Analysis of Instrumental Practices in Collaborative Design: Method of Identifying Needs, Means and Their Effectiveness

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Abstract. This paper presents a user-centered data collection method, concerning "means of design" and "representation supports" implemented in a collective architectural design process. Our aim is to study how these observed means and representations are adapted to agile design methods. Our method - applied on several long (3 months) architectural design processes – allows us to identify patterns of use and to consider their efficiency level brought to designers.

Keywords: Collaborative and multimode working environment · Architecture and engineering · Instrumented practices · Cooperative design analysis methodology

1 Introduction

Several fields of expertise are increasingly required in the domain of architectural design. Similarly, the constraints, which are applied at the beginning of the phases of production and in the realisation of coordination and performance, are present from the initial phases of conception. These constraints increase the number of mechanisms used in the design phase and make them more complex [1]. Are these means truly suited to the methods of design? Are they efficient for the users? Do they allow for a flexible mode of design? In order to answer these questions, this article proposes a user-centred method of data collection.

2 Latest Developments

In collaborative design, collective activity is based on 3 major types of action [2]: (1) communication: exchanging information between creators about the architectural target; (2) coordination: organising collective work; and (3) production: defining the architectural target. In this article, we associate "production" to an action achieved through the "means of design" and "communication" to one achieved through "support-representations".

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2.1 Means of Design

What interests us is not the representation of the product in and of itself, but the type of action used to conceive the project and to produce the desired representation. We are in no way affiliated with the software used to carry-out the different actions. On the basis of Safin's work [3], we have kept 8 types of action:

(1) Reference image: design through analogy vis-a-vis the pre-existing representations.
(2) Paper drawing by hand: design via a graphic production by hand on paper.
(3) Digital drawing by hand: design through a graphic production by hand on digital material.
(4) CAD 2D: design via a two-dimensional graphic production assisted by a computer.
(5) CAD 3D: design via a three-dimensional graphic production assisted by a computer.
(6) Model: design through the production of a three-dimensional physical model.
(7) CAD Parametric: parametric design assisted by a computer.
(8) Prototype: design through static or dynamic simulations.

Hereunder, we will use the terms "means of design" or "means" when referring to these different actions of production.

2.2 Support-Representations

Under the term "support-representations", we will discuss the external representations used as a support for the discussion. As Safin highlights, "these external representations consist of all the possible representations of information (namely, the architectural target)" [3, p. 35]. They lighten the mental burden of materialising information, and thus improve the effectiveness of cognitive activities [4]. On the basis of the works of both Safin [3] and Elsen [5], we classify the different possible representations into 7 categories.

(1) Reference image: image, sketch or photo that is not created by the creators.
(2) Written text/keywords: words that constitute an independent representation.
(3) Annotation: sketches or notes overlayed on a pre-existing representation.
(4) Blueprint/sketch: symbolic production simplified by hand or on a computer.
(5) 2D plan/cut: two-dimensional graphic production in the form of a plan or a mix of objects.
(6) 2D perspective: fixed point of view on a multi-dimensional support of a three-dimensional object.
(7) 3D immersion: immersive numerical or physical three-dimensional model.

For the ease of the reader, "representation" and "support representation" will be used interchangeably.

2.3 Methods of Data Collection

Different methods of observation and analysis of the uses of architectural design have already been used in other studies. Gero [6] suggested using principles of encryption of the process to understand both the behaviour of actors and the uses of the object and

tools. Other authors, such as Ericsson et Simon [7], discussed the evolution of the object and the tools independent from their uses, while Otjacques [8] retraced the uses of a tool for exchanging emails in the entire design process. Others, such as Defays [9], conducted a detailed study on a precise moment in the process which was analysed minute by minute. On the other end of the spectrum, the method suggested by Calixte allows for the observation of the uses of different tools over a long period of time [10]. None of the aforementioned methods allow for the observation of a process over a long period of time without disrupting the users.

3 Issue

Our goal is to streamline the process of design to allow for the collection of data regarding the uses of "means of design" and how they complement one another. Our research was conducted over a four-month period. To date, no other approach has been implemented in such a way. In addition, we have developed a data collection tool that is simple, fast and unobtrusive for the users. One that only intervenes at key moments to collect specifically targeted information at the heart of the design team.

4 Proposition and Methodology

Our method collects data by way of a questionnaire that is filled out by the members of the design teams who are observed at key moments during the design process. These short periods are chosen in advance and delimit the steps for the different sub-goals in the overall process of the completion of the project. For example, one of these sub-goal steps can be a presentation made to the supervisors about the structural principles or a meeting with the client about the volumetry or frontage.

The questionnaire consists of two questions. The first deals with the means of design used solely in the productive phases, and the second relates to the topic of support-representations used during the discussion between the designers in the team.

Both questions follow the same structure. They ask members of the design team:

- to cite the means and the representations used in the previous questions. The respondents are asked to indicate the means they used, in order of importance. That said, designers are free to interpret the word "importance". They could interpret it to mean importance of duration of usage, frequency, the order or impact of the design. This freedom of interpretation is crucial, as it allows the respondent to explain his/her real use of the means and the criteria that he/she finds important. It is key not to guide the respondents in their answers.
- to evaluate on a scale of 1 (very good) to 4 (very bad) the relevance of their usage as it relates to the creator's objectives. This speeds up the encoding of the data collected and it forces the respondent to take a stance. Given that the scale only has 4 levels, it is not possible for respondents to stay neutral.
- to explain, in a few words, the reasons for their evaluation or to their choice of the means and/or the representation.

– to propose an alternative option, if necessary.
– to explain in a few words, the reasons for their choice of an alternative option.

The data collected from the first question gives an understanding of the reasons behind the choices of the means and their real usage. The data from the second question allows for the identification of the needs as they relate to the task of communication between designers. The questionnaire is in paper format and does not exceed one A4 page, in order to reduce the amount of time that the designer spends on completing it. Each respondent submits one sheet with their name. This makes it possible to link the data collected from each designer during the entire design process.

Our method has, thus, 4 strengths: (1) it is immersive: data is collected during the entire process after the completion of each individual step, without interrupting the process; (2) it is centred around the user: on the one hand, the data reflects the deliberate practices and the personal opinions of the user, and on the other, it is designed for the purpose of simplicity and rapidity for the designer (less than 10 min to complete); (3) it collects information during key chosen moments: this allows for the simplification of the survey process for the designer, while covering the entire process; (4) it allows for freedom of expression: with the exception of the evaluation of the relevance, the sub-questions are open and not multiple choice. This avoids any problems linked to not understanding the suggested answers.. It also allows designers to develop their answers and thus, to go beyond the objectives of the first question.

5 Context

This method was applied in the context of an architectural workshop in the Master of Civil Architectural Engineering at the University of Liège over a four-month period, from September to December 2018. The group studied consisted of 8 teams of 3 to 4 designers, all architects and engineers. Their objective was to develop a pilot for a complex building intended for multi-purpose use: 7500 m^2 museum in an urban site. The particularity of this integrated activity resided in the liberty given to the teams in the tools that they could use.

There were 5 key moments chosen for the collection of data. Each chosen moment corresponded to the main steps of the review of the project that marked an important point in the evolution of the designed object and met a specific requirement in the deliverables and expertise (intentions, structure, budget ….).

The designers were invited to answer the paper version of the questionnaire before each review step. This protocol prevented long response times, distortions of the answers resulting from negative emotions and, more specifically, it allowed for the evaluation of the relevance of the tools.

6 Data Collected

131 questionnaires were collected in total from the experiment. Each question had 50 pieces of data, thus 6550 in total. This data covers:

- the number of uses of each means throughout the 5 sequences.
- the share of the usage of each means by the entire group of designers throughout the 5 sequences and over the entire process.
- the detail of the first, second, third, fourth and fifth mean chosen in the order of importance for each designer throughout the 5 sequences (Fig. 1).
- the average order of importance of each mean that was used throughout the 5 sequences by all the designers.
- the number of times each representation was used throughout the 5 sequences.
- the usage share of the different representations by all designers throughout the 5 sequences and in the overall process (Fig. 3).
- the average rating, of all designers, of the pertinence of the data for each means and representation used throughout the 5 sequences.
- the detail, one per designer, for each means and each representation used and their rating of their pertinence throughout the 5 sequences.
- the share allotted for each means and representation by the entire group of designers, and the different ratings given during the evaluation throughout the 5 sequences and the overall process.
- the share at different levels (designer, team, all respondents) of the different reasons for the choices of the cited usage of means and representations at each sequence and throughout the whole process.

The visualisation software Common Tools [11] was used to process the data collected. It generated different visual protocols and analysed the answers of each user, team and the entire group of designers.

7 Discussion

7.1 Feasibility

Of the 135 questionnaires that were distributed, 131 were completed. This represents a response rate of 97%. Thus, the results were representative of the group surveyed. On the scale of the design team, all the designers systematically completed the questionnaire in 6 of the 8 teams that participated. Aside from a good response rate, we were able to analyse a majority of the teams through complete data.

These numbers confirm that this method is not time intensive for the designers. This is due to the simplicity of the questions as they relate to mental energy and the rapidity of the answers (less than 10 min).

Contrary to other existing protocols that interrupt the designer in his/her activity, this data collection method perfectly slipped into the process without causing any disturbances.

Moreover, this method offers the advantage of covering many design teams at the same time during short collection periods (5 times 10 min per designer over 13 weeks). It also permits the collection of analysable data at different levels: by studying only the designer, the design team or the entire group of designers.

Its weakness lies in the respondents' understanding of the questions. Following the first completion of the survey, and after having received an explanation beforehand, it was necessary to re-explain each question and to give examples of possible answers. It should, therefore, be noted that for future use, this method of collection needs to be accompanied by a session wherein respondents are given a detailed explanation of not only the concepts and useful categories, but also the vocabulary used. It also seems necessary to give examples of possible answers on the questionnaire itself.

Lastly, certain designers did not perfectly follow protocol, as they completed the questionnaire after and not before the project review. This protocol was put in place to avoid any influence that a negative review may have on the designer's evaluation of the relevance of the means of design. From our post-experiment discussions with the respondents, it seems that negative reviews did not have an impact on their answers.

7.2 First Results

In order to prove the efficiency of this method, the writers propose to choose two types of data collected to show the way in which they can be used. The first chart (Fig. 1) details the means chosen in the order of the most important for each designer throughout the 5 sequences of the process. In the same way, we are able to obtain detailed charts for the means chosen in the order of the second, third, fourth and fifth most important for each designer throughout the 5 sequences of the process. It is, therefore, interesting to reconstitute the means chosen in order of importance for each actor in sequence 1 of the process and then in sequence 5 (Fig. 2).

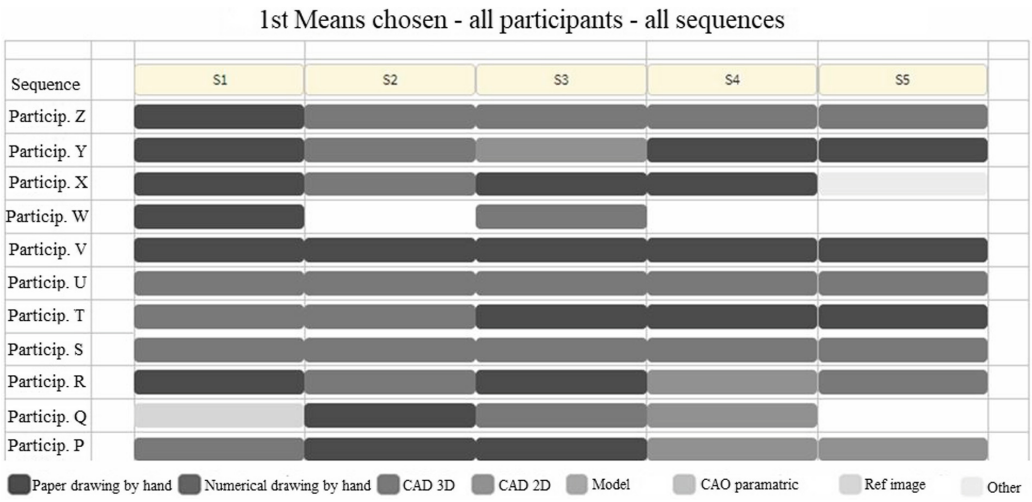

Fig. 1. Means of design chosen in order of importance.

On the basis of this data, we can identify patterns of use and how they complement one another throughout the different sequences and during the overall process. For example, two patterns that occur in sequence 1 are the series of "Paper drawing by

hand – CAD3D" and "Paper drawing – Reference image". These two patterns are no longer present in the sequence 5, where we observe a series of "CAD2D – CAD3D" instead.

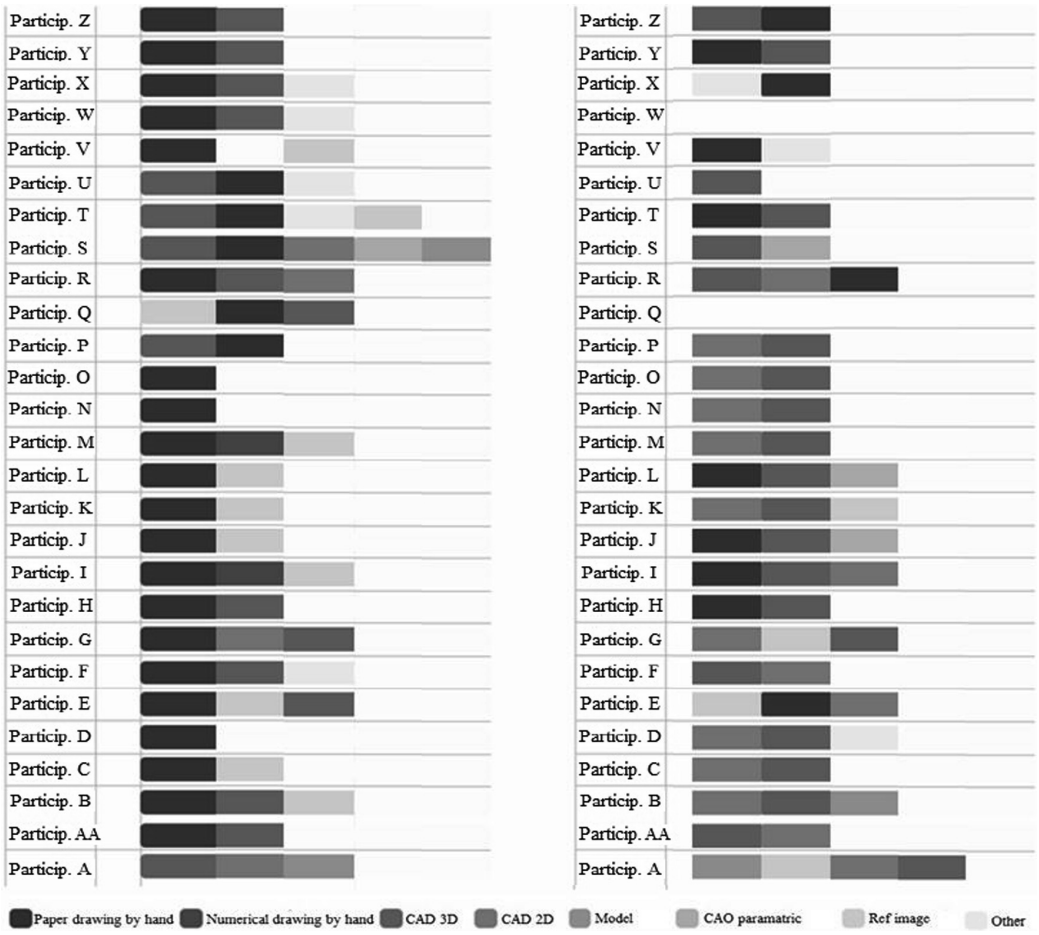

Fig. 2. Means chosen in sequence 1: on the left and in sequence 5, on the right, by order of importance.

The second chart, used to illustrate this method (Fig. 3), shows the proportion of usage of the different representations by all the respondents throughout the 5 sequences and the overall process. It can thus be seen which representations were used the most and the least in each sequence and in the overall process. Also it shows whether their uses fluctuated throughout the process. We observe, for example, that blueprints and sketches were considerably present at the beginning of the design, but they decreased with a slight, but gradual consistency throughout the process. The plans and cuts were also widely used. While they appear from the beginning of the process, they are particularly significant in the more advanced phases of design. As for the reference images, they are constantly used to support the discussion and other representatives, irrespective of the moment observed.

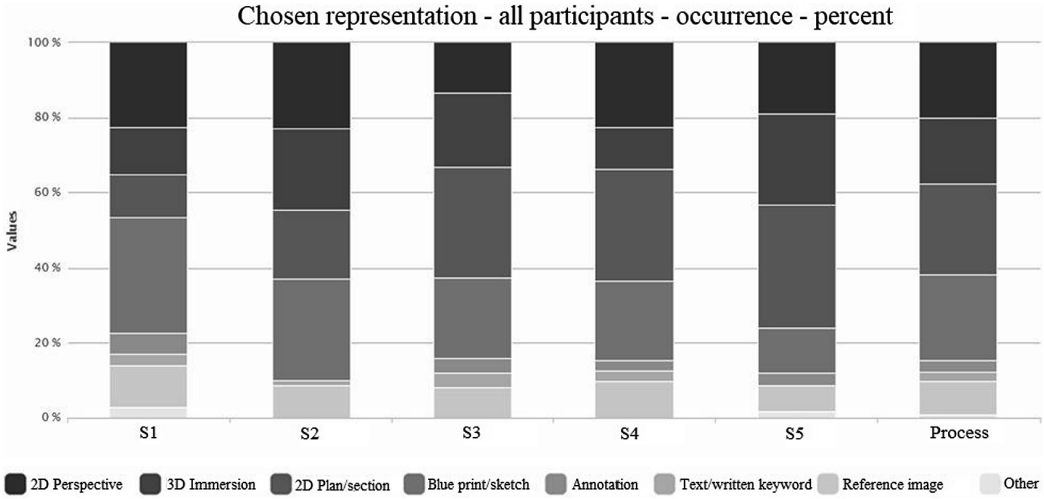

Fig. 3. Percentage between the chosen representations.

8 Conclusion

8.1 Summary

The data collection method presented in this article collects different data on the uses of means of design and support-representations throughout a four-month collective process of architectural design. It demonstrates which means are truly adapted to the methods of design and, more specifically, it shows the recurrent patterns of use. It illustrates the frequency of use, the usage, user satisfaction and the reasons for the choices of the tools.

As a result of the descriptions of the different means available to the designer, this method permits the researcher to trace their usage throughout the entire process.

Immersive and centred around the user, this method demonstrates the importance of keeping research protocol as light as possible for the designer so not to encumber their mental charge or to disturb the design process.

Aside from these patterns, the data allows us to respond to other themes such as the alteration of the means and the value-added potential of their appropriation by the user, as well as the respect of the spontaneous process of the designer in the conception phase, the efficiency of the means and the representations ….

8.2 Limitations

Three limitations were observed during this experiment. The first was the understanding of the questionnaire by the respondents. They had issues understanding the concepts and the questions. The writers' perfect understanding of the Master's workshop allowed them to identify key moments for data collection. This could prove to be more difficult in a less-controlled environment or in a professional setting.

Lastly, the designers had the same background, even if some of them had different Bachelor's degrees. The first convergent results would have likely been impacted had this not been the case.

8.3 Outlook

This work presents an initial view of the usage of the method presented in this paper.

This method appears to be equally appropriate in a larger framework with more design teams and/or more designers per team. Therefore, we plan to apply it in a professional setting beyond the pedagogical context presented in this paper.

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