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Crowdsourcing with online quantitative design analysis

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ABSTRACT

Design is a balancing act between people's competing concerns, design options and design performance. Recently collecting data on such concerns such as sustainability or aesthetics has become possible through online crowdsourcing, particularly in 3d. However, such systems rarely present more than a single design alternative or allow users to change the design and seldom provide quantitative design analysis to gauge design performance. This precludes a more participatory approach including a wider audience and their insight in the design process.

To improve the design process we propose a system to assist the design team in exploring the balance of concerns, design options and their performance. We augment a 3d visualisation crowdsourcing environment with quantitative on-demand assessment of design variants run in the cloud. This enables crowdsourced exploration of the design space and its performance. Automated participant tracking and explicit submitted feedback on design options are collated and presented to aid the design team in balancing the demands of urban master planning. We report application of this system to an urban masterplan with Arup.

1. Introduction

Urban master planning is a balancing act between many inter-related design parameters and performance goals. Some goals are explicit and quantitatively measurable (e.g. water consumption), other aspects are implicit and not easily measurable with many being dynamically driven by human preference and market forces (e.g. aesthetics or city zoning ordinances). Optimization alone will not help find the most appropriate solutions as it does not known all of these implicit constraints. Indeed evolving a design toward optimal is a task beyond any one architect or engineer as different disciplines and stakeholders each have their own constraints and design options. To improve the design process we propose crowdsourcing augmented with design performance analysis to explore these aspects and guide us to a set of the most synergetic solutions.

The design process involves experts from many disciplines making a plethora of decisions which will affect the urban environment and those who live and work within it. The design space has a very large scope including not only choice of architectural forms but also a huge number of design decisions which must be made to implement the vision of the development. Such design decisions range from the number of parking spaces to the amount of green space included these create a vast number of design scenarios to be explored under which the design's performance will vary across many KPI's.

Aside from such design decisions the threat of climate change imputes a requirement to minimize the carbon emissions of a development by the adoption of mitigation strategies. Sustainability strategies such as the adoption of solar thermal panels or the use of water efficient fixtures and fittings have impact across multiple disciplines and Key Performance Indicators (KPI's) and require multidisciplinary collaborative exploration to enable their implementation. For example the implementation of a district energy system, where heating is provided by a central plant, will impact upon carbon emissions, water consumption and the urban landscape as well as the mechanical systems required for each building. Each aspect requires a different expert to collaborate to identify implications and benefits across the design space.

Such strategies are, of course, constrained by cost both in capital and operating expenses as well as impacts upon other resources such as water or energy consumption, creating a challenging optimization problem, particularly as many of the constraints are either undefined or cross traditional discipline boundaries. Such optimization of the design for an urban masterplan is rarely conducted with detailed quantified assessment neither is that assessment repeated for more than a couple of design cycles [1] neither does it often involve the key group of stakeholders the people who will live and work in such an environment.

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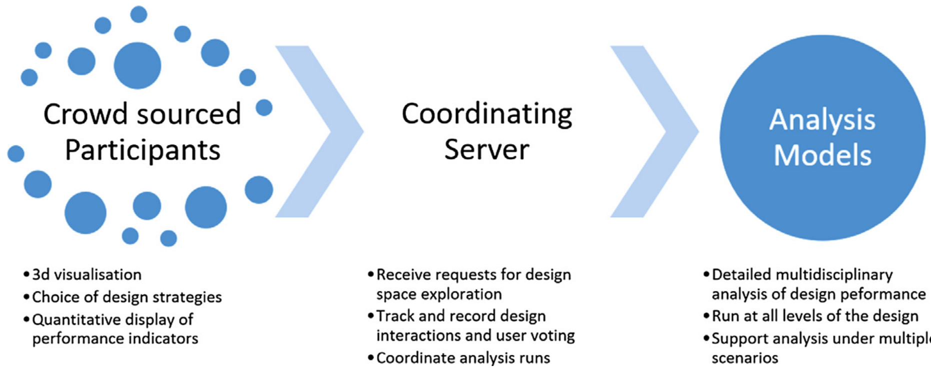

Fig. 1. Our proposed methodology for enabling crowdsourced design space exploration backed by quantitative analysis of design variants.

2. Related work

In this context we seek to apply the crowdsourcing of design feedback to enable wider participation in the design process[2]. Crowdsourcing is the approach of seeking to involve a large number of individuals to solve a set challenge[3]. The advantage of this is to leverage the "Wisdom of the Crowd" [4] with many views and unique experience the problem is approached from more angles and different challenges and solutions may be offered [5]. Since the internet enabled its rise [4] in the early 2000's Crowdsourcing has be used extensively [6] to **gather data** most notably in the open street map project [7], to **conduct large-scale user studies** such as how people perceive different types of visualization [8] or **to solve particular puzzles** [9] for example in solving math problems [10]. One notable example is the use of large groups of people contributing data in disaster zones[11] with reports of forest fires, property and risk to life being collected by the crowd.

Crowd sourcing in design is thought to be particularly effective if conducted early in the design process through participatory design [12–15]. In recent years online web-based tools [16–19] are enabling residents and members of the public to submit their feedback. This enables many people to provide comment on design choices, contributing their insight by geospatial tagging [16,3] to highlight design issues. This technique has also been used to gather feedback on changes in the rural landscape [20] as well as the more general planning process [21].

As outlined in [5] who try to provide a unified definition of crowdsourcing it is important that participants feel there is a mutual benefit to the contribution of their time and expertise, this is particularly important in urban design [22]. In the context of design we see a positive benefit that the participants proposals may be included in the design for its betterment also negatively the participant may hope that the worst impact of a design or urban development may be avoided - for example in the placement of a windfarm[23]. Additionally one would hope that in the realm of urban planning citizens civic pride would help them to invest in the development of their local environment. An increasing literature suggests this future for urban planning[24] and for local government more widely[25].

Crowdsourcing is a good technique for this as it can help explore distant parts of the design space - see [26]. Each participant explores in their own direction based on their own experience and in aggregate we hope will explore a wider area of the design space than a professional design team could feasibly explore. A number of researchers have recommend the application of crowdsourcing in planning practice [27]. However, in general such systems are used to gather feedback on a single design option or a small number of design variants [20]. This presents a clear and constrained choice to the participants and focuses input to decisions of interest to the design team. However, the design space is dramatically larger than that exposed through these tools as there are many more design variants and improvements which could be made. To enable this the crowd would need to be given tools to explore the design space and assess the performance of design variants. This is the approach we introduce in this paper which as in [21] is unified by visualization.

The fusion of crowdsourcing into urban planning remains an active research front [28,2,27,25,23,24] and the authors hope this paper demonstrates the value of a computational design analysis framework to empower crowdsourcing as a technique to benefit urban planning.

3. Approach

In the context of this multidisciplinary design optimization problem, with its large design space, and the need to involve a range of stakeholders in design decisions we propose to augment a 3d visualization environment with a quantitative design assessment by providing online assessment of design choices in the cloud. Crowdsourced feedback is recorded and analyzed to provide a guide to the design team to improve decision making. This is enabled by an online workflow system capable of running design analyses automatically.

Real-time automated assessment enables a more flexible design space to be explored in directions not thought of apriori by the design team. This flexibility enables gathering of intention, for example, city planners using this tool may explore the implications of mandating electric vehicles for a campus, something not explored by the design team. On the other hand residents may be interested to learn the trade-off between density of urban form and carbon efficiency, enabling participation in exploring design options. We hypothesise that viewing a wide range of design options and their performance is likely to lead to greater acceptance of design variation and hopefully create a consensus.

Specifically, we propose the following technical systems approach, summarized in Fig. 1:

1. An interactive, web-based, 3d environment for exploring proposed designs, annotated with design performance and enabling exploration of the design space for carbon mitigation strategies. Many aspects of design in the urban environment are inherently geometric (e.g. line of sight, shadowing) and are best understood through 3d visualisation.
2. We couple this with a detailed analytical model [29] and a computational framework for design exploration [30] providing real-time quantitative analysis of the masterplan's performance across a range of KPIs.
3. This enables exploration of the design space by a large number of participants each able to explore the implications of adopting carbon mitigation strategies on the macro (masterplan) and micro (building) level across the development.
4. Such crowdsourcing of the design space is tracked providing a quantified insight into how the design space is explored and areas of interest or otherwise identified by the participants. This may be