

Data-driven Urban Design

Conceptual and Methodological Interpretations of Negroponte's 'Architecture Machine'

Jeroen van Ameijde

The Chinese University of Hong Kong (Hong Kong)

Abstract

Nicholas Negroponte and MIT's Architecture Machine Group speculated in the 1970s about computational processes that were open to participation, incorporating end-user preferences and democratizing urban design. Today's 'smart city' technologies, using the monitoring of people's movement and activity patterns to offer more effective and responsive services, might seem like contemporary interpretations of Negroponte's vision, yet many of the collectors of user information are disconnected from urban policy making. This article presents a series of theoretical and procedural experiments conducted through academic research and teaching, developing user-driven generative design processes in the spirit of 'The Architecture Machine'. It explores how new computational tools for site analysis and monitoring can enable data-driven urban place studies, and how these can be connected to generative strategies for public spaces and environments at various scales. By breaking down these processes into separate components of gathering, analysing, translating and implementing data, and conceptualizing them in relation to urban theory, it is shown how data-driven urban design processes can be conceived as an open-ended toolkit to achieve various types of user-driven outcomes. It is argued that architects and urban designers are uniquely situated to reflect on the benefits and value systems that control data-driven processes, and should deploy these to deliver more resilient, liveable and participatory urban spaces.

Keywords

Urban Analytics, Data-driven Design, Participatory Design, Urban Placemaking, Public Space Design

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Introduction

The increasing integration of information and communication technologies into buildings and urban spaces allows for cities to become 'a reflexive test-bed and workshop for connected habitation in enmeshed digital and physical space' (Ratti and Claudel, 2016, p.23). Data-driven systems can establish feedback loops between city users and their environment, enabling data-driven design decisions actualized through traditional forms of construction, or through electronic systems for control and communication.

The emerging field of urban analytics offers methodologies for data-driven types of urban studies, allowing new insights to be informed by detailed datasets of human activities and everyday interactions. This could help bridge the gap between the social sciences and urban planning practice (Dyer et al., 2017), as urban studies employ human-centric scientific research methods, while urban planning 'best practice' methods may prioritize commercial rather than community interests (Nisha and Nelson, 2012). Rather than being based on assumptions, urban design practice can now foreground human-centric and evidence-based methods for the design and management of cities.

The wide range of emerging 'smart city' technologies might seem to enable citizen empowerment and societal progress, as cities promote the synergy between 'smart cities' and 'smart people' (Hong Kong Government 'Smart City Blueprint', 2017). However, in many instances, these systems are operated by private organizations that monopolize data for commercially strategic reasons. Many urban scholars argue that smart city technologies will have a profound effect on the freedoms, inclusivity and sense of participation experienced in future public spaces, and Lefebvre's notion of 'the right to the city' (1968) is threatened by 'ecosystems of technology' that 'derive maximum resource efficiency by working coherently and systematically' (Adam Greenfeld, quoted in Ratti and Claudel, 2016, p.31).

Data-driven urban design processes may already be shaping current and future cities in different ways, often outside current modes of urban design practice. There is an urgent need for architects and planners to adopt a leading role in the exploration and discussion of new urban processes and systems, as a lack of engagement may leave them powerless in tomorrow's technology-driven society.

This article presents a series of research projects and experiments, aimed at providing insights and discussion around designers' potential to engage with data-driven methods for urban analytics and generative design. It will discuss in detail how these processes can be broken down into separate components of gathering, analysing, translating and implementing data. As each of these operations can be conceptualized in relation to the politics of urban space, we aim to illustrate how designers can deploy a new toolkit for the creation of human-centric urban design.

The Architecture Machine

The idea of integrating physical and digital layers in the built environment has been conceptualized since the early 1960s by pioneers such as Christopher Alexander, Cedric Price and William Mitchell. Gordon Pask's 1969 article 'The Architectural Relevance of Cybernetics' described architecture as 'a mechanism of information exchange' and called for architects to adopt the role of 'system designers' (Steenon, 2017, p.17). In books published in 1970 and 1975, Nicholas Negroponte and MIT's Architecture Machine Group speculated about man-machine processes to translate client requirements into architectural designs solutions without the interference of the architect's self-interest:

In most cases the architect is an unnecessary and cumbersome (and even detrimental) middleman between individual, constantly changing needs and the continuous incorporation of these needs into the built environment. The architect's primary functions, I propose, will be served well and served best by computers. (Negroponte, 1975, p. 1)

The best-known project produced by the Architecture Machine Group was an art installation titled 'SEEK', on show during the 'Software' exhibition in New York in 1970 (Fig. 1). The installation consisted of a large plexiglass enclosure containing a three-dimensional landscape of small cubes, and a number of small, mouse-like animals (gerbils) whose movements disrupted the cubes. A computational feedback loop consisting of a camera and a robotic arm was calibrated to analyse and amplify changes made by the gerbils. The ideal 'final' configuration of the cubes would emerge over time, out of the interaction between the inhabitants and their architectural environment.

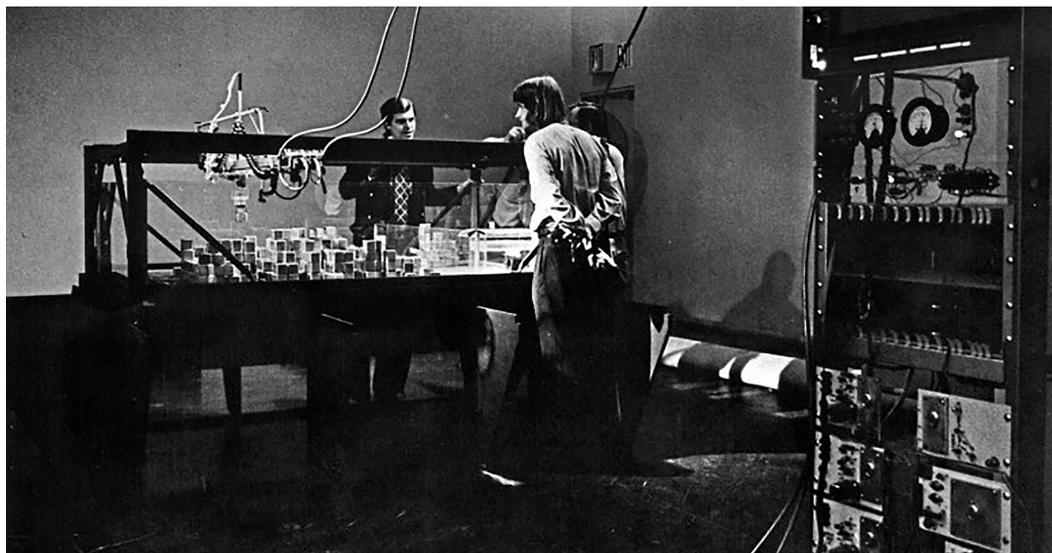


FIGURE 1 'SEEK' installation by Nicholas Negroponte and the Architecture Machine Group, 1970. (Photograph by Harry Skunk and János Kender J., image courtesy of Paul Getty Trust.)

While the 'SEEK' project was criticized for 'inappropriate abstraction of real-world constraints and too great a scope of the design problem at hand' (Steenson, 2017, p.184), Negroponte's experiments made a provocative and influential contribution to the discourse around participatory urban design. It demonstrated the ambition to 'bring urban design back to the ordinary man' (Rowe, 1972, p.12), allowing citizens to be involved in the complex negotiations around urban problems through the mediation of a fair and transparent system containing computational rules.

Negroponte's collaborators Gordon Pask and Yona Friedman helped to define the 'SEEK' experiment as a cybernetic system, consisting of the separate processes of scanning and processing environmental data, and of responding and implementation with environmental remediation (Fig. 2a). While this feedback loop should function autonomously without the interference of designers, there was a crucial human role in defining the interpretation and reaction policies that should drive the environment's evolution. Figure 2b interprets this dynamic according to Friedman's principle of a 'non-paternalist' hierarchy: denying the designer a close association with the computer system to avoid interference based on preference, but instead having the computer be part of the environment. The designer's role is to conceive, test and develop the machine protocols and machine-environment interaction, evaluating their capacity to produce satisfying outcomes.

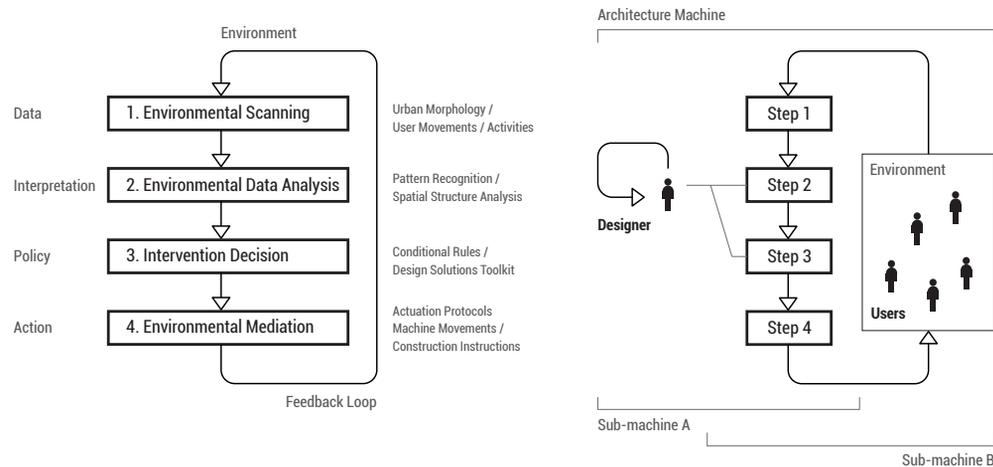


FIGURE 2 System diagrams of the 'SEEK' experiment, describing the relationships between environment, computer and designers of the system (Source: author, based on Friedman).

When evaluating these early conceptions of interactivity and participation explored by Negroponte and his contemporaries, it is easy to draw parallels with today's technological cities as described by Ratti and Claudel. As primitive computing systems and clumsy robotics are replaced by powerful miniaturized and distributed devices, there are clear opportunities to redefine the role and responsibilities of the urban designer. Negroponte's experiments aimed to provoke a debate about the ethics of creating controlled social environments, a topic that deserves urgent scrutiny in relation to the research around smart cities and urban analytics. Similar to the growing concerns about the negative effects of social media and the dilemmas in policing their complex systems of governance, it is crucial to reflect on the increasing influence that ubiquitous computing systems will have on the qualities of our urban spaces. While Negroponte and his contemporaries saw the consistent logic of computing operations as a tool to upgrade and democratize design processes previously limited by a single human designer, the current 'second digital turn' (Carpo, 2017) in society shows how computational systems can easily generate too much complexity, bias or undesirable results if they are not guided by human-defined limitations or ethical guidelines. While Ratti and Claudel are reservedly positive about Big Tech companies offering free services in exchange for the commodification of user data, their preferred models of augmented urban life are based on open data and platforms that enable grassroots initiatives and non-profit models of 'urban co-creation' (Ratti and Claudel, 2017, p.146). The objective of this article is to explore the tools, processes and socio-political implications relating to data-driven strategies for public space management. As we translate the various components of the 'SEEK' project to a range of contemporary tools from the fields of urban studies and generative design, we introduce open-ended technologies for human-centric and community-oriented design.

Methodologies for Integrating Urban Analytics and Data-driven Design

Component 1: Environment Scanning

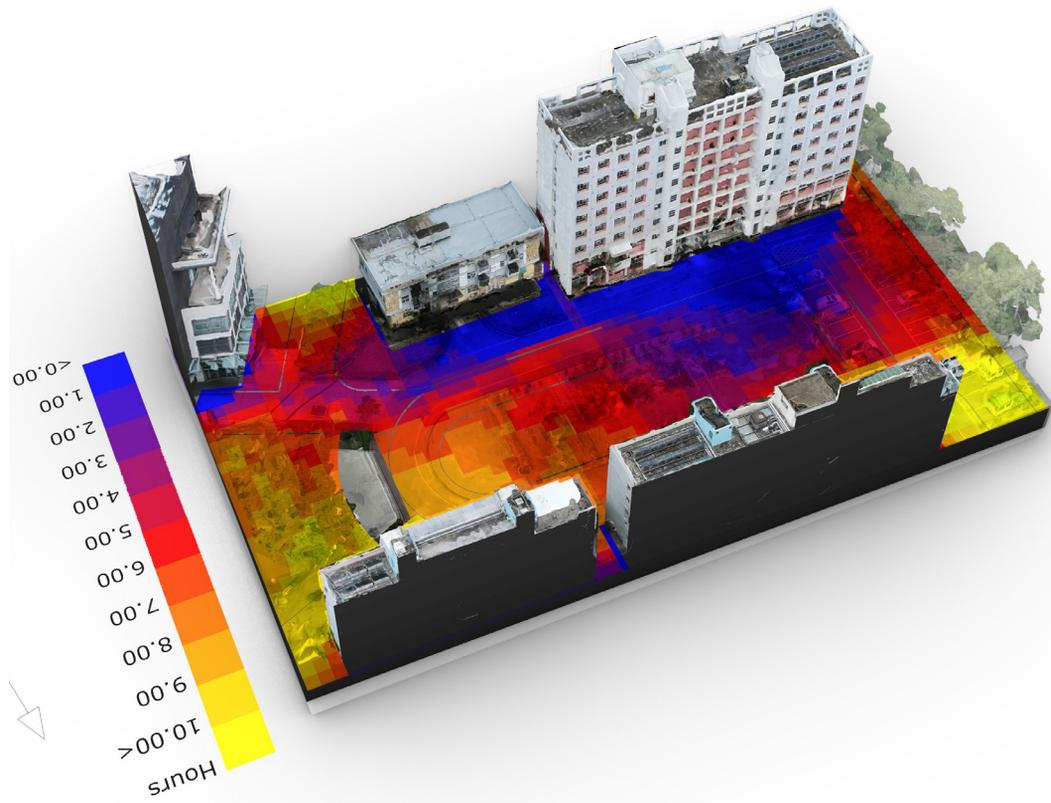
The first component of a multi-stage workflow around data-driven urban site analysis and design should be a scanning methodology capable of harvesting detailed spatial data on the morphology of an urban site. In our experiments, we employ unmanned aerial vehicle (UAV) based site scanning techniques using aerial photography and photogrammetry software. A 3D model of buildings or spaces is generated by processing images captured with the UAV-mounted camera and on foot (Fig. 3).



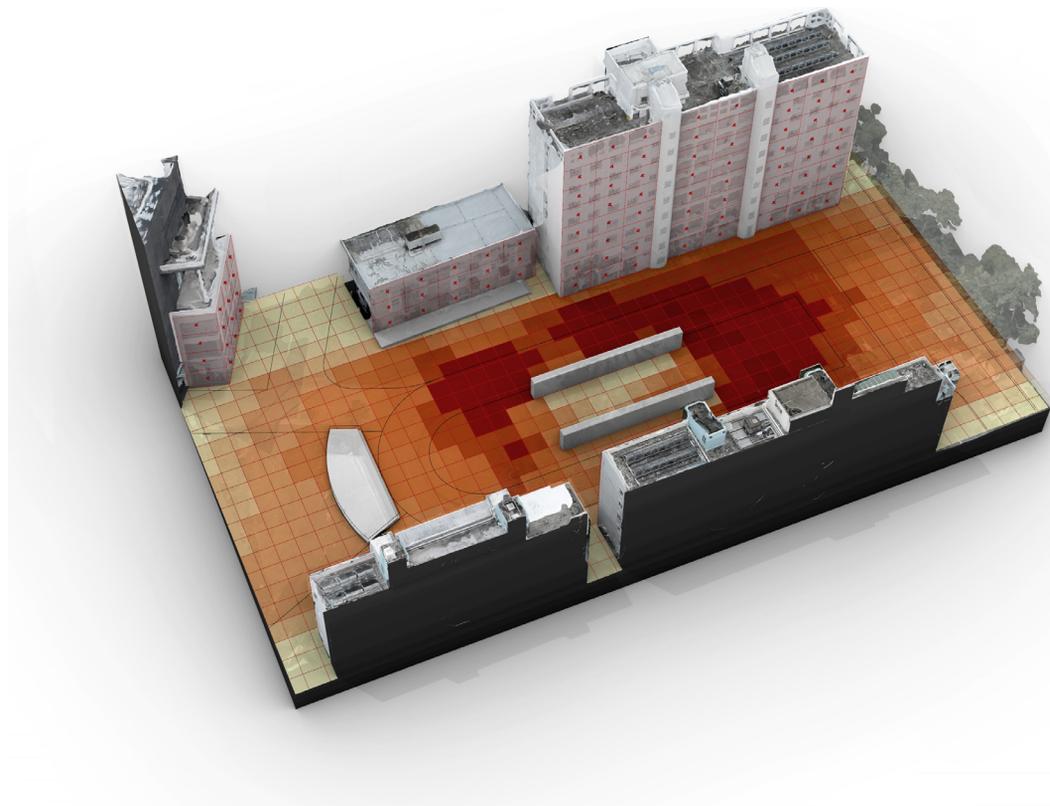
FIGURE 3 Point cloud model constructed with RealityCapture photogrammetry software, based on terrestrial photo datasets

Component 2: Environment Analysis

The 3D site models allow data compilation and analysis using a wide range of plug-ins and compatible software. In our workflow, we employ Visibility Graph Analysis (VGA) and Stamps' isovist, enclosure and permeability theory (2005) to evaluate the urban morphology, and the environmental and psychological comfort aspects of public open spaces. Our workflow has adapted the isovist analysis algorithms developed by Turner (2001, 2007) and Abdulmawla et al. (2017), as well as climate comfort analysis tools developed by Roudsari (2012). Figures 4a and b demonstrate the analysis of sunlight hours and visibility parameters across an underused public open space within the campus of The Chinese University of Hong Kong, which was scanned using drone and terrestrial photogrammetry.



a



b

FIGURE 4 Environmental analyses based on urban morphology, including sunlight hours (left) and surveillance mapping based on sight lines from surrounding windows to the public space (right).

Component 3: People tracking

Jane Jacobs (1961) famously demonstrated the value of social mechanisms within neighbourhoods, analysing the daily patterns of movements, activities and interactions that create resilient urban communities. Our workflow employs qualitative and quantitative documentation of activities in public spaces, following the methodology for the ethnographic study of space outlined by Low (2000; 2016; 2019). As part of our ongoing research, the use of digital cameras and image recognition software is being developed based on previously established methods for the analysis of people's movements and activities (Hanzl and Ledwon, 2017). We employ disguised naturalistic observation methods outlined by Cuttler (2019) who notes that 'ethically, this method is considered to be acceptable if the participants remain anonymous and the behaviour occurs in a public setting where people would not normally have an expectation of privacy' (Jhangiani et al., 2019, p. 170).

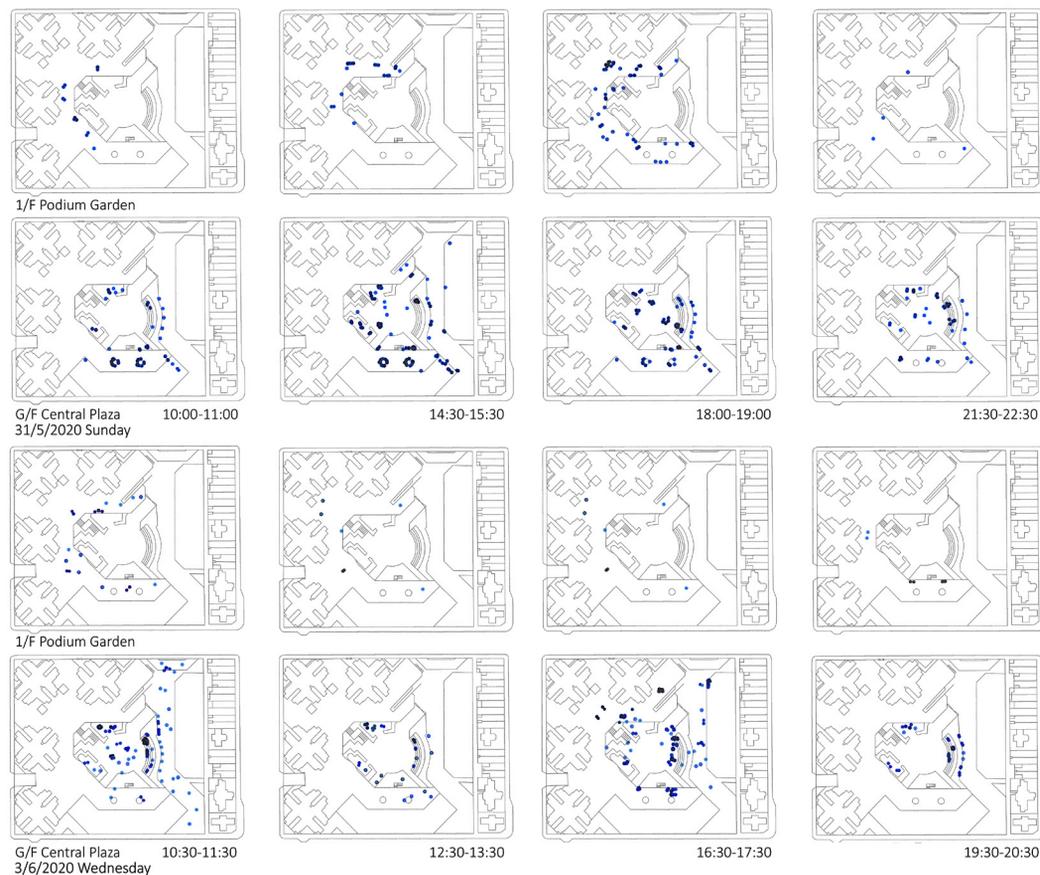


FIGURE 5 Documentation of people locations across various time intervals in the Prosperous Garden housing estate in the Yau Ma Tei district, Hong Kong.

After documenting data across specific periods of time, the movement and activity locations can be translated into time-based spatial data in the form of geolocation coordinate points. Figure 5 shows an example of a limited data set in this form, produced during a short ethnographic study of social activities in one of Hong Kong's public housing estates. For this case study, user data was collected across four one-hour intervals on a typical weekday (31 May) and Sunday (3 June) in 2020. Just under 600 datapoints were collected by a team of four observers. Referred to as 'snapshot' observations, these field studies have limitations compared to a structure study across longer time frames but can provide valuable initial insights into the general social dynamics of a study site.

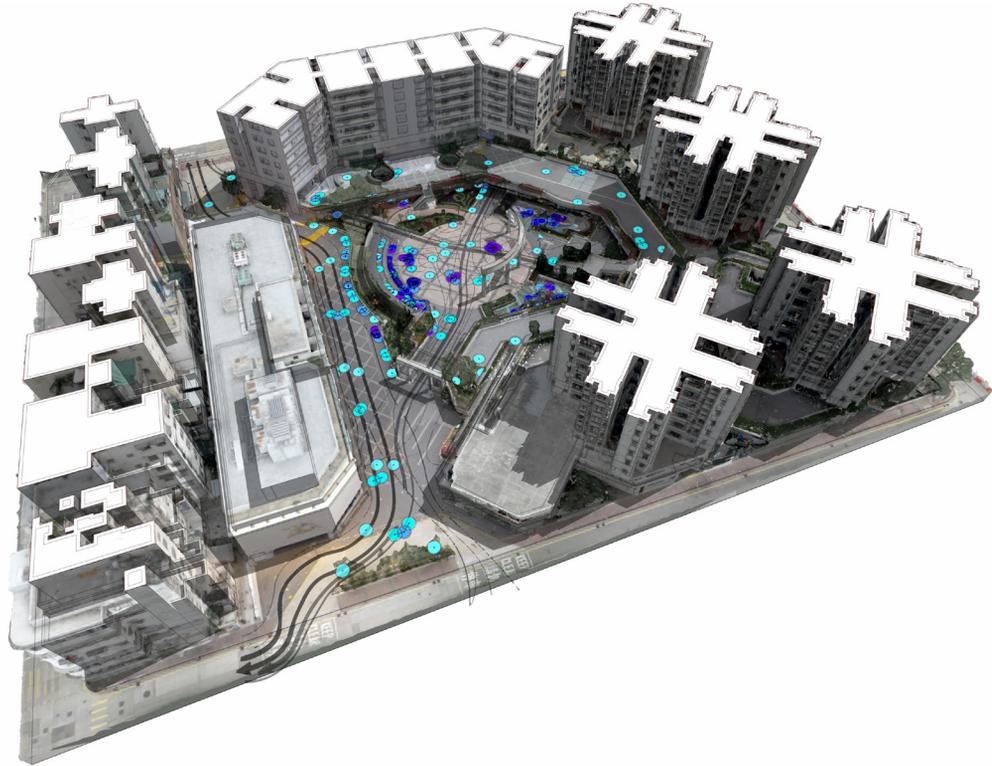


FIGURE 6 Analysis of people locations and closeness, based on a weekday snapshot (16:30-17:30) observation at the Prosperous Garden housing estate.

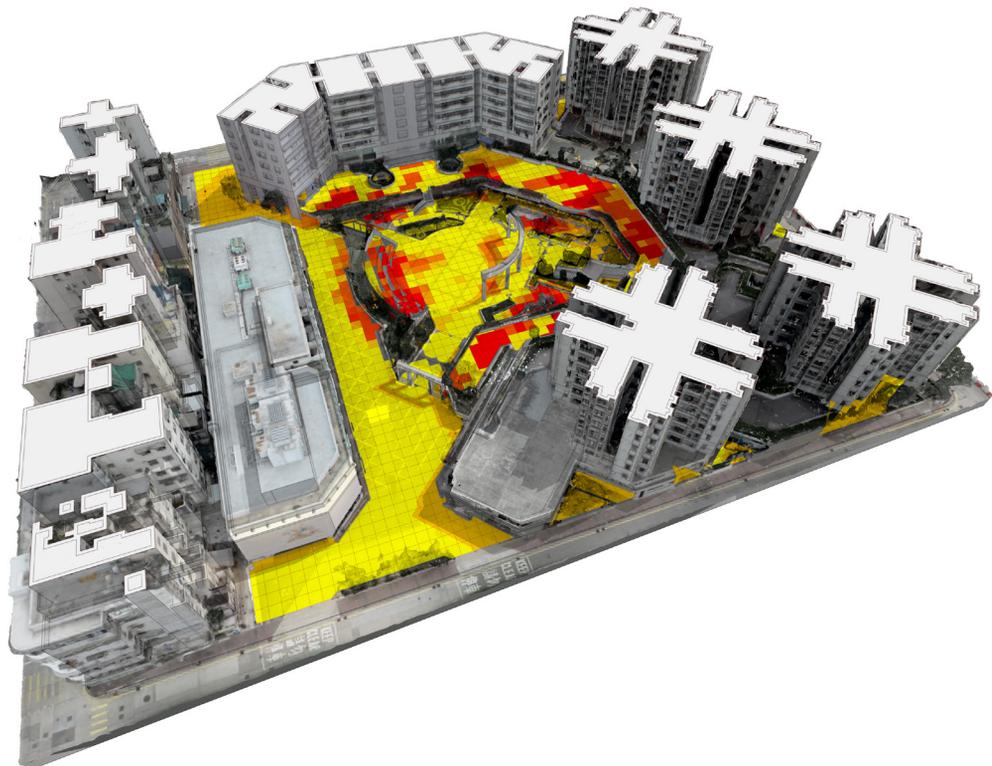


FIGURE 7 Space-centric analysis of people locations and closeness, based on a compilation of all weekday snapshot observations documented in Figure 5.

Component 4: People location analysis

To translate the basic data of movement and activity locations into meaningful insights about the intensities of use of public spaces, basic statistical analysis can be performed through computational processing. In addition to location data, we can analyse the degree of *closeness* – the physical distance between people and the in-between space that facilitates co-presence and regulates interpersonal relationships (Madanipour, 2003, p. 206). We can evaluate various distances based on *proxemic interactions theory*, and the discrete proxemic zones defined by the anthropologist Edward T. Hall: *intimate* (0 - 0.5 m), *personal* (0.5 - 1 m), *social* (1 - 4 m) and *public* (> 4 m) (Hall, 1966; 1968). Our algorithm uses lighter colours to indicate private individuals or couples, and increasingly darker colours to indicate social groups of three or more people (Figure 6).

In a final step of data translation, the statistical occurrence of user presence and co-presence is defined as a feature of the various locations within the case study space. The mapping process follows a basic logic of defining a spatial grid of cells (Fig. 7). For this analysis, multiple datasets relating to various time intervals can be combined, to produce insights into the general statistical patterns of space occupancy as they occur over longer periods of time.

As this article focuses on a conceptual and procedural overview of the separate components of a data-driven urban design process, the detailed findings of the particular case study research shown here will be discussed in different article. Instead, it is important to reflect on the critical overview and integration of the different stages of such a process, and how decisions around data-interpretation can be guided by socially-oriented policies.

Component 5: Data-driven design policies

In the previous sections of this article, we have outlined separate but interrelated steps for the scanning and processing of environmental data, including urban morphology and people location analysis. Following our interpretation of the Architecture Machine concept, the data-driven nature of the public space analysis now allows us to conceive a design intervention in the same space, as part of a cybernetic system aimed at empowering its inhabitants. Negroponete's vision to 'eliminate the middleman' between the individual's needs and the incorporation of those needs into the built environment, seems to align itself with the concept of 'the right to the city' introduced by Henri Lefebvre (1968). This concept argues for 'the right to belong to, and the right to co-produce the urban spaces' (Aalbers & Gibb, 2014, p. 208). To achieve this goal, we should set up policies for public space design and management that aim to fulfil as many user requests as possible, with a minimal amount of coordination and regulation to resolve conflicting demands of different groups of end users. This is in contrast to current public space planning policies in many cities, which often focus only on facilitating activities and behaviours of a certain desirable range.

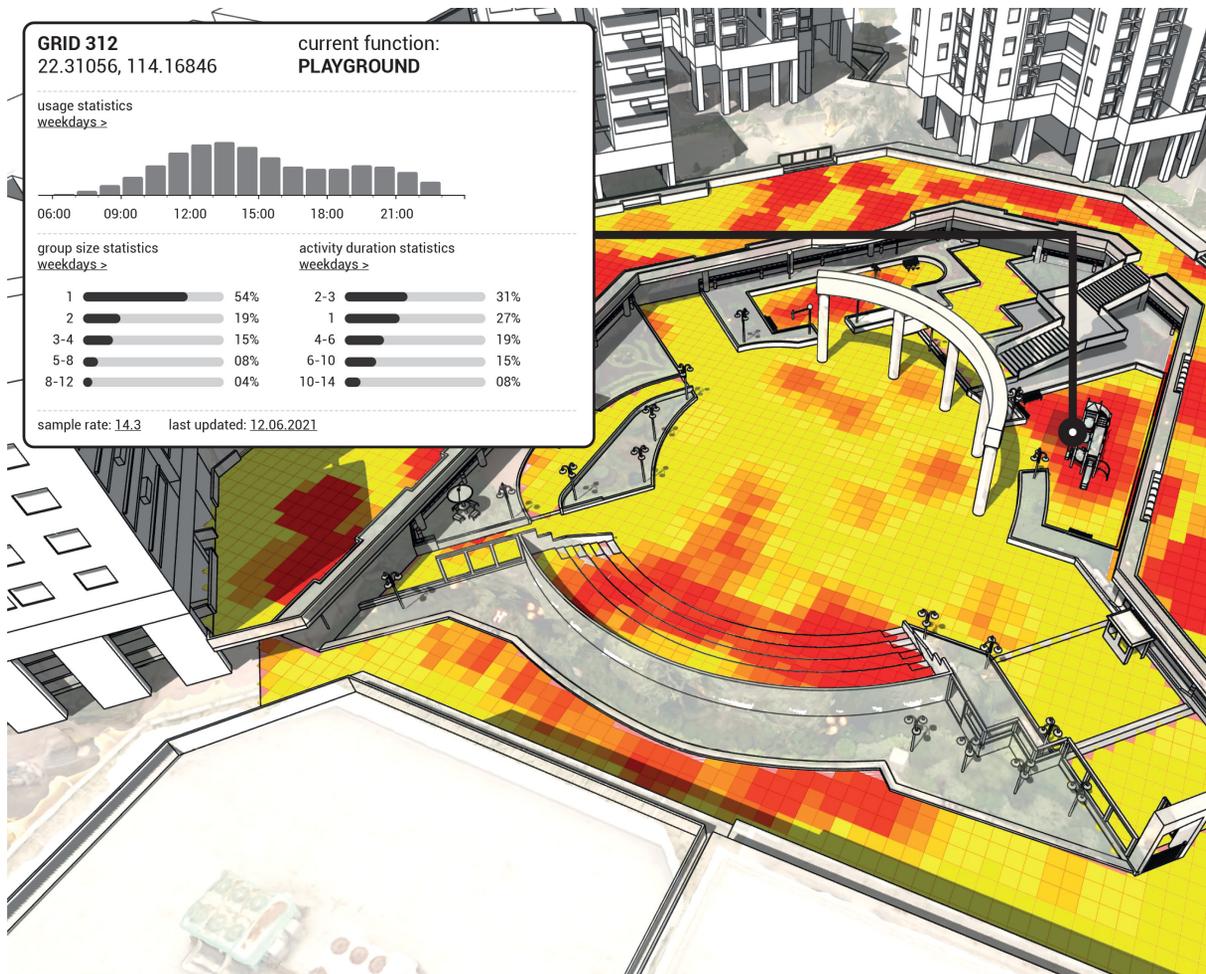


FIGURE 8 User data evaluation on specific public space locations or elements, such as the visit intensity statistics, including group sizes and duration of the visit in minutes.

Component 6: Data-driven design systems

In our case study experiment at the Prosperous Garden Estate, we speculate about a design strategy which matches supply to demand, providing public space facilities to the real-world usages as monitored. A permanent site monitoring system would be installed using CCTV camera feeds, and employing anonymized data collection as a formalized commitment to performance evaluation (Fig. 8). Facilities that prove to be less used could have their quantity or location priority reduced, and for elements that are often used to full capacity, additional elements would be installed. Changes would also be based on correlation analysis, analysing combinations of facility types and urban morphology characteristics that may produce more frequent user engagement. Instead of the notion of the 'masterplan' as an overarching, top-down framework of design decisions determined by planners, the project employs a catalogue of urban design elements, able to be installed on site in a range of configurations (Fig. 9). Decisions on the implementation of changes on the site would be made autonomously by a system that continuously monitors human activities and interactions, guided by a set of policies that facilitate democratized and participatory modes of design, to produce a community-driven and supportive urban environment.

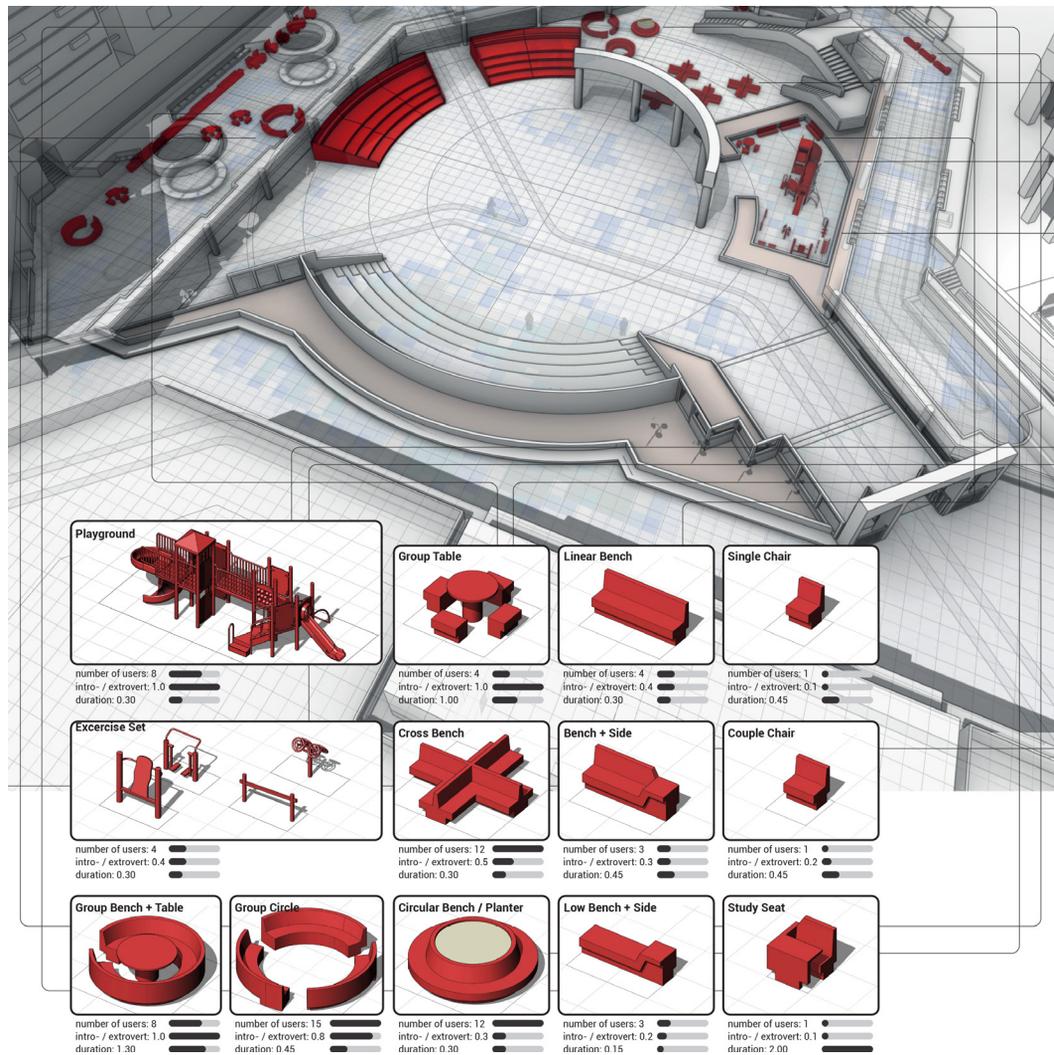


FIGURE 9 Potential data-driven urban design implementation at Prosperous Garden Estate, where the placement of furniture is evaluated in real time based on the evaluation of people's activities.

Discussion and Conclusions

In this article, we have traced some of the ambitions of the early explorers of cybernetic systems in architecture and urbanism, and attempted to reposition these in the context of the emerging opportunities offered by public space design in the age of ubiquitous computing. The visionary scenarios of Negroponte, Pask and Friedman highlighted the limitations of human designers, and proposed that machine systems of control would be better suited to translate the complex requirements of end users into appropriate design solutions. As identified by Negroponte and emphasized in this article, autonomous systems could produce desirable or highly undesirable outcomes, and 'architecture machines' would have to be sensitive and open to human criteria and interventions. The key issue is to focus on the overarching objectives governing these systems, to verify whether data-driven systems produce meaningful management scenarios that implement positive social policies in relation to human-centric urban theories, such as the notion of 'the right to the city' and that of 'spatial justice'. The real-world implications of these theoretical concepts involve social, political and economic rights, and a production of urban spaces that contributes to enabling people rather than excluding or exploiting them.

In our own data-driven design experiments and speculations, we aim to develop an open-ended approach to data gathering and analysis that is able to learn about the requirements of diverse public space users, without making specific presumptions or prescriptions. We speculate about how the central component of Negroponte's 'Architecture Machine', the feedback loop, could translate into cybernetic systems that continuously evaluate and improve the infrastructure for social activities in public urban spaces, to improve recreation, socializing, community formation and participation. While the monitoring of daily activities should adhere to research ethics and privacy protection protocols, the contemporary state of technologies now allows exciting new types of analysis of the behavioural, cultural and sociological aspects of interactions between people in urban spaces. We are only at the beginning of a paradigm shift, in which new types of computational systems and emerging modes of practice allow us to start testing real-world scenarios of intelligent adaptive environments.

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