Integrating Crowdsourcing & Gamification in an Automatic Architectural Synthesis Process

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This work covers the methodological approach that is used to gather information from the wisdom of crowd, to be utilized in a machine learning process for the automatic generation of minimal apartment units. The flexibility in the synthesis process enables the generation of apartment units that seem to be random and some are unsuitable for dwelling. Thus, the synthesis process is required to classify units based on their suitability. The classification is deduced from opinions of human participants on previously generated units. As the definition of “suitability” may be subjective, this work offers a crowdsourcing method in order to reach a large number of participants, that as a whole would allow to produce an objective classification. Gaming elements have been adopted to make the crowdsourcing process more intuitive and inviting for external participants.

Keywords: crowdsourcing and gamification, urban density, optimization, automated architecture synthesis, minimum apartments, visual openness

INTRODUCTION
The era of machine learning proposes that information is one of the most valuable resources in modern times. The collection and analysis of as much data as possible has become a crucial step in making automated models, which use the data to make predictions or determine preferences. In many cases, the information is provided willingly, through the process of crowdsourcing. In the field of architecture, such models can be used as an aid for architecture designers and urban designers and planners, by providing instant feedback on their designs. This can become an important evaluation tool in complex dense urban environments. This research is a part of an ongoing project exploring the utilization of machine learning methods in architectural processes. Currently, the research focuses on minimal apartment units, which serve as the smallest compartment in a dense urban context. Following Fisher-Gewirtzman (2016, 2017), the design of minimal units should provide dwellers with low perceived density as a requirement for well-being. In this work, the minimal units are generated automatically (with parametric design); in order to avoid random and unsuitable designs, the process should recognize the suitability of the units’ configuration. As the definition of quality architectural spaces is vague, the collection of a large range of subjective opinions, through crowdsourcing, could lead to the formation of an objective prediction model.
RESEARCH OBJECTIVE
The research seeks to develop an automatic synthesis process for minimal apartment units, designed to provide spaciousness and a sense of wellbeing, and designated for dense urban environments. The process is defined to respond to perceptual and functional requirements, using a learning model composed of optimization and classification modules incorporating crowdsourcing through gamification. The objective of the optimization is to identify apartment units with high values of calculated visibility; this quality indicates designs with low perceived density, and thus suited to densified environments. The solutions of the optimization enrich the database which the learning model bases its conclusions upon. The objective of the learning model is to ensure that the optimization identifies rational solutions, in a vast and flexible search space also containing many solutions that, based on their interior configuration, can be classified as unfit for habitation. It does so by correlating between the parameters of the units in the database and the opinions on them, the latter received from crowdsourcing.

RESEARCH BACKGROUND
Crowdsourcing, or more precisely crowd-rating, is a systematic approach to collecting a large quantity of opinions that collectively form a comprehensive assessment; this is also referred to as the “wisdom of the crowd.” Relying on a large number of willing participants improves the quality and objectivity of the averaged assessment (Morschheuser, 2016), and thus refines the predictions made by the machine learning model (Smola, 2008). Studies have shown that gamifying the process of crowdsourcing–using gaming elements in a non-gaming context–increases the sense of engagement in participants, and their willingness to provide thoughtful input (Morschheuser, 2016). In an architectural context, game elements can be used to stimulate a desired interaction with the visualized space, and to promote impulses for discovery and criticism (Aydin, 2014).

The calculation of visible volume has been found to be directly linked to the levels of perceived density attributed by research participants toward a given space (Fisher-Gewirtzman, 2003; Fisher-Gewirtzman, 2016; Fisher-Gewirtzman, 2018). Thus, the value of visible volume through simulated human vision can perform as an analytic evaluation for spatial configurations with regard to perception of openness. Furthermore, the geometry–apartment units, in this case–can be optimized to reach a higher sense of openness. A common practice when optimizing a geometry in architecture is to define the parameters of the geometry as the decision values, and the performance value as the objective value (or fitness), (extended survey by Grobman 2008). Since the value of the 3D visibility is analyzed from the geometry of the 3D-generated apartments, the appropriate optimization method would be a genetic algorithm. The method simulates an evolutionary process, one in which an initial population of solutions are created randomly. In the subsequent steps of the process, a group of low-performing solutions are eliminated, while the parameters of the other solutions are reproduced, through crossing, to create new solutions. The goal of the process is to create better performing “descendant” solutions with each generation of the genetic algorithm. The genetic algorithm can also be defined to use a binary classification formula, which with each newly generated solution will decide whether the solution should join the population, or should be filtered out entirely.

Binary classification (Smola 2008) is a method of producing a prediction model, which when given input variables outputs a binary outcome, thus classifying the item between two groups. The model is produced by correlating sets of existing data. In the model described in this paper, the input data is the unit apartment solutions, created by the optimization; the output data relates to the suitability of each unit, and is deduced from human opinions, gathered through crowdsourcing.
THE DEVELOPED LEARNING MODEL

The learning model is a periodic process composed of three major compartments: Optimization, crowdsourcing, and classification. Each compartment uses the results of the preceding compartments in an effort to automatically generate minimal apartment units, which hold a reasonable/logical design, where the logic is defined by human participants. The periodic process is presented in Figure 1.

The optimization’s role in the model is to be the actual generator for apartment units, through parametric design (Jabi 2017), thus creating the data utilized by the machine learning process. The optimization procedure is developed in the CAD program “Rhinoceros” and its algorithm editor “Grasshopper,” and uses the genetic algorithm method, with the “Octopus” add-on. The procedure is defined to evolve a variety of apartment units, each with maximized visual openness, a mental need in a densified habitation environment. Visual openness is calculated through the deployment of rays that represent the human line of sight, from three common viewpoints in each unit (the entrance; the sofa or bed; and from the window, facing into the interior space. See Figure 2). The rays are interrupted by collision with obstacles (furniture or walls), and the fitness value for the optimization is the accumulated length of all rays.

The parameters which make up the search space for the optimization are the dimensions of the units and the positioning of interior elements, e.g. bathroom, kitchen, bed. The genetic algorithm operates with the population of solutions, and so it is able to filter units from entering the population if they are classified as unreasonably organized. The decision is made by inserting the parameters of each generated unit into a classification formula, which automatically indicates whether the unit should be analyzed for its visual openness or be discarded from the process. As spatial “reasoning” is challenging to define, the developed learning model uses no prior assumptions as to what a rational solution should be. Instead, it is based on analyzing the opinions provided for previously generated apartment units by external participants, through gamified crowdsourcing. The collected opinions are correlated with the parameters of the units, using the data analyzer “Eureqa”; the correlation forms the classification formula to be used in the next optimization process. The cycle continues as the classification formula is refined by using more generated data, the optimization producing better unit apartments in turn.

THE CROWDSOURCING COMPARTMENT

Crowdsourcing creates an opportunity for capitalizing on the “wisdom of the crowd,” by turning to willing participants to offer their opinions, and aggregating and averaging them into an impartial rating that can be used for machine learning (Chang 2017). Opinions on architectural and interior design may be subjective and differ from one person to another; thus, reaching an objective conclusion for each solution requires gathering a large amount of opinions.

In the current research project, the crowd-rating method was used to collect opinions on the apartment units that were generated by the optimization. Each unit is presented to many participants in a random order. As the classification is simplified into “suitable” and “unsuitable,” the human participant applies variant criteria in order to make a decision on each dwelling unit. Thus, the ambition is to refrain from giving additional weight to opinions by specific groups of people. As an example, architects or students of architecture may prefer specific designs, while what is desired from the process is a more comprehensive insight. Thus, each participant receives an equal vote, and the votes are averaged into an objective assessment of whether the unit is well or poorly organized. Access for participants is facilitated through gamifying an experience which allows the participant to explore apartment units as a first-person agent inside a 3D model. (See Figure 3.)

The simulation, developed with the “Unity” engine, loads solutions that had been deemed suitable with high visual openness by the optimization process. The solutions are stored as the numeric parameters of the optimization. A parame-
A computerized algorithm was developed in order to represent the apartments as three-dimensional virtual models. This procedural 3D space generator spares the use of heavy geometry files, making it easy to update the simulation with new apartment units in each cycle. Due to the small size of its digital weight, the game can be accessed with a web browser (www.appartment.webutu.com), open to anyone who wishes to participate. Opinions provided by participants on units are recorded in a PHP database. The participants are presented with a random apartment unit and are asked whether the unit has, in their opinion, poor or good interior design. This is similar to the intended classification for the learning model. No standards are offered for the participant to base their decision upon. The game is designed to incite a sense of curiosity, and at the same time to allow the participant to provide an unprejudiced opinion of each unit. The purpose of this approach is to avoid biased opinions due to excessive instructions, and to ensure that every thought or decision made by the participants, intentionally or subconsciously, is incorporated into their answer.

The simulation is intended to be practiced in first-person, to reach an immersive experience of discovering each new random unit. The first-person mode is directly derived from 3D gaming experiences. Enabling the participant to move the simulated agent forward and backward and to the sides of the virtual space, along with a mouse-controlled head movement, allows for the easy and intuitive exploration of any given space. The participant is required...
quired to enter each new generated unit by walking through the door, and thus to form a first impression significantly influenced by the visual openness (Fisher-Gewirtzman, 2016). The participant is then free to “walk” virtually around the unit and examine the walkability and the general feeling influenced by the spatial configuration of the space. The game also offers the opportunity to explore each unit in external view, if the participant prefers this and finds it a more effective way to reach a conclusion regarding the units. The website which hosts the simulation has been published to the general public, and participants are encouraged to share it with family and friends. As of today, the developed crowdsourcing process has succeeded in gathering thousands of opinions, all provided willingly.

**DISCUSSION**

The opinions gathered so far formed the classification formula that was used for the next optimization process in the on-going cycles of the learning model. The participants created the boundaries which indicate the difference between suitable and unsuitable solutions, thus enabling the model to limit the vast search space regarding the optimization of more suitable apartment units. This was achieved without setting assumptions regarding the definition of “suitability” in terms of dwelling units. Consequently, the model gives an objective and comprehensive prediction of a notion which otherwise might have been too subjective to be manually defined. Each cycle of the learning model showed a degree of improvement over its predecessor. This suggests, that the filtration of configuration faults in the generated units will continue to be refined if the process continues to expand the database of units and collect opinions from participants.

This research demonstrates the feasibility of utilizing machine-learning methods in an architectural context based on crowd-rating through gamification, where the objective for self-generated spaces relies on perceptual and cognitive requirements. The methods presented in this work are not limited to minimal apartment units, and can be used to simulate, gather opinions, and produce prediction models for complex architectural spaces, such as multi-rooms apartments, large interior spaces, built compounds and urban fabrics. Other than the geometry, the objectives of the optimization and the subject of the classification can also differ while maintaining the structure of the developed learning model.

While the simulation played a major role in
the crowd-sourcing, the research is yet to conclude whether the participants found the first-person experience to be as intuitive and inviting as assumed. A suggested future research project would be to calculate the ratio of participants to use the first-person view over the external view, and the number of units that each participant rates before leaving the simulation. Recent developments in virtual and augmented reality technologies enable a much more significant immersive experience. A work that utilizes them may shed light on whether the gamification and immersion approach in the research was in fact effective in attracting participant to engage in the crowdsourcing.

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