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DOI
10.7480/rius.4.1367

Publication date
2016

Document Version
Final published version

Published in
Research in Urbanism Series (online)

Citation (APA)
Nijhuis, S. (2016). Applications of GIS in landscape design research. *Research in Urbanism Series (online)*, *4*(1), 43-56. https://doi.org/10.7480/rius.4.1367

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Applications of GIS in landscape design research

STEFFEN NIJHUIS

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Abstract

Despite its widespread availability there is evidence that GIS is underused in the realm of landscape design research. Though recognized as a useful tool for mapping and planning, the potential of GIS is often still underutilized due to a lack of awareness and prejudice. This paper explores some concepts of GIS-based analysis which link to the very heart of landscape architecture in a natural and intuitive way. Hence the possibility to break down barriers of using GIS in landscape architecture this paper aims to put forward some characteristic principles of study and practice that can be made operational via GIS while cultivating spatial intelligence in landscape design through exploiting its powerful integrating, analytical and graphical capacities. In this respect educational and research institutions have an important role to play, they must take the lead in knowledge acquisition on GIS-applications and passing it on, contributing to the academic underpinning and development of a digital culture in landscape architecture.

KEYWORDS

GIS; Landscape design research; Principles landscape architecture; Design knowledge

1. INTRODUCTION

Despite its widespread availability there is evidence that GIS (Geographic Information Systems) is underused in the realm of landscape architecture and related disciplines (Drummond & French, 2008; Göçmen & Ventura, 2010). Though recognized as a useful tool for mapping and planning, the potential of GIS is often still underutilized due to a lack of awareness and prejudice. This paper aims to put forward some important concepts of GIS-based analysis which link to the very heart of landscape architecture in a natural and intuitive way. Hence the possibility to break down barriers of using GIS in landscape architecture this paper aims to put forward some characteristic principles of study and practice in landscape architecture which can be made operational via GIS while cultivating spatial intelligence by means of geo-information technology. Here the focus is on applications of GIS in landscape design research – investigating landscape designs to understand them as architectonic compositions (architectonic plan analysis) (Steenbergen et al., 2002). By exploring landscape architectonic compositions with GIS, design knowledge can be acquired useful in the creation/refinement of a new design (Nijhuis, 2014 & 2015). Like other tools, such as microscopes and telescopes, GIS can help landscape architects to see what cannot be seen by the naked eye, realistically simulating past, present and future situations or superimposing information for means of analysis.

The next section addresses landscape design research and its principles of study and practice, followed by a brief discussion on why GIS is underused in the field. The next section elaborates on how these principles can be made operational through GIS-applications in landscape design research. The paper closes with some concluding remarks.

2. LANDSCAPE DESIGN RESEARCH

Landscape architecture is according to the International Federation of Landscape Architecture (IFLA): "A profession and academic discipline that employs principles of art and the physical and social sciences to the processes of environmental planning, design and conservation, which serve to ensure the long-lasting improvement, sustainability and harmony of natural and cultural systems or landscape parts thereof, as well as the design of outdoor spaces with consideration of their aesthetic, functional and ecological aspects" (Evert et al., 2010, p. 509). Within this broad definition there are three main areas of activity: landscape planning, landscape design and landscape management (Stiles, 1994; Thompson, 2008). These activities overlap and address different spatial levels of scale with different degrees of intervention. They require a multi-layered understanding of landscape regarding its spatial structure, development over time, the relational context, as well as the ecological, economic and social processes involved. Hence, over time a repertoire

of principles of study and practice typical for landscape architecture has been developed to understand landscapes as (1) three-dimensional construction, (2) history, (3) scale-continuum, and (3) process (Nijhuis, 2013; cf. Prominski, 2004; Marot, 1995). These principles and their interplay are considered to be characteristic for landscape architecture and are embedded in theories, methods/process and products of design; landscape architecture's body of knowledge.

Particularly the products of design – landscape architectonic compositions – embody a great wealth of design knowledge regarding the application of the principles. Landscape architectonic compositions carry knowledge about how to satisfy certain requirements, how to perform tasks, and it is a form of knowledge that is available to everyone (cf. Cross, 2006). The concept 'composition' refers to a conceivable arrangement, an architectural expression of a mental construct that is legible and open to interpretation. In that respect the landscape design is regarded as an 'architectonic system' by which rules of design common to all styles are established (Colquhoun, 1991; Steenbergen et al., 2002). By studying landscape architectonic compositions landscape architects can acquire knowledge of the possible relationships between conceptual thinking and the three-dimensional aspect (Steenbergen & Reh, 2003). Landscape design research is a vehicle to acquire knowledge of spatial composition via architectonic plan analysis. It is a matter of developing and deploying spatial intelligence, the architectural capacity or skill to think and design in space and time (Gardner, 1999). In short: understanding is the basis for intervention. This implies that landscape design research is at the core of landscape architecture. But how can GIS be used in landscape design research?

3. GIS AND LANDSCAPE DESIGN RESEARCH

The uptake on using GIS is remarkably slow in landscape architecture, and when utilised it is often restricted to the basic tasks of mapmaking and data access. There still appears to be a lot of confusion regarding the use of the tool. Surveys show that the complexity and the wide range of possibilities of the software, as well as access to and availability of data are important factors in the neglect of GIS in landscape architecture (cf. Drummond & French, 2008; Göçmen & Ventura, 2010; for more backgrounds see Nijhuis, 2015). Scholars and practitioners in general are also not aware of the full potential of GIS in landscape architecture, particularly landscape design research. Another reason is that GIS is usually introduced not by need or demand, but by the mere possibility of using the novelty program. The effect of the use of GIS is thus largely up to the individual users who have a special interest in the technology, while combining it with skills in landscape architecture. Therefore, aside from training and data issues, a lack of knowledge of the possibilities

of GIS in landscape architecture appears to be a significant barrier preventing greater use of GIS.

Knowledge development and dissemination of applications of GIS in landscape architecture are key factors in the awareness of the potential of GIS. A brief literature survey, spanning the period 1990–2013, exemplifies the observation that knowledge development and dissemination are lagging behind in comparison with landscape architecture or GIS as autonomous fields (respectively 16,220 and 61,000 references; Table 1) (Nijhuis, 2015). When combining landscape architecture and GIS, the query only brought up 187 references; 1.15% of all landscape architecture references in that period (Table 1).

KEYWORDS	N-PUBLICATIONS		KEYWORDS	N-PUBLICATIONS	
landscape architecture	3,840		landscape architecture, GIS	9	0.23%
landscape planning	3,510		landscape planning, GIS	89	2.50%
landscape design	5,300		landscape design, GIS	26	0.49%
landscape management	3,570		landscape management, GIS	63	1.70%
total	16,220	100%	total	187	1.15%
KEYWORDS	N-PUBLICATIONS		KEYWORDS	N-PUBLICATIONS	
GIS	61,000				
urban planning	15,200		urban planning, GIS	429	
urban design	10,900		urban design, GIS	149	

Table 1. Literature research based on title keywords, 1990-2013.
(Numbers based on analysis by Google-Scholar and Scopus using key phrases in the title of indexed publications, accessed: 27th February 2013. For Google-Scholar the operator 'allintitle:' is used.)

As indicated by the survey it is important to develop and disseminate knowledge of GIS-applications in landscape architecture. This will stimulate the use of the tool by the mere possibility of 'following' the discipline and developing aspects of it, and by setting in motion fundamental developments in the field. In particular for landscape design research as a core activity there is a lot to gain. The assumption is that GIS can enrich procedures of investigation and analytical techniques in landscape design research providing alternative readings of landscape architecture designs.

4. GIS-APPLICATIONS IN LANDSCAPE DESIGN RESEARCH

The application of GIS in landscape design research is here understood as an extension of the fundamental cycle of observation, visual representation, analysis and interpretation in the process of knowledge acquisition, with alternative visualisations and digital landscape models as important means for this process (Nijhuis, 2015). Using the calculating power of computers, combined with inventive modelling, analysis and visualisation concepts in an interactive process, opens up possibilities to reveal new information and knowledge (Figure 1).

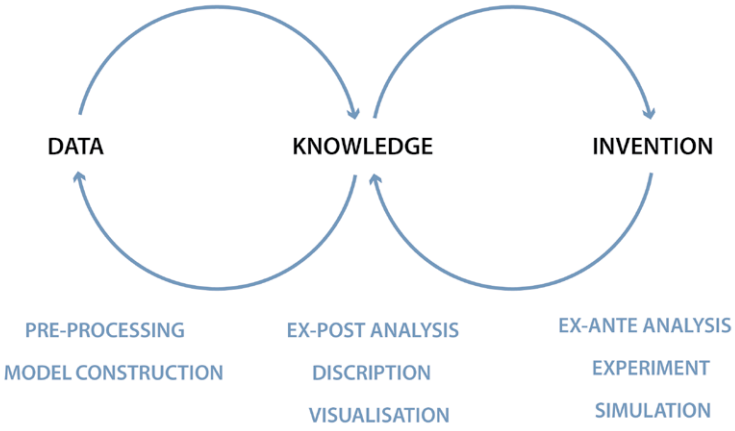


Figure 1: GIS as a facilitator and mediator in the knowledge formation-cycle and design generation-cycle: an iterative process from data to knowledge, from knowledge to invention (source: Nijhuis, 2015).

As such can GIS be regarded an external cognitive tool that facilitates and mediates in design knowledge acquisition. GIS facilitates in the sense that it can address the 'same types of design-knowledge' regarding aspects of the landscape architectonic composition, but in a more precise, systematic, transparent, and quantified manner. GIS mediates in the sense that it influences what and how aspects of the composition can be understood and therefore enables design researchers to generate 'new types of design-knowledge' by advanced spatial analysis and the possibility of linking or integrating other information layers, fields of science and data sources.

There are at least three operations in which GIS could be useful for landscape design research exploiting GIS in its powerful integrating, analytical and graphical capacities (Nijhuis, 2015):

- GIS-based modelling: data acquisition and the description of existing and future landscape architectonic compositions in digital form;

- GIS-based analysis: exploration, analysis and synthesis of landscape architectonic compositions in order to reveal latent architectonic relationships, while utilizing the processing capacities and possibilities of computers for ex-ante and ex-post simulation and evaluation;
- GIS-based visual representation: representation of (virtual) landscape architectonic compositions in space and time, in order to retrieve and communicate information and knowledge of the landscape design.

These operations have a great potential for measurement of relevant and new aspects of landscape architectonic compositions, as well as offering an alternative ways of understanding them. In particular while using the typical principles of study in landscape architecture as a point of departure for computer-aided architectonic analysis a 'toolbox' emerges for GIS-based landscape design research. This toolbox consist of a set of GIS-analysis methods and techniques stratified according the typical principles of landscape architecture. In that way concepts of GIS-based analysis can be linked and deployed in accordance with the experience of landscape architects.

4.1 Understanding landscape architectonic compositions as three-dimensional construction

In this principle the focus is on GIS-applications for exploring the landscape architectonic composition 'from the inside out', as it could be experienced by an observer moving through space using concepts of GIS-based visibility analysis (e.g., viewsheds, isovists) and virtual 3D-landscapes. Here GIS is employed to explore the visual manifestation of open spaces, surfaces, screens and volumes and their relationships in terms of structural organisation (e.g., balance, tension, rhythm, proportion, scale) and ordering principles (e.g., axis, symmetry, hierarchy, datum, transformation) (cf. Bell, 1993). The basic premise is that the shape of space, plasticity (form of space-determining elements) and appearance (e.g., colour, texture, lighting) of spatial elements in the composition determine the relation between design and perception. GIS-based landscape design research addresses the form and functioning of three-dimensional landscape space, which creates a certain spatial dynamic. Here GIS is employed to describe and evaluate volumetric characteristics of landscape architectonic structures, scenography and movement, the treatment of the panorama, or development over time. In this way the framing of a landscape or urban panorama, or the construction of a spatial series along a route, making a pictorial landscape composition, can be studied further (Figure 2).

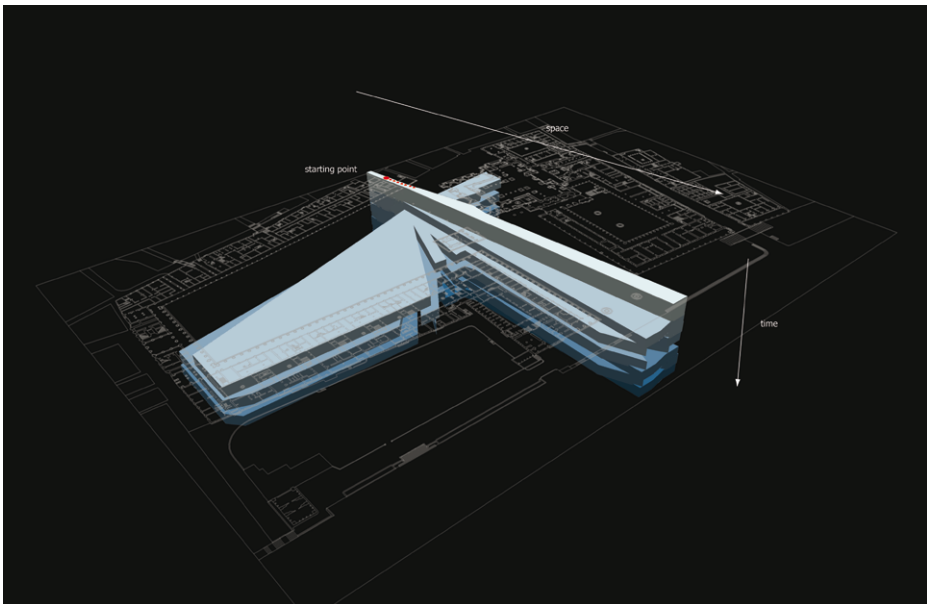


Figure 2: GIS-based visibility analysis in which successive fields of vision are calculated from the entrance to Piazza San Marco, Venice (Italy). Known as a Minkowski model, it shows from top to bottom how the square 'unfolds' – from a tightly framed view of the water to a view of the entire square (source: Nijhuis, 2014) .

4.2 Understanding landscape architectonic compositions as history

GIS-applications focus on 'reading' the landscape as a biography, as a palimpsest that evidences all of the activities that contributed to the shaping of that landscape. Here the landscape architectonic composition is regarded as a layered entity where traces that time has laid over can reinforce or contradict each other. Knowledge of these layers is one of the starting points for new transformations of the composition involved, or adding a new design layer. This principle involves the evolution of the composition over time and investigates operations of 'erasing' and 'writing' history (Lukez, 2007). Operations of erasing history include: complete or partial eradication, etching, excision, entropy and excavation. Operations of writing history include: parcelling, infill, addition, absorption, enveloping, wrapping, overlay, parasitize and morphing. Here GIS is employed to get to know the historical situation and the development of the composition via time-slice snapshots. Via the construction of GIS-based virtual historical landscapes of a certain time-slice snapshot or comparisons of several of them (via overlay, attributes or in a series) the dynamics and change over time can be explored (Figure 3).

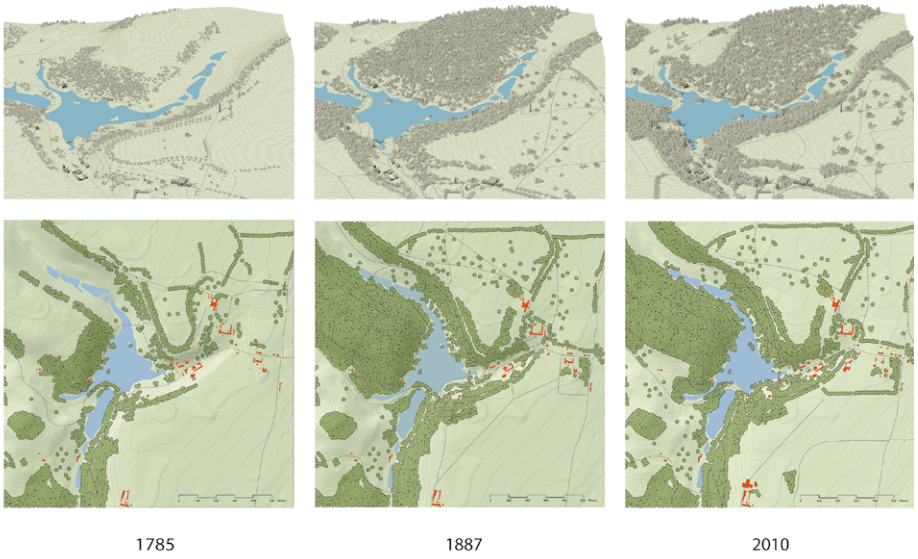


Figure 3: GIS-based reconstructions of Stourhead landscape garden (Wiltshire, UK) in different time stages of its development represented as virtual 3D landscapes and maps (source: Nijhuis, 2015).

4.3 Understanding landscape architectonic compositions as scale-continuum

In this principle the focus is on GIS-applications addressing the landscape architectonic composition as being part of a scale-continuum. The level of scale of a composition under study is important, because any size larger than that of the study area supposes a 'larger context', but any size smaller than that of the smallest detail supposes context as well (De Jong, 2006). The composition is considered to be part of a relational structure connecting scales and spatial, ecological, functional and social entities. GIS-applications focus on exploring topological (vertical) and chorological (horizontal) relationships, the embedment of a specific site or location into the broader context at different scale levels. Here spatial patterns are studied by map dissection (selection and reduction) as a basis for spatial association analysis, which explores the relation between different patterns. Techniques for spatial association analysis are overlay analysis and cross-reference mapping. Here GIS is employed to explore for instance the position of the designed landscape in its natural, cultural or urban context on multiple scale levels (Figure 4).

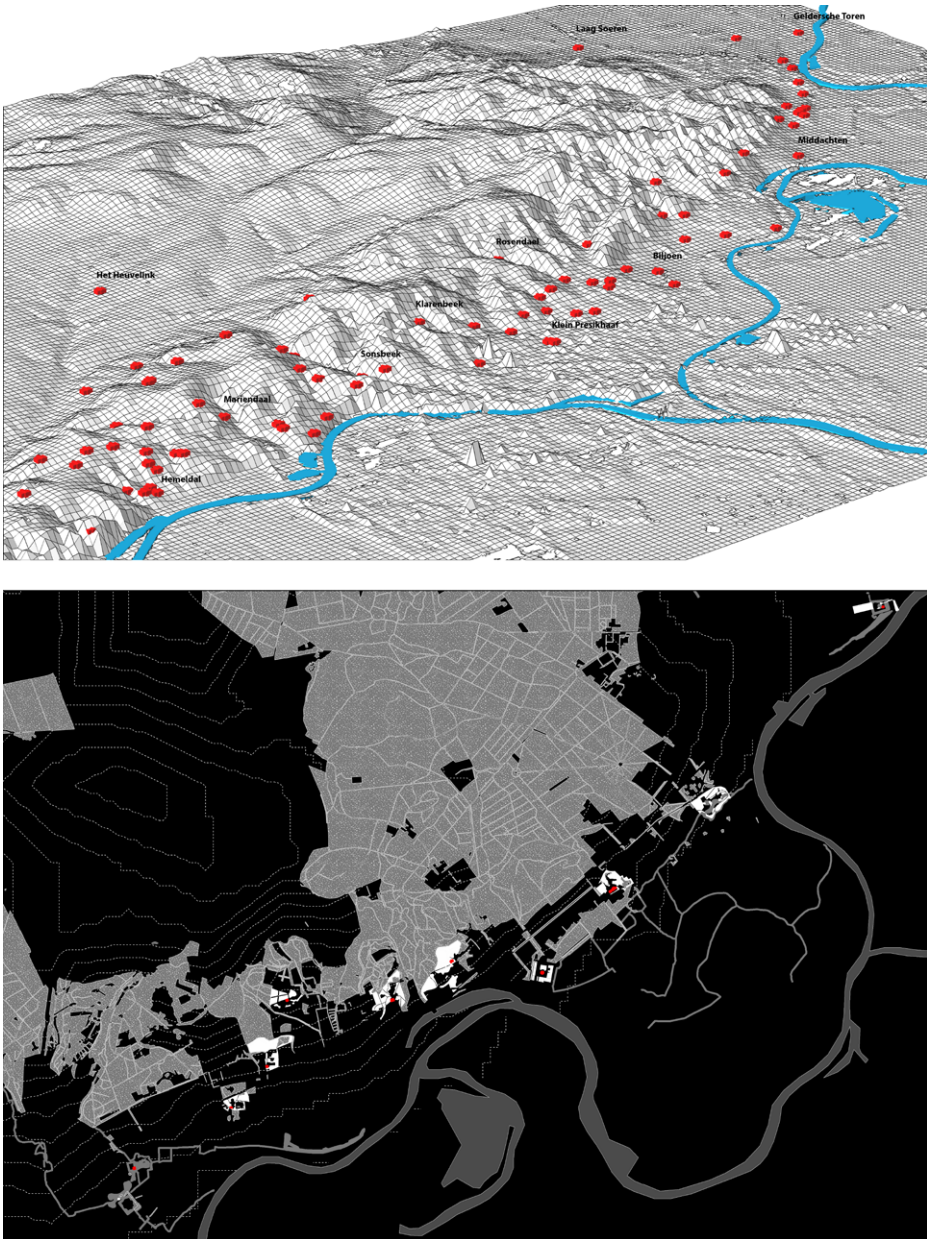


Figure 4: GIS-based spatial association analysis of the distribution and allocation of historical estates of Guelders Arcadia (near Arnhem, Netherlands) in the natural landscape dominated by the ice-pushed ridges of the Veluwe-East (top) and analysis landscape architectural compositions of selected individual estates which show a remarkable sensitivity towards natural conditions at multiple scale levels (source: Nijhuis, 2016).

4.4 Understanding landscape architectonic compositions as process

GIS-applications focus on the interaction between landscape processes and typo-morphological aspects and address aesthetic, functional, social and ecological relationships between natural and human systems. The landscape architectonic composition is regarded to be part of a holistic and dynamic system of systems as an expression of the interplay between formal aspects and interaction between ecological, social and economic processes (Zonneveld, 1995). The composition is considered as an ongoing process rather than as a result. Natural and social processes constantly change compositions, making the dynamics of the transformation a key issue in research and design. Here GIS is employed to understand the landscape as a system employing geo-computational models (deterministic or stochastic) such as morphological models exploring the social logic of space, or ecological process models investigating the spatial development and expression ecosystems (Figure 5). Also time-geographic models, traffic and transport models, planning models, economic models, cognitive models, multi-actor models, building technology and logistical models, hydraulic engineering models, nature and environmental models, agricultural models, energy models are of use. Spatial association analysis and (automatic) construction of virtual 3D landscapes are useful analytical operations.

5. CONCLUSION

The here briefly discussed toolbox for GIS-based landscape design research is not about presenting new GIS-analysis methods and techniques. It rather re-presents or frames useful GIS-concepts from the perspective of landscape architecture. Hence, this toolbox embodies a way of thinking typical for landscape architecture which is visible in landscape architecture theories, planning and design processes and products. It offers the possibility to link concepts of GIS-based analysis to the very heart of landscape architecture in a natural and intuitive way in the hope to break down barriers of using GIS in landscape architecture. The typical principles of landscape architecture can also serve as a basis for cultivating spatial intelligence by means of geo-information technology while raising awareness and take away prejudice.

Studies such as Nijhuis (2015) point out that GIS can extend the design researchers' perception via measurement, simulation and experimentation, and at the same time offer alternative ways of understanding the landscape architectonic composition. This offers possibilities of exploring important aspects of landscape design research, such as the visible form and kinaesthetic aspects, analysing the composition from eyelevel perspective.

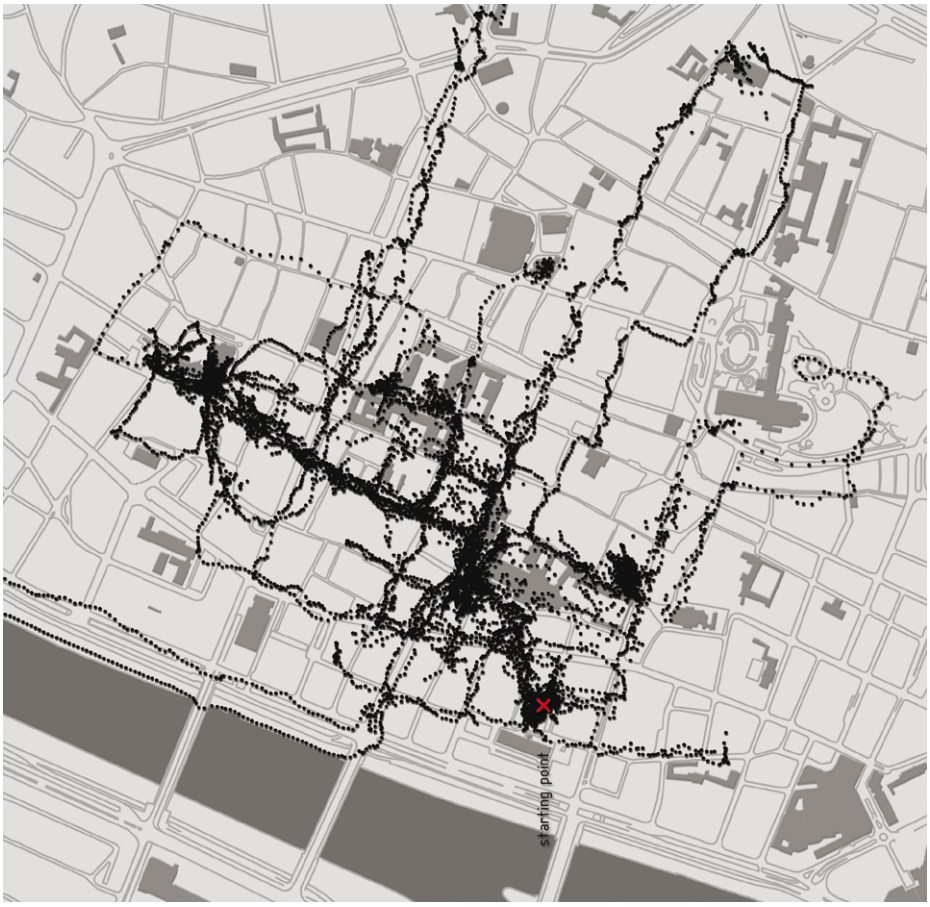


Figure 5: GPS-monitoring of pedestrian movement by tourists in Rouen (France). In order to reveal their movement behaviour several dozens of tourists were asked to carry GPS-devices while visiting the town centre, here represented as a map
(source: Nijhuis, 2015)

GIS has the potential to measure phenomena that are often subject to intuitive and experimental design, combining general scientific knowledge of, for instance, visual perception and way-finding, with the examination of site-specific design applications. GIS also enables one to understand landscape architectonic compositions as a product of time, via the analysis of its development through reconstruction and evaluation of several crucial time-slice snapshots. As such GIS-based landscape design research can serve as a basis for the academic underpinning and the development of a digital culture in landscape architecture exploiting GIS in its powerful integrating, analytical and graphical capacities. Educational and research institutions have an important part to play, they must take the lead in inspiring students and practitioners, building up their knowledge and passing it on, and adding new tools to the traditional craftsman's toolbox.

ACKNOWLEDGEMENTS

This paper is based on material developed for the 'Geodesign Summit Europe, 11–12 September 2014, Delft University of Technology (Netherlands)' and the 'ECLAS conference, 11–14 September 2016, Rapperswil, Zurich (Switzerland)'.

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