Towards a novel method for Architectural Design through μ-Concepts and Computational Intelligence

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Abstract. Architects typically tell stories about their design intentions and then translate the verbal descriptions into action-based commands in Computer Aided Design tools. In other words, during the creative process the designer works in a "concepts space" that is different than the "properties space" available in the software virtual world of CAD tools. In this paper we propose to study the vocabulary of concepts used in architectural design by employing machine learning methods over large data-sets of architectural drawings and their storytelling descriptions. The intention is to computationally characterize the meaning of a set of high-level concepts in architectural design, which we call them as *μ-concepts*, in terms of a set of low-level properties of drawings. With such a correlation, new opportunities can be explored for radically different design tools that allow architects to design by operating over such high-level architectural concepts. Eventually, this will can also provide a novel way of understanding the mental process of architectural design through verbal concepts.

1 Introduction

We are motivated by the linguistic depth with which architects think and communicate while developing their designs. Considering then that an architect conceptualizes design thoughts primarily through Computer Aided Design (CAD) software, we identify a gap between the linguistics of exchanging ideas at a conceptual level and visualizing them in the computer setting. If an architect is able to *use the linguistic schemata of conceptual thinking directly in the CAD software*, then the gap can be significantly bridged allowing for the *emergence of novel design tools*.

A major challenge is that the concepts and words that architects use are neither limited to a certain number, nor inscribed by any means of literature of design theory. Therefore, any approach that studies some specific cases over a "fixed" vocabulary is limited and biased towards the subjective choice of concepts at the particular time and space of the analysis. Employing modern computing paradigms that reveal the "collective wisdom" of communities, we aim at introducing an intelligent system that can learn any set of concepts from given examples and provide an automated form of understanding and detecting those concepts on designs and drawings.

The greater vision of the proposed line of work is to incorporate a computational understanding of conceptual thinking in the design process of architects. One can imagine a new generation of CAD software (or plug-ins for existing ones) that will feature tools related to high-level concepts rather than tools that perform low-level actions. For instance, instead of applying the basic command "break" of a line or a solid object in Rhino software, we can ask the program to "make the object smaller". What this project proposes is a rich set of concepts or ideas that are currently used in the design world as a "specialists slang" language: "make it larger", "make this volume sharper" or "create an introverted composition around the courtyard", to become a central integral part of design architectural tools.

2 Studying μ-Concepts in Architectural Design

What are we trying to achieve and why will it make a difference? We believe that currently there is a gap between the thought process of architects and the actions they can take in a CAD environment. In reality this gap refers to the separation of human intelligence from computer intelligence [10], in the sense that during the creative process the human designer works in a different "concepts space" than the "properties space" available in the software virtual world. The goals of this line of research revolve around bridging this gap and enabling novel forms of collaborative design between designers and computational machines in a new generation of CAD software tools, as follows.

Goals. A primary goal is to identify a set of design concepts currently used by architects in the form of verbal communication. Architects regardless of national or linguistic differences often utilize a set of special words in order to express design intentions. Although the actual meaning of those words might be slightly different in different contexts, architects do inscribe certain design concepts to them. A technical goal then is to create a system that is programmed to understand automatically those concepts by reading architectural drawings and text descriptions and correlating formal (low-level) design properties to casual (high-level) architectural concepts. Every single architectural drawing operates as a source of quantifiable data that describe space and architectural form. Simultaneously, verbal or written descriptions express design information. Thus, both architectural drawings and text descriptions operate as repositories of architectural information. The final goal is to embed the ability of understanding concepts, through the developed system, to novel architectural design tools and methodologies.

How does the proposed line of work go beyond the state of the art? The introduction of Computer Aided Design (CAD) tools has revolutionized a number of creative industries, and substantially changed the pipeline for creating new products, with architectural design being one of the most striking examples. CAD tools are used in creative tasks in order to minimize development time and cost, reduce human effort, and support collaboration among members of a design team. In practice CAD tools operate as "the designers slave" [7, 9] following the tasks instructed by the human designer and often carrying out labor-intensive low-level operations, e.g., simulations, calculations, etc. The design process becomes more interesting when the computer takes the role of a “colleague” [4] and can contribute to the design by proposing different alternatives and allow the co-creation of less conventional ideas. Classic work such as [2] as well as recent work in the so-called mixed-initiative design paradigms, e.g., [3, 13], show that this direction can be very helpful in the similar design setting for virtual spaces in videogames. The novelty of the research project is that it not only envisions the architectural CAD software as a collaborator to the human designer, but also incorporates essential high-level design concepts human-computer discussion, which are missing from all currently existing tools.

What is the expected impact of this line of work to architectural design? We expect that the realization of the goals and objectives will enable a new perspective in the methodology of architectural design and will open up novel opportunities in all aspects of architecture. These include the vocabulary used in the design process and the story-telling for architecture results, the CAD software tools capabilities, as well as the understanding of the cognitive processes carried out by designers. In particular, this line of research offers a revolutionary way for looking into the designers internal thoughts and representations by correlating the concepts they use verbally with formal elements that can be identified in the drawings.

3 A Five-Phase Research Plan

In order to realize the identified goals, we will follow a 4-phase technical plan as follows. In Phase 1, we will investigate and specify the set of μ-concepts that we want to incorporate into a new generation of design tools. In Phase 2, we will look into the low-level properties that can be identified directly from architectural drawings, such as dimensions, local or global area, thickness of walls, length of openings, number of columns or structural elements, relations between elements, etc that represent specific values and quantitative data. In Phase 3, we will use the output of Phase 2 along with user-generated content for existing architecture designs in order to populate a large dataset of information that demonstrate organic examples for the correlation of low-level properties and the high-level emotive concepts. In Phase 4, we will employ standard machine learning tools in order to train an intelligent system using the dataset from Phase 3. Finally, in Phase 5 we will look into how this new automated form of understanding for architectural drawings can be incorporated into a new CAD tool and motivate a novel design methodology.

3.1 Phase 1

This research will specify μ-concepts in architectural design. Right now, architects tell stories about designs metaphorically using multiple words enabling multiple design possibilities. However, the storytelling process for designers does not consist of a set of predefined words, but rather as a selection of words with relatively close meaning. At this point, we will study the literature of architecture, design and computation, as well as linguistics, in order to find similar case studies. Simultaneously, we will use methods from earlier work in the Plethora Project [11] in order to identify a variety of concepts that architects and non-architects use when they narrate a story of a 2D or 3D representation. In the context of Plethora subjects were asked to produce sketches of existing models and then map models to existing sketches. In our case the subjects will be asked not only to tell a story, but also to identify concepts as keywords for their stories. Acquiring knowledge from architects and non architects will allow us to map concepts that are repeatedly used by one of the groups or by both architects and non-architects.

3.2 Phase 2

Through this research, we will identify low-level properties of drawings, and develop a tool that performs automated extraction of the properties from a given diagram. Right now, low-level properties of drawings such as dimensions, area, the ratio of volume and void, etc. are defined by CAD software. CAD tools understand designs as local and global topologies of points and lines in the design space, with specific values. Considering that the current low-level properties in CAD have particular values, we will be able to extract values for properties that are not visible by the user, but they have hidden values. For instance, the length of the openings on a plan can be measured by the length of the lines with specific width or the length of the exterior walls by the thickest lines. In this way, the proposed apparatus can extract data from any architectural drawing in an automated way, and provide a mathematical representation of the properties and relations of the elements in the design.

3.3 Phase 3

The system will build a dataset to be used for training a machine learning system that identifies μ-concepts in drawings. At this step, we will create a dataset of properties and μ-concepts that are extracted by a large set of existing drawings and descriptions. The system will extract values from drawings for the given set of properties using the automated extraction tool of Phase 2. Then for the extraction of μ-concepts we will use a small collection of commonsense rules and higher-level reflection patterns similar to the ideas developed in Genesis project [12] in order to extract the μ-concepts from the stories or descriptions that are available for the drawings in the dataset. The engagement with Genesis project will give us the chance to explore how groups of words or intentions are recognized under the influence of particular words that describe an architectural project, even though certain concepts are not mentioned. An alternative way to "extract" the μ-concepts for architectural design in the dataset is by engaging architects to provide *user-generated content*. With a simple smartphone application that demonstrates drawings and asks the user to flip left if it is "fragmented" or "flip right" if not, architects can provide the information missing about μ-concepts such as "fragmented" or "extroverted", and generate a complete dataset in the form of the following figure.

3.4 Phase 4

The proposed system will develop a tool for the automated evaluation of architectural drawings with respect to the specified μ-concepts. This phase utilizes the dataset that

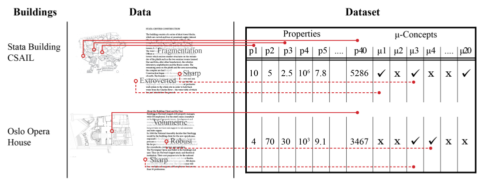

Fig. 1. The dataset for Phase 3: properties will be extracted from drawings and μ-concepts will be extracted from accompanying text.

Fig. 2. Architects can select through an app whether a μ-concept is supported in an architectural drawing.

comes out as output from Phase 3 in order to train a machine learning system that can understand μ-concepts and evaluate drawings with respect to those. More formally, the system developed in this phase will take as input an architectural drawing and will give as output the support level as a percentage for each of the μ-concepts specified in Phase 1. For realizing this system we will rely on existing successful methods for "supervised learning" from the academic field of artificial intelligence, that allows to automatically infer a function from labeled training data [6]. In this context, the system receives positive and negative examples of concepts along with the values for the properties (i.e., the dataset from Phase 3) and is able to train itself to identify μ-concepts from the properties that are extracted from the drawing.

3.5 Phase 5

Having a trained system that can evaluate architectural drawings with respect to μ-concepts, in this phase we will investigate how this can be embedded in existing CAD tools and motivate novel design processes. One direction is to explore how a computer designer-collaborator can offer a list of possibilities for the evolution of the current design according to actions that bring the design closer to supporting the different μ-concepts, following a mixed-initiative design approach similar to [3, 13]. Another direction is to look into inverting the internal machine learning interpretations of the system in order to apply the understanding of the μ-concepts in the ongoing works of a designer, similar to earlier work done for images, e.g., in [5]. Finally, we will explore how the μ-concepts can be used to specify a novel design methodology and a new generation of CAD tools that allows the designer to operate on high-level concepts instead of low level actions.

4 Conclusions

The proposed line of research is a multi-faceted project challenging the current ways of producing and communicating architectural design. By identifying μ-concepts emanating from architectural design process and providing automated tools for detecting those concepts through machine learning, we can eventually propose novel design methods based on the quantification of concepts. We envision that through work towards this direction, in the future architects will be able to design by a means of visual conversation that allows the designer to ask the next generation of CAD systems to alter the design along the lines of making it “more fragmented” or “extroverted”.

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