Facilitating Communication in a Design Process using a Web Interface for Real-time Interaction with Grasshopper Scripts

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Urban design project development encompasses a wide range of disciplines and approaches, which often have separate goals, frameworks, and software tools. Lack of timely alignment of the disconnected expert inputs to the common vision leads to an increasing number of revisions and decreases chances for finding a compromise solution. We developed an intuitive browser-supported interface in order to incorporate various types of expert inputs and ways of representing the information to take a first step towards facilitating collaborative decision-making processes. The current paper describes the application of the developed tool on three exemplary case studies, where the expert and non-expert users' inputs are combined and analysed using Grasshopper scripts at the back-end. Pilot user studies conducted with professionals have shown that the tool has potential to facilitate collaboration across disciplines and compromise decisions, while most of the participants were still more likely to use it for communication with customers rather than the design team. It suggests that the interaction scheme of different actors with the tool needs to correspond better to the interaction of different actors during common negotiation processes. The findings suggest that the type of involvement of different stakeholders should be explored further in order to find the balance in functionality suitable for different parties.

Keywords: *computational design, design exploration, collaborative design*

INTRODUCTION

Urban design projects require various types of expertise; therefore, a design process involves a collaboration of the actors that are specialized in design as well as non-design fields. Various involved parties often have mismatching views on design problems, and these discrepancies are limiting opportunities for effective communication and decision-making. "[...] architects, urban designers, landscape architects, and design-oriented environmental specialists can be around the table, all embracing the general idea of planning-as-design, but cherishing a different variation of the planning/design dialects, inherited from their disciplines [...]" (Van Assche et al., 2013). Several connected fields, such as urban design and transport engineering, might refer to the same element using different definition (street, pedestrian versus route, agent), assign to them different attributes (width, proportions, character versus design speed, traffic flow, density), have different representation in mind (plans, sections versus tables, graphs). Using a shared platform to communicate one specific problem at one time between multiple parties would ensure that all parties have a similar understanding of the matter and can participate in discussion in a way that is suited to each.

Computational design support is often used as a mean for combining multiple requirements and negotiating design decisions. Oriented primarily at quantitative properties of design options, existing computational design support tools are not embracing the full diversity of the knowledge and expertise involved in the discussions. Design options are, therefore, regarded as finalized solutions that can be ranked and prioritized, rather than a constantly evolving process with changing concept and aims.

The paper presents the development of a design support tool aimed at facilitating collaborative decision-making processes within or beyond a team of design experts. The tool is providing a web-based interface for negotiating individual design questions that need to be compromised between collaborators with different professional background. While the design task in focus and discussion results are displayed in a web-browser, back-end functionality, such as generative and analytical algorithms, is being executed in Grasshopper script running on a remote server. Such setup allows the right professionals to support discussion in the right way while keeping the focus on the negotiable outcome. The crucial property of the tool is the support of the inputs suitable for various collaborators (drawings, numerical values, hand sketches at the front-end and computational scripts at the back-end) and appropriate for most professionals and non-professionals formats of the outputs (plans, 3d models, simulations, quantitative evaluation parameters).

Three case studies were developed to explore the flexibility and limitations of the tool. Each case differs in the following aspects:

- design scale: from masterplan to community space;
- support for input formats: from economic parameters to the location of street furniture;
- information representation: from masterplan to simulations, to 3d models;
- interaction mode: one shared interface versus multiple connected ones.

Following sections of the paper provide an overview of the conflicts between design processes and existing design support tools supported by a summary of their primary functionality. Further, the setup, technical features and intended use of the developed tool are described. Three interface examples targeting distinct design questions are illustrated as a proof-of-concept of the applicability of the tool. Finally, pilot user studies are discussed with the conclusions regarding the potential area of use, prospective collaborators and benefits to the design process.

STATE OF THE ART

Urban design, like any other type of design, is an opportunistically organized problem-solving activity, where problems are generally ill-defined and indivisible into sub-problems, and the solutions are satisficing rather than optimal with lack of pre-defined objective evaluation criteria (Visser, 2009). Due to these qualities a variety of existing computational design support methods and tools that can deal with contradicting design requirements (Harding and Brandt-Olsen, 2018; Vierlinger and Bollinger, 2014) still are not able to fully address the complex process of collaborative decision-making. Below, we provide a set of common issues limiting the efficiency of computational design support tools.

Firstly, as summarized by Harding and Brandt-Olsen (2018), built environment design complexity cannot be minimized to an objective function defined by metrics, especially considering the evolution of both requirements and design objectives with time. Due to this a design proposal can hardly be optimised holistically. This makes the quantitative-driven design support tools hard to combine with evaluation methods from a wide range of actors.

Secondly, the computational methods developed to support design processes operate on a different platform and use a different language than other involved experts. Urban design theory, compared to computational design, can provide a discussion of the role of accessibility in a district, but often does not provide instructions on how accessibility should be measured and quantified (Handy, 2005). At the same time, computational design support tools cannot directly operate with complex definitions such as mixed-use development, unique qualities of the environment (cosy, open, easy to navigate), or contextual integration.

Lastly, effective communication with stakeholders might be done via different means on a case-to-case basis. Except for combining necessary functionality that suits methods of various expert fields, appropriate ways of representation and exchange of information are needed. Therefore, a design exploration interface is one of the crucial points in solving the communication gap. The majority of currently available exploration interfaces in the computational design are performance-driven and can hardly be adapted to key negotiation points, such as conceptual design phase or other qualitatively driven decision-making processes (Harding and Brandt-Olsen, 2018).

As shown in Table 1, design exploration interfaces (mostly based on the models from Rhinoceros and Grasshopper) primarily serve for:

- providing easy-to-use web-based viewer for model exploration;
- allowing to explore fully or partially predefined set of parametric solutions;
- prioritizing options according to quantitative or qualitative design goals.

Except for several tools allowing manual input (Giraffe, TestFit), the main limitation for using the de-

Table 1
Summary of existing or in-progress design exploration interfaces

Tools	Primary functions
Spectacles [1] Platypus [12] Iris [2]	Model visualization in a web viewer.
ShapeDiver [5] RESThopper [3] Spider [4] Scout (Wilson et al., 2019)	Model visualization in a web viewer; basic interaction by changing parametric indicators.
Speckle [6]	Model visualization in a web viewer; basic interaction by changing parametric indicators; real-time model update across several software packages.
Giraffe (Leung et al., 2019).	Model visualization in a web viewer; interaction with parametric model via quantitative and graphical inputs; real-time model evaluation according to predefined analysis types.
Design Explorer [7] Thread [8] Design Space Explorer (Fuchkina et al., 2018)	Quantitative performance-driven prioritization of solutions.
StructureFIT [9] Biomorpher (Harding and Brandt-Olsen, 2018)	Mixed quantitative and qualitative user-guided prioritization of solutions.
TestFit [10] MetricMonkey [11] Envelope [13]	Exploration of conceptual design space; alignment of design options with existing local regulations or available budget.

scribed tools for decision-making processes is the limited opportunity to contribute to the design from the interface side. In other words, exported parametric model, in most cases, predicts a hundred percent of all future variations, which largely constrains exploration process. In this situation, most of the existing tools serve primarily for the demonstration rather than negotiation means. Also, most of the tools do not consider a range of stakeholders who might be using them, their background and role in the discussion.

PROTOTYPE

Based on the above, we argue that there are three crucial issues to address in order to take full advantage of computational design support as a mean to improve multi-stakeholder collaboration:

1. Maximising opportunities for model exploration and interaction with various stakeholders, by allowing it to take place outside of a professional CAD environment.
2. Making a computational model responsive to the other types of inputs (manual drawings, georeferenced data) while maintaining its functionality and providing real-time feedback.
3. Targeting tasks that are most commonly being addressed via computational design.

The technical setup of the pilot prototype was created using a combination of Grasshopper, HTML and javascript codes with the scheme provided in Figure 1. While every Grasshopper script needs to be created in its original visual programming environment, only the essential settings are integrated into the web interface, which is aimed to be a focus of the discussion. The model display includes a variety of representations: manual sketches, conceptual building volumes, simulations, 3d models and numerical values. Such setup is using the intended benefits of computational design: the ability to serve as a mediator between various stakeholder backgrounds, ways of perceiving information and design interests.

The setup of the tool is designed for discussing questions with a low level of complexity, where a limited number of collaborators need to make a compromise decision. The tool is aimed to support the points on the timeline, where experts with their distinct workflows need to find a common solution providing limited knowledge in each other's fields. The setup allows to collect essential requirements/algorithms from the experts (through parametric Grasshopper script), discuss and adjust other types of inputs (through web-interface) and receive feedback in a range of formats (through web-interface).

The questions aimed to be addressed by the use of the tool are the common issues that are being already addressed via computational design means. This narrows down the range of applications, but instead, ensures better integration into current project workflow without the need to develop additional brand-new algorithms. Even then range of possible applications still remains nearly unlimited: exploring scenarios for masterplan development (Konieva et al., 2019; Wilson et al., 2019), initial predictions on the qualities of urban space, such as acoustic environment (Gisladottir et al., 2018), spatial cognition (Filomena et al., 2019), outdoor thermal comfort

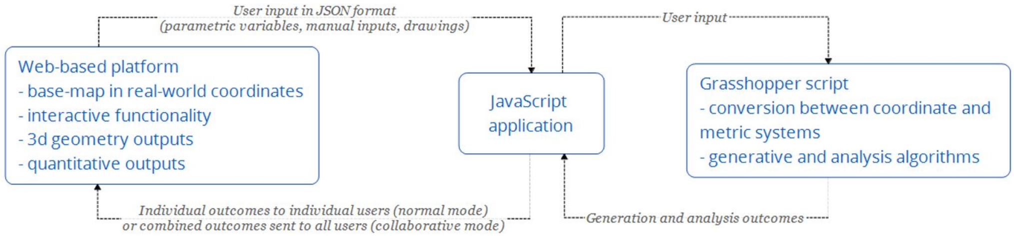
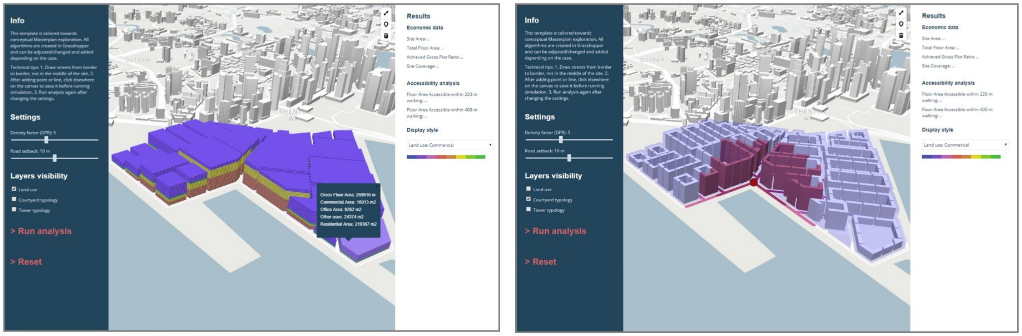


Figure 1
Technical setup of the prototype



a b

Figure 2
Example 1 with conceptual density and land use distribution (a) and preview of the potential building typologies (b)

(Shashua-Bar et al., 2012), potential presence of people in public spaces (Herthogs et al., 2018), floorplan arrangements (Daher et al., 2018) and many more. The present paper describes three examples of the application of such algorithms using the developed prototype.

The first example targets the masterplan scale, where the aim is to develop a set of rules which could subsequently take a different shape and accommodate different development scenarios. This template is relevant for tasks such as preparing competition guidelines for project bidding, masterplan regulations creation, volumetric studies, land use studies, exploring economic site potential. Decision-making at this stage of development is primarily done by non-design experts, for whom quantitative indicators and normative conformity serve as KPIs. Therefore, a low level of stakeholder engagement is expected, limited to representing and quantitively evaluating possible variations within a given physical and normative space. The algorithms connected to the interface can range from creating district volumetric envelopes to complex generative scripts with predefined building typology.

The first example is shown in the Figure 2. It uses Grasshopper scripts for dividing the site into street blocks and distributing densities and land uses according to location of the major transport hub. This template contains predefined housing typologies and leaves opportunity to adjust the desired density and road setback. This example can be replicated for any location by adjusting the parameters stated above. This setup allows stakeholders to collaborate (possibly remotely) on one model, add more types of evaluation and requirements from other fields of expertise and involve the experts with any background into a design discussion. Most importantly, it visualises the interdependencies between changing requirements and results in real time; and these interdependencies are often not intuitive considering the number of disciplines involved.

The second example (Figure 3) is oriented at smaller scale with the aim to optimise specific parameters of buildings and public spaces. This is still a part of conceptual phase, which has potential to give preliminary assessment of variety of parameters from pedestrian flows to energy use of the district. Here the design decisions are made by a range of design- and non design-oriented experts, as well as by external stakeholders. All participants of negotiation process should be able to explore not only a predefined design space, but also their own ideas and combination of ideas with qualitative and quantitative outputs. For this purpose, additional mode of interaction is introduced, where simultaneous users of the platform are seeing the same model with the inputs from every participant and overall analysis results.

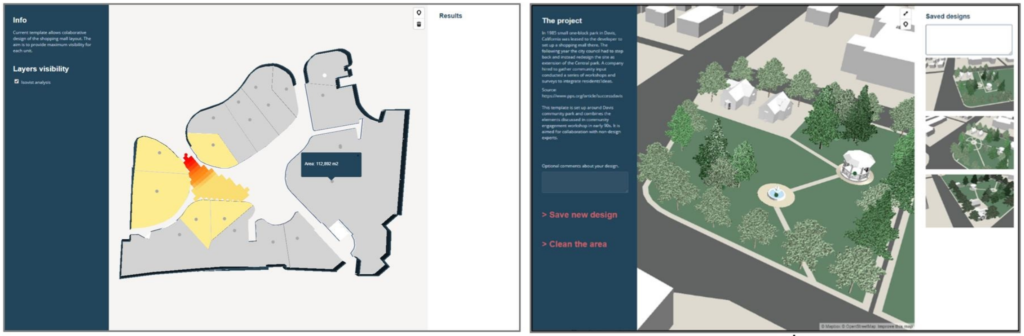


Figure 3
Example 2 (a) demonstrating collaborative floorplan generation accompanied by visibility analysis; example 3 (b) showing the community design case study

The third example (Figure 3) is oriented at small-scale interventions with little or no effect on project quantitative indicators. These are particular arrangements of public spaces and street furniture or building interiors. Maximum engagement from the users is expected, with the opportunity to combine manual inputs and generative algorithms where appropriate. Primarily visual means of representation are used for communicating and comparing design outcomes.

Three provided examples are demonstrating opportunities for facilitating communication between various types of stakeholders, using different visual means, accepting multiple types of inputs and engaging with the model on different level.

USER TEST

The first step towards validation of the chosen approach was conducting pilot user studies, where participants were offered to explore the tool using three algorithms as examples. First, the main concept of the tool and intended use was introduced to the participants. Then, three examples were shared one by one for the users to explore. Finally, possible questions from the participants were clarified and the questionnaire was offered. In total 11 responses were collected. At the time of completing the survey, nine participants were working in research or academia, and two in architecture or urban design company. However, most of the participants who were invited had prior experience working in the industry.

Majority of participants agreed on the possibilities that the tool opens for more efficient multidisciplinary collaboration and finding a compromise solution (Figure 4). Nevertheless, the integration with the existing project was not seemed durable, due to the lack of option for adapting and uploading existing files. Opportunity to integrate traditional and computational design approaches was perceived rather neutral, partially due to the same reason, and partially due to limited interaction opportunities (selecting and modifying the generated design, not being able to modify/understand the work of parametric script).

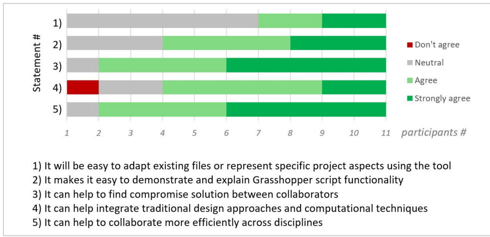


Figure 4
General application assessment

The usefulness of each of three featured functions - real-time Grasshopper analysis, manual graphical input, attachment to the real-world coordinate system - was ranked as average. General perceived limitations for using the tool in on-going projects was lack of the functions such as uploading own models and more flexible interaction with designs. Drawing function was also perceived as not fully corresponding to its purpose due to difficulty in producing results that would be close to hand sketches.

Amongst three examples provided in a user study, the conceptual exploration of the masterplan was chosen by the majority as the most probable to be used in the industry. Nevertheless, the common consideration was the difficulty in revealing such points of intervention, where the interests and degree of involvement of all decision-making parties could be balanced through such interface. This might have led to the following tendency in responses, where participants indicated non-designers (customers, authorities, citizens) as the main beneficiaries of using the proposed tool.

Pilot user studies were conducted in an early stage of development, in order to ensure the right direction and adjust approach early enough. Due to this, in several cases too premature development stage caused misunderstanding among participants regarding the evaluation of the interface features versus evaluation of the technological potential and contribution to the decision-making process. These and previous feedbacks need to be taken into account for adjusting the approach towards facilitating communication in a design process.

CONCLUSION

The current paper describes an approach to using computational design as a mean for facilitating decision-making processes. A collaborative interface was developed, which is combining multiple expert inputs in one viewer, gives feedback from the connected Grasshopper script and displays output for further discussion. The functionality of such setup was provided with consideration to the actors taking part in the design process, their role and nature of professional knowledge. It was the first step in finding an efficient solution for facilitating multidisciplinary communication in project development.

Pilot user studies have demonstrated several limitations of our approach. Firstly, there was a perception of not enough control over generated models and ability to introduce changes without the work of a computational designer. Secondly, the roles of collaborating parties in decision-making processes are not reflected in the way decision-making processes are represented in the tool setup. Lastly, the highest potential of the use of the tool was indicated as a demonstration mean rather than a medium for balanced negotiations.

On the other side, several participants responded positively to the prospective use in the industry of one of the suggested examples. Majority of the participants also agreed that cross-disciplinary information barriers can be reduced using the tool for negotiations. Not least important, the expert conclusion was rather positive regarding finding compromise more efficiently due to the aggregation of multiple expert inputs.

FUTURE WORK

As the results have shown, more work is needed to be done towards understanding of relationship, influence and interests of multiple actors involved in urban design project development. Better insights are needed into the negotiation processes using computational design support and other methods. This knowledge will be crucial for developing more effective decision-making support methods.

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