Flat Form:
A Software Design for Capturing the Contribution of Personality and Ordinary Activities in the Design Process

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Abstract. Flat form is an ongoing research that introduces a workflow that aims to enhance the contribution of the user during the design process. At first, implicit as well as explicit data, about both space as a living place and the user as a personality, will be captured. Then, the data will be analyzed in order to build an ontology that will eventually be visualized in human readable format. After that, an external application will evaluate the resulting data structure, pointing out any potential conflict between the spatial arrangement and the user’s desires. The outcome will be visualized in a form of a topological diagram that will constitute a new augmented “active” memory for the architect.

Keywords: Participatory Design, Ontology, Topological Representation, Human-Computer Interaction

1 Introduction

What is a design process? A brief answer could be that a design process is a reaction to a design problem. Usually, such a reaction is considered as a cognitive process that receives, manages and infers information in order to recall or create units of knowledge in the context of a problem-solving method (Definition: Symbolic Order, 2016, Hamel, 1995, Norman, 2013). The information or the unit of knowledge is either stored to or extracted from memory. According to Hamel, memory is divided into three sections, “Long Term Memory”, “Short Term Memory” and “Working Memory” (Hamel, 1995). Each part refers to nonactive, active, and instantly activated information respectively each time a problem solving process occurs.

Normally, humans break down the whole, maybe yet unknown, problem into clear parts using their “active” memory. At the same time they retrieve further information from both “working” and “long term” memory in order to eventually find a solution. Especially for design problems some extra data is required deriving from additional external sources such as visualizations (Hamel, 1995, Alexander, 1965), interviews or live data monitoring.
The limited capacity of the “active” memory (Hamel, 1995), the intense need for different data sources, and the inability of the human mind to access too complex data structures “in a single mental act” (Alexander, 1965) are the key motivating challenges for this research.

2 Defining Design Process

How is the design process generally applied? The immediate response to a problem usually drives to an intuitive and likely rough solution. Most of the time, the initial satisfaction is temporary, the need for improvements emerges and thus an optimized version is achieved. This step is repeated until the optimal solution is found. Through this trial and error method, all the potential aspects of the design problem that may emerge are integrated into the solution over time (Lawson, 1997). This “craft-based” method, that is mostly common in vernacular design problems, created a one-to-one relationship of master and apprentice. The most common workspace in which this relationship was developed was the house of the craftsmen. As a result, in the pre-industrial era work space and domestic space were identical. This mix also had a high impact on the way of life (Forty, 1995).

On the other hand, in the post-industrial society, the notion of the house was totally different obtaining its own substance distinct from the workplace (Forty, 1995). As a result of the removal of the working place from the houses, the model of everyday life changed completely. The house “acquired a new and distinctive character, which was vividly represented in its decoration and the design of its contents” (Forty, 1995). The desire of having a place that people could relax away from the “oppressive conditions” of the working environment, transformed the house to a “mirror of self” (Marcus, 1995).

Since the nineteenth century, the house was already identical to the personality of the owner. Although it was supposed to reveal especially aspects of the housewife’s character, this assumption was superficial and strictly related to her femininity (Forty, 1995, p. 105). During the twentieth century, though, as psychoanalysis was gaining ground, the relationship between the house and the habitat started to become more substantive. In a deeper analysis of human nature, George Herbert Mead mentions the contribution of physical objects to the form of self-identity. Although still mostly driven by external sources like magazines and books, the unconscious selection of furniture for a house describes aspects of our character (Marcus, 1995).

In this social context, Richard Neutra developed his own design method which was a primary form of participatory design. Although Neutra was an important figure of modernism, he brought the user in the centre of the design process, objecting to a mass housing approach. Many years before psychoanalysis become widely accepted as an official therapeutic method, Neutra was engaged with the impact of “empathy” on architectural space. Because of his close relationship with Freud he soon developed an increasing interest in psychology and the ways it could affect space. He was always curious about “the unconscious and all kinds of irrational motivations that swirl around the production and reception of architecture” (Lavin, 2004). Highly influenced by Freud’s text ‘The psychopathology of everyday life’, he focused on
"the most unconscious and habitual minor details of domestic life" (Lavin, 2004). Considering also Wundt’s theory about the relationship of the sensory apparatus with consciousness, he developed his own design process trying to objectify “the body and its perception” in the notion of home while the contemporary architecture was trying to rationalize the program and the structure of a house building (Lavin, 2004). His overall goal was to embody “mood” in the space. He truly believed that this could happen through the close relationship he was creating with his clients through extended interviews, continuous correspondence and detailed questionnaires. Using this intense communicative method to extract data, he believed that he could transform the house to an affective emotional environment (Lavin, 2004).

In the contemporary era, within a totally different context from that of the architectural practice, a pioneering research group of MIT develops contemporary user - centered architectural design strategies integrating various digital processes. The academic research is highly focused on the study of the interrelations between the user, the technology and the house in a complex network of living ("House_n Introduction," 2016). In order to collect the “live” data required, the laboratory established real scale “living labs”. The research methods aim to study human behaviors, to identify interaction patterns and to reveal implicit needs and desires through the live monitoring of everyday life. The space used for current projects is called “PlaceLab” and is fully equipped with different kind of sensors and monitoring devices so as to capture any potential data for both the user and the activities that are being held. Potential users can voluntarily participate in the project for various durations ("House’n The PlaceLab," 2016).

The above mentioned examples constitute two leading approaches of architect-client interaction in the context of user-oriented design methods. The former refers to a preparatory stage of the participatory design in terms of user’s desires’ extraction through intensive communicative processes. The later presents an academic research which uses cutting edge technology to capture live data about the everyday life and bring user’s participation on a more active level. Although the two processes presented are completely different regarding the social context, the user’s approach and technology available, the perennial goal is still to capture as many implicit data relevant to the user as possible. In between an unspecified number of studies have been carried out addressing similar challenges (e.g. Graham, 2015, Cemons, 2004, Torabi, 2012).

### 3 Looking for a Knowledge-Based Data Structure

The main challenge a designer has to confront is the nature of implicit data. Describing attributes and relationships among entities, it is neither quantitative nor visually perceivable. In mathematical terms, objects that share the same attributes regardless of the way they are represented are considered as topologically equivalent ("Topology – from Wolfram MathWorld," 2016). Thus, in this research the data required are considered as topological data. In order to collect, organize and eventually use this data, a particular structure is necessary. The most important aspect of the qualitative data is that it has to be inherently enriched with knowledge in order to be significant. As a result, a knowledge-based data model is required. Such a
conceptual model is called a semantic model. Since a semantic model represents a set of relationships, and includes entities describing the way these concepts are informed by each other. The occurring concepts should correspond to a part of the real world, and the overall structure should be capable of answering real problems. Semantic models are widely used in research to capture topological information regarding either the geometry of space (e.g. Tamke, 2014, Langenhan, 2011) or space as emerged through user’s needs and actions (e.g. Meagher, 2016). An advanced version of semantic model constitutes an ontology ("What’s a semantic model and why should we care?" 2007). In the contemporary world various projects are based on ontology-based applications. However, this method of data manipulation is not widely used in the design process yet (Meagher, 2016). Most design applications that use ontologies aim to the creation of a data warehouse as a meaningful case library of topological characteristics of the building, in terms of geometry, to be used in BIM or other applications (e.g. Lin, 2013).

4 Methodology

The aim of this project is to create a hybrid design method integrating computational operations as an extension of the mental process. The mixed strategies help the designer to visualize all the aspects of the architectural problem enhancing the “active” memory of the architect. The variety of the research methods that have been chosen proves that the different stages of the process are neither clearly distinguishable nor linear. Aiming for an alternative representation of the everyday life of the user, as well as the identification of the “kind of personality” the research methods comprise data collection, software development and information visualisation.

Data collection is the most common step in research. During this stage the researcher identifies the most appropriate questions that address the subject and starts gathering information about the respective variables. This process “enables one to answer stated research questions, test hypotheses, and evaluate outcomes” (“DataCollection," 2016). The data collection could be either an active or a passive process. Active processes involve human interaction whereas passive methods are focused on mere observation. The methods employed for this project stem from both types and are summarized in an architectural drawing, a personality test, a sketch and an interview (Fig. 1).

The architectural drawing can be either provided by the user or designed by the architect on a previous visit to the place during the first meetings of the stakeholders. The data captured form the measured drawing consists of the dimensions of the space in order for the relative size of each room to be identified based on its area, the spatial characteristics of the space like surfaces and columns as well as the adjutancy of the rooms.

Trying to decompose and understand the human personality scientists conducted series of statistical analyses regarding the words people usually use to describe themselves as well as other people. As a result the Five Factor Model (the Big Five) was created ("Personality and Social Dynamics Lab I Sanjay Srivastava," 2016).
Extraversion, agreeableness, consciousness, neuroticism and openness to experience are the five factors of personality traits emerged. Depending on the objectives of the research a further level of distinction may be useful. For that reason different kinds of inventories have been created. For the purpose of this study the IPIP-NEO (International Personality Item Pool Representation of the NEO PI-R™) by Dr. John A. Johnson is used. Some of the advantages of this particular inventory are that it is free when accessed online for educational purposes, it is based on the International Personality Item Pool - A Scientific Collaboratory for the Development of Advanced Measures of Personality and Other Individual Differences (IPIP) by Dr. Lewis R. Goldberg and it provides instant online and quite descriptive response. However, because its primary purpose is to educate people and because only the shorter version is available without cost it may impose some limitations on the accuracy of the results ("IPIP NEO-PI, Introductory Information," 2016).

An additional way to extract more implicit data for the personality of the user is to use art therapy. This approach uses “art-based assessments to evaluate emotional, cognitive, and developmental conditions” ("Art therapy," 2016). House - Tree – Person (HTP) is one of the tests that employs visual expression. The patient has to produce detailed drawings of a house, a tree and a person. These drawings are then analyzed by the therapist based on both qualitative and quantitative criteria. Focusing on the house’s analysis some of the important aspects are the overall size of the drawing, the stroke of the lines and the scale of spatial elements (windows, doors) in comparison with the whole house. For example, a considerably small size of drawing could be interpreted as rejection of the family life and weak lines on the walls could imply weakness in the ego ("House Tree Person Drawings," 2016). Although there is a detailed manual in order for the examiner to score appropriately the outcome, the test remains to a large extent subjective. For that reason, the person who evaluates the test should be trained in the method in order to extract as accurate results as possible ("House-tree-person test," 2016). Following the principles of the HTP a sketch drawing method is employed. The importance of the sketch lies in its use as self-expression. The user is free to draw his home as perceived on a piece of paper. The only restriction is that at the end he should use trace paper to superimpose on the top of the sketch a colour-coding of spaces according to activities. This annotation is useful because the range of space used for each activity can be instantly visualized. The analysis of the sketch according to HTP is followed by a set of questions which can either be selected from the manual or be created by the examiner. In the case of this project the questions are created by the researcher and they are integrated in the follow-up interview.

The last input needed for the system to start analyzing the data is a semi-structured interview. The architect initiates the process asking the user to describe verbally the sketch of the dwelling. After that questions about the everyday life of the user follow. The sequence of ordinary activities and the domestic habits as well as their correlation with the space and the spatial qualities (lighting, ventilation, transparency) it is quite important to be mentioned during the interview. The last area of interest is about the potentials and the obstacles of the house to become the user’s home, the desires and the dissatisfactions (Forty, 1995).
Among various knowledge-based models, ontology is the most appropriate for the purpose of this research. Ontology relationships between those concepts ("What’s a semantic model and why should we use it?" 2016). A descriptive vocabulary is established and the knowledge captured becomes instantly explicit. The information is available to be analyzed, shared and reused ("What is an ontology and why we need it," 2016). In order for that knowledge to be represented and both human and computationally interpretable, a semantic data obtains properties and property values ("XML RDF," 2016). Based on these relationships built is called the "triplet" and consists of a "subject" and an "object". Thus,

Fig. 1. Diagram representing the entity of home as well as the contribution of input data to the overall process

5 Developing Software

In order to capture the information desired as described above both manual and automated processes are applied either on an analog or on a digital mode. The data from the interview and the sketch are extracted manually by the architect. The direct interaction of the two people helps to enhance their relationship as well as to capture the overall abstract perception a user has about his dwelling (Cemons, 2004). Thus in this stage an automated process would be responsible for potential loss of information. However, the automation is useful in terms of time saving, so it can be used to extract quantitative data from the personality test and the architectural drawing. The personality test using a Likert scale ranking is already analyzed by Dr. Johnson. On the other hand, the analysis of the architectural drawing does not include any automated operation yet. In the future work of this research though it will be analyzed based on an image-analysis algorithm which will provide data about the area of spaces, the spatial characteristics and the accessibility of the room.

Depending on the methods of data collection the information has already a specific structure. One of the project’s objectives is to integrate all these different structures in a single knowledge-based data model. A software development is thus employed. Among various knowledge-based models, ontology is the most appropriate for the purpose of this research. Ontology “consists of a network of concepts and the relationships between those concepts” ("What’s a semantic model and why should we care?" 2007). A descriptive vocabulary is established and the knowledge captured becomes instantly explicit. The information is available to be analyzed, shared and reused ("What is an ontology and why we need it," 2016). In order for that knowledge to be represented and both human and computationally interpretable, a semantic programming language is required. To enhance the interoperability of the software a Web Ontology Language (OWL) is employed. OWL is built on the XML and RDF formats. XML (Extensible Markup Language) is a passive programming language unable to carry out any function unless an application is executed. The main purpose is to facilitate the process of building an ontology, to combine the data, building the interrelationships. The relationship built is called a "triplet" and consists of a "subject" and an "object". Thus, the author is able to create his own vocabulary using customized tags and build a self-contained descriptive data structure. The format used to store the data is plain text which makes the document readable by both humans and electronic devices. The use of text also improves interoperability between different applications and operating systems. Although these attributes make the data quite flexible in terms of usability they do not provide any kind of semantics. This gap can be covered by RDF (Resource Description Framework) standards. RDF is a computer readable framework which provides any kind of semantics. This gap can be covered by RDF (Resource Description Framework) standards. RDF is a computer readable framework which provides any kind of semantics. This gap can be covered by RDF (Resource Description Framework) standards. RDF is a computer readable framework which provides any kind of semantics. This gap can be covered by RDF (Resource Description Framework) standards. RDF is a computer readable framework which provides any kind of semantics. This gap can be covered by RDF (Resource Description Framework) standards. RDF is a computer readable framework which provides any kind of semantics. This gap can be covered by RDF (Resource Description Framework) standards. RDF is a computer readable framework which provides any kind of semantics. This gap can be covered by RDF (Resource Description Framework) standards.
advantage is that the stored information can be transferred wrapped in tags. Thus, the author is able to create his own vocabulary using customized tags and build a self-descriptive data structure. The format used to store the data is plain text which makes the document readable by both humans and electronic devices. The use of text also improves interoperability between different applications and operating systems. Although these attributes make the data quite flexible in terms of usability they do not provide any kind of semantics. This gap can be covered by RDF (Resource Description Framework) standards. RDF is a computer readable framework which combines the data, building the interrelationships. The relationship built is called statement or “triplet” and consists of a “subject”, a “predicate” and an “object”. Thus, data obtains properties and property values ("XML RDF," 2016). Based on these principles OWL uses more semantics structuring the data model accordingly. In order to facilitate the process of building an ontology, Protégé ontology editor is used.

Once the ontology is structured, an external application is needed to evaluate it and mention any potential conflicts identified. As already mentioned some of the automated process are not digitally applied yet, so at this step the evaluation of the ontology is conducted manually by the author. Each activity according to the vocabulary of the ontology triggers a personal trait and occupies a certain space. The first step is to set the conflicts between the personal traits which are self-evident. After that the opposing activities are inferred from the ontology or defined manually by the user. Some of the relationships emerged between the ontology’s entities are architecturally contradictory while some others are considered by the user as such. All these inconsistencies constitute the evaluating application’s rules. The ability of constructing customized rules makes the application flexible and efficient. Thus, Flat Form creates five conditions to evaluate the whole structure.

#rule 1
If activity’s experience is rated as negative by the user
#rule 2
If two contradictory activities occupy the same room
#rule 3
If two related activities which trigger conflicting traits occupy the same room
#rule 4
If an activity affects more rooms than the one it occupies
#rule 5
If an activity occupies rooms which are not adjacent

then conflict is identified

6 Visualizing Information

The most effective way to communicate complex information is to use a visual sign-system. Using the processes of human cognition and the “schemata” developed, the visual perception is able to capture instantly multiple data in a non-linear order, evaluate it and create inferences. In this workflow there are various levels of
visualization. Although ontology creates a human readable data structure preserving the inherent complexity of the data collected, it is still too difficult to understand it because of the text format. A topological diagram which describes objects and their emerging relationships is therefore the most appropriate graph for this research (Meagher, 2016, p.4). Topological graph consists of a network graph, which communicate the knowledge carried by the data structure ignoring any morphological aspect of the data described. Consequently, a vocabulary of logos is established by the author in order to depict the knowledge acquired (Fig. 2).

![Fig. 2. Legend of topological diagram created by the author.](image)

The final step before user’s feedback is for the architect to use the above mentioned graph and translate the data captured into space. The ability of visual perception to capture data in all three dimensions is now necessary to be triggered in order for the spatial information to be communicated. As the term of visualization is continuously updated, Virtual Reality (VR) is now considered as a contemporary interactive technique of visualizing information (Fuller, 2008). The immersion helps the user to envision the changes implied by the space on his everyday life regarding activities and feelings rather than a lifeless space. Using this method the feedback the user provides at the end is as close to the reality as possible.

### 6.1. Case Studies

In order to test the initial hypothesis that the user’s personality and ordinary activities could inform the design process through software development two case studies are implemented. In the context of this research a comprehensive outline of the whole
workflow is designed as a proof of concept. This paper constitutes a part of an ongoing research so it is focused more on the operations during the early design stages. The processes which are supposed to be automated are manually conducted in order to save time from troubleshooting. Thus, selected operations are presented. As case studies a studio and an one-bedroom flat are selected to limit the complexity of multiple users (Graham, 2015). Following the research methods as presented, the data required are collected, an ontology is developed and the rules of the evaluating application are implemented to identify any potential conflicts.

The first step in order to facilitate the overall process for the user is to create a friendly and familiar “environment” which will ensure a gradual and pleasant interaction with both the physical and computational agents. To collect the data required for the following analysis a first layer of a completely digital interaction is activated. The goal of the first contact with the system is to use the interface provided to upload the data required without precaution due to any potential involvement of the architect. The initial welcome screen functions as an interactive guide which will help the user to navigate through the platform. Three main buttons are instantly available. “User” and “architect” buttons provide the necessary instructions for the data to be uploaded while “about” button gives a brief description of the application. Once the user is selected the next screen shows a menu which guides him to a step by step process to import all the data about himself as well as his dwelling. Two additional buttons for the “personality test” and the “sketch” become available (Fig. 3).

![Instructions](http://www.personal.psu.edu/~j5j/IP/IP/ipineol300.htm)

Fig. 3. User’s interface - Screen of personality test

After the completion of these steps the “home” button should be pressed in order for the architect to get involved to the process by clicking the respective option of the initial screen. The first interaction between the two persons is an extended interview which includes open questions about the domestic life of the user and a further discussion about the sketch created. The last upload needed is an architectural drawing of the house including all the measurements.
At this point the aforementioned data is categorized in classes and attributes introducing the vocabulary needed for the knowledge-based model. Based on this vocabulary a semantic model is eventually structured. OntoGraph plugin is used by the architect to navigate in the ontology editor in order to access the whole data-model (Fig. 4). Subsequently, the evaluation of the data structure takes place in order to visualize potential conflicts regarding activities.

![Ontology Visualization](image)

**Fig. 4.** Part of ontology visualization using OntoGraph plugin – indication of object and data properties related to “cooking” concept

Afterwards, the architect considering the outcome of the evaluating application is able to translate the topological diagram into VR space. The scenarios suggested rearrange the space in order to eliminate the difficulties encountered during the respective activities as well as to enhance the overall home experience.

A studio of 25m² constitutes the first case study. The design of the apartment does not predicate any change to properly accommodate different activities in the same room. So, the coexistence of a fixed private space with a potentially shared one makes the place inadequate to host guests. However, the most salient traits of user A were extraversion and openness to experience. Thus, based on rules 1, 2 and 3 a conflict regarding “socializing” and “sleeping” activities has been identified.

Analyzing case study B the activity of cooking was identified as problematic because of the rules 4 and 5 (Fig. 5). Expanding the concept of “cooking” in the ontology, two object properties are firstly activated. The information acquired is that user B usually cooks with friends because the two activities (cooking and socializing) are interrelated and “cooking” is considered as hobby as well. In a further expansion some spatial relationships are revealed. Although “cooking” occupies the kitchen, in this case kitchen is “split” in two non adjacent rooms. In addition, the main space
used for the activity is quite small to accommodate more than one person. Consequently, spatial conditions are against the desired experience.

Fig. 5. Part of the topological diagram presenting the conflict identified regarding the activity of “cooking”, according to rules 4 and 5

7 Discussion

Sometimes even if the user is able to recognize the difficulties of everyday life it is not possible for him to identify the source of these problems. Quite often the problems start from or even are reflected to the personal space which thus becomes a crucial factor in the equation. The implicit nature of those problems constitutes one of the main concerns of this project. The research conducted explores the contribution of software development in a participatory design process. However, the workflow is a combination of both analogue and digital operations in order to reinforce the direct relationship between the architect and the user (i.e. interview, sketch) while taking advantage of time-consuming procedural tasks (i.e. computational data analysis, ontology) and evaluating the initial hypothesis (i.e. visualisation). As this paper is a part of ongoing research there are still areas for continued development. In future work, some of the limitations of the research will be further investigated such as the status and the number of users involved in order for the design process suggested to be used in various contexts. Additionally, the digital operations required, such as image analysis, are going to be automated, so as to be able to save time and maintain a concise structure of all data used. Finally, the link of the ontology to the 3d
Immersive environments will be further explored in order to enhance the “active” memory as mentioned in the final steps of design process as well.

Acknowledgements. “This work was conducted using the Protégé software, which was developed by the Stanford Center for Biomedical Informatics Research at the Stanford University School of Medicine.

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