experiment on the observations?

6.3.1 The influences on the work of analysis

The architectural programme proposed in the expression constrains from the outset the object of our analysis. In this case, the formal/functional differentiation is important, given the subject of the expression (to design a secondary, or high school). Other architectural programmes can widen the fields of design by inviting a more extensive use of the designer's thinking to focus on the other, more dominant aspects in their case : the structural aspect (the principles which guarantee the stability of the edifice), the production aspect (the implementation techniques), the integration aspect (the environmental design), the maintenance aspect, etc.

6.3.2 With regard to the processes observed

The length of time taken for the composition is managed solely by the student-designer. But this exercise takes place in a context which implicitly imposes its conditions : linked to a course among others as part of the curriculum of the final year's studies, no student can really afford to devote more than eight hours to this exercise. Nevertheless, we must be mindful of the fact that the student is responsible for managing his/her resources, and in achieving this, we believe he encounters the same type of conditions as those of the professional architect.
In this time management, we have noted the importance of pauses, taken in the sense of a complete cessation of design work, and which is, in general spread over at least two days. The choice of the time these pauses are taken during the design process is directly linked to the designer's state of mind, and obviously influences the dynamic of his process. Here we note three types of attitude which are characteristic.

a) Having worked for a certain time without success, the designer feels overloaded, and requests a break so that he can stand back and observe his work in a more detached manner. It would appear that this type of pause facilitates cognitive work, however unaware the person may be, because it can be achieved while carrying out other activities, after which the designer can resume his work with an enhanced vision of his problem (the emergence of a pre-structure, for example?).

b) Wrapping up what he considers to be a completion - which sometimes corresponds to a cut-out phase in our analysis - the designer, who is at this stage quite satisfied, does not wish to move on to a new stage of his design for the moment. We feel this attitude stems from a dual preoccupation : on the one hand, offering oneself a certain reward having achieved this partial success, and, on the other hand, an unwillingness to risk jeopardising this success by continuing with his work before having had time to let it settle in. This "settling in" of partial solution also requires an unconscious cognitive effort, just as in the previous case.
c) The external environment can also determine the pace of the designer's work : a daily timetable to be complied with, the slightest problem with the designer's work tools (if he runs out of paper, for example), can cause him to lose the thread of his thoughts. In the case we have been able to observe, the designer continues his work, which had been interrupted for several days, as though he had merely taken a break for several minutes. There is perfect continuity in the movement of the process designed in our diagram. In the example we observed with this designer who is accustomed to a strict rhythm of work he has to follow, this type of break he is obliged to take does not appear to imply an intermediary cognitive work.

6.4 Risk management and efficiency

The efficiency of the approaches is not comparable. The designer who tends to be formal, working on an analogical plan, draws on a reply (pre-)structure, in which he merely has to verify the adequacy (verification process). This approach, more characteristic of the work of an expert, is probably very effective. The designer with a functional aim first constructs his concept. In this way he wishes to control his emergence conditions. It goes without saying that this type of construction takes more time, but the control it affords reduces the risk of major incompatibility such as that which can be encountered by the designer who tends to have a formal approach.

7. Conclusions

We take the view that computer-aided design in architecture can only truly be envisaged when the software back-up environment is capable of detecting the operating strategies implemented by the designer who uses it.
Prior to that, it is necessary to be able to represent the design process and to identify the particular traits which enable them to be qualified.
Our experimental programme proposes a simple protocol, which draws on the work carried out by Rasmussen, which, to begin with, makes it possible to study a certain architectural practice, atypical for practicians who use the analogical approach, but whose general principles underlie all acts in architectural design.
We have noted and analysed here two characteristic examples and shown how they can be distinguished by studying their procedural dynamic. The observations carried out lead to classical conclusions which could be anticipated by any teacher of architecture who comes across our experiments. Our objective is not to rediscover the evidence, but to put forward a protocol for codification, reading and analysis, which makes it possible to identify the particular traits and to recognise the type of operating mode which the designer has drawn on. In the experiment described here, we were able to identify an initial set of attributes in the dynamic of two process models :

- the functional approach which develops the examination of the conditions to be encountered for the emergence of a concrete design;
- and the formal approach which starts with a symbolic concept, and then works on rendering it tangible by adjustments to its framework conditions.

The following stages in our research will involve an attempt to overcome the formal/functional dichotomy and, in particular, an attempt to translate our current proposals into practical specifications with the ultimate aim of a software module to monitor the design process.

References

Discry, F. : 1997, Performance and Learning in a Dynamic Situation. Annual meeting of the Belgian Psychological Society, Brussels.

Dupagne, A. (for the CIB consortium prof. A. Dupagne, ed) : 1992, The Design in Stage. CIB - Computer Integrated Building, Technical Final Report. ESPRIT II exploratory action n°5604.

Do, E. and Gross M.D. : 1996, Drawing as a mean to design reasoning, Visual representation, reasoning and interaction in design, Artificial intelligence in design '96 (AID'96), Standford University.

Leclercq, P. : 1996, From an architectural sketch to its semantic representation, International Journal of Construction Information Technology, Vol 4, n°3, University of Salford, UK.

Leclercq, P. : 1994A, Environnement de conception architecturale pré-intégrée. Eléments d'une plate-forme d'assistance basée sur une représentation sémantique, doctoral thesis in applied sciences, Faculty of Applied Sciences, LEMA, Liège University, Belgium.

Leclercq, P. & Heyligen, A. : 2002, 5,8 analogies per hours, 7th international conference on Artificial Intelligence in Design, AID'02, Cambridge UK.

Locus, M. : 1999, Représentation de processus en conception architecturale, Méthodologie à base expérimentale, thesis in architect-engineering, LEMA, Liège University, Belgium.

Rasmussen, J. : 1990, Mental models and the control of action in complex environments. Mental models and human-computer interaction 1. Ackerman D. and Tauber M.J. (Eds). Elsevier Science Publisher B.V., Holland.

Mr. Leclercq P. Pierre
University of Liège, LEMA - Laboratoires d'Etudes Méthodologiques Architecturales
Chemin des Chevreuils - B52, B4000 Liège
Email: pierre.leclercq@ulg.ac.be