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TOWARDS PEOPLE-CENTRED PRECEDENTS FOR PARAMETRIC DESIGN

The Case of Wayfinding in Large-Scale Public Buildings

Vasiliki Kondyli[1], Mehul Bhatt[2], and Timo Hartmann[3]

Abstract: Large-scale public buildings need to ensure an effective wayfinding performance for different user groups. Recent precedent based design approaches take spatial cognition into account by analysing the visuo-locomotive experience of users with the aim to interpret their behaviour and integrate it into a people-centred design. The paper focuses on the process from the analysis of precedents and the visuo-locomotive experience to the definition of design constraints that can be embedded into a parametric design for wayfinding. Primarily, we pursue a qualitative analysis of the visuo-locomotive experience of wayfinders in a healthcare built environment, with the use of cognitive-assistive and immersive/ virtual reality technologies. The outcome, presented through immersive reality, is correlated with the morphological analysis of the space and leads to precedents evaluation about design for wayfinding and the definition of new design constraints. The process is approached through an example, the environmental aspect of visual range. We conclude that this practice can overcome some of the experience based design practices of today but is not yet ingrained in the architectural and engineering design processes of public buildings.

Keywords: precedent based design, immersive reality, spatial cognition, wayfinding, people-centred parametric design.

1 INTRODUCTION

Precedent based design refers to the design process that embeds explicit learning from previous knowledge and earlier experience, which a designer draws upon in order to take appropriate design decisions (Tzonis 1992). Studying precedents helps in understanding new situations and projecting older solutions into new problems. Precedent based design methods are directly related to theory development in design disciplines; they are a common practice in architecture design theory, synergising closely with methods for evidence-based design, post-occupancy evaluation (POE), and design critique. In practice investigating user's embodied visuo-locomotive experience leads to behavioural evidence valuable for establishing new precedents. This procedure falls into the agenda of Evidence-Based Design (EBD) and is fundamental for understanding the impact of architectural design decisions, and functional building performance from the

1 Ph.D. candidate, DesignSpace Group (www.design-space.org), Faculty of Informatics, University of Bremen, Germany kondyli.v@gmail.com
2 Professor of Informatics, DesignSpace Group (www.design-space.org), Faculty of Informatics, University of Bremen, and Stiftungs Professor, German Research Centre for Artificial Intelligence (DFKI Bremen), Germany bhatt@uni-bremen.de
3 Professor for Systems Engineering, Department of Civil Systems Engineering, Civil Engineering Institute, TU Berlin, Germany timo.hartmann@tu-berlin.de

viewpoint of areas such as environmental psychology, wayfinding research, human visual perception studies, spatial cognition, and the built environment.

Design for large-scale public buildings has to ensure that people-centred design objectives are fulfilled (e.g., people should (not) get lost; the environment should fulfil universal design criteria for diverse user groups and situations, e.g., disabilities, geriatric care, emergencies). Research in environmental psychology and spatial cognition has started to remediate this situation (Bhatt and Schultz 2016). In this interdisciplinary field, a well-versed evidence-based understanding is developed by evaluating precedents and analysing behavioural evidence about user's visuo-locomotive experience during wayfinding tasks (Hamilton and Watkins 2009). Toward this direction, designers and architects need access to assistive technologies, people-centred design systems that manifest a basic understanding of human behaviour in spatial environments.

Despite the current popularity of parametric design tools, a people-centred approach on this is not yet reached. People-centred parametric design systems aspire to combine the advantages of parametric design (such as the quick generation of design possibilities, adaptation and modification (Boucherie et al. 2012)), with the knowledge provided by the experience. Such a link would allow the designer to automatically evaluate a vast amount of alternatives that parametric tools generate, by using the results of visuo-locomotive analysis about human wayfinding in indoor environments. In practice, as parametric synthesis seeks the specification of the properties of the elements present in the encountered topology (Norton 2003), this study presents the process from the analysis of users' experience in space to the definition of design constraints that can be embedded into parametric design.

2 Learning design precedents from visuo-locomotive user experience

2.1 Multi-modal analysis of wayfinding behaviour

A multi-modal analysis of users' visuo-locomotive experience in large-scale built-up spaces, encompasses the measurement and qualitative analysis of a range of aspects including people's visual perception, their decision-making procedures, and intentions, the affordances of the environment itself, etc. Our approach is driven by cognitive vision theory and the high-level semantic analysis of multi-modal perceptual data currently encompassing mobile eye-tracking data and corresponding visual perception analysis; analysis of visual data from external cameras along the route and ego-centric camera (onboard the eye-tracker); people-movement trajectories based on locomotive path taken by subjects, including other events (e.g., asking for help, looking around) that are recorded during the experiments by an experimenter using a mobile device (Figure 1). For the purpose of wayfinding behaviour understanding, the computational "semantic analysis" and "perceptual sense making" of multi-modal visuo-locomotive data are combined with the morphological analysis of the structure and layout of the environment (e.g., topology, routes, isovists) computed from available 3D models of the building (Bhatt, et al. 2016; Bhatt and Schultz 2014).

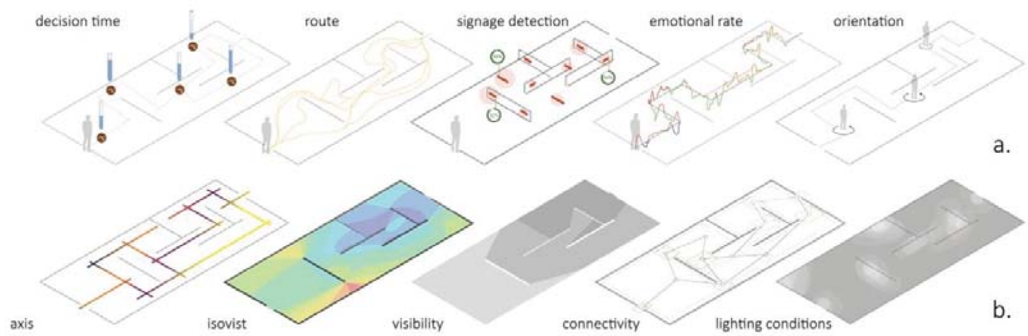

Figure 1: An overview of the possibilities to analyse (a) visuo-locomotive behaviour data and (b) morphological data.

2.2 Environmental Aspects Influencing Wayfinding Performance

The analysis of the embodied visuo-locomotive experience during a wayfinding task reveals the individual-based factors and the environmental factors which have an impact on user's behaviour and performance. Numerous studies have demonstrated that many navigation problems are caused by the problematic arrangement of complex decision points, their linking paths, the vertical incongruence of floors (Arthur and Passini 1992; Weisman 1981; Devlin 2014) or other environmental aspects as location, size, distance, direction, separation and connection, shape, pattern, and form (O'Neill 1991). To summarise, wayfinding performance according to bibliography (Montello 2005, Weisman 1981, Carpman 1985) is correlated mainly with environmental characteristics such as:

- plan configuration,
- geometry of the environment,
- available visual range,
- architectural differentiation, and
- manifest cues (landmarks and signage).

2.3 Summarisation and Archival of Evidence: The Role of Immersive / Virtual Reality

The observations and the multi-modal data are processed, analysed, and integrated into a holistic model of visuo-locomotive narrative experience at an individual and aggregate level. The results are externalised in an immersive reality setup at an individual as well as aggregate level respectively. The tool that we are using for this process is based on the development of "MindYourSpace" (Schultz et al. 2013), a technological framework consisting of complementary tools that generate virtual and immersive reality-based analytical summarisations of large-scale multimodal data (i.e., resulting from environment-behaviour experiments, e.g., concerning wayfinding studies, signage perception testing (Figure 2). The final outcome in immersive reality environment is implemented using a combination of the Vizard VR Software and compatible Head-Mounted Displays (HMDs) (e.g., Oculus Rift). These tools give us also the opportunity to test human visual perception and navigation performance for predictive purposes. For example, we can test the geometrical modifications required according to the behavioural evidence acquired from an empirical study.

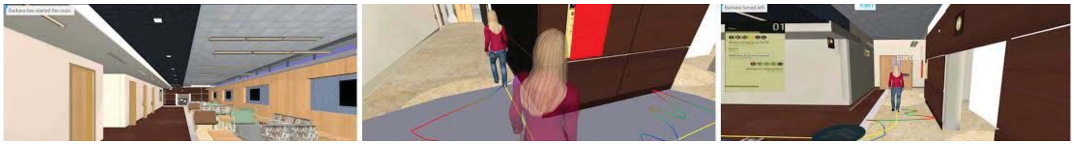

Figure 2: Computationally generated immersive reality experience based on multi-modal perceptual data and its high-level grounding and analysis - such as fixation analysis from eye-tracking data and automated signage extraction from video - based on the architectural Building Information Model (BIM) standards.

3 From evidence to precedents: the case of visual range

Visual range is exceptionally important for wayfinding at the level of reachable or visible space around the body but not for the level of navigation space that cannot be apprehended at once. As a result we focused on precedents related to visual range and we drew connections with the behaviour evidence derived from the case study.

3.1 Precedents about the Visual Range

The role of visual connectivity or mutual inter-visibility between parts of a building has been established in wayfinding design (Gibson 1979). Visual attention studies also support that people tend to move towards the direction of the depicted area with the longest line of sight (Wiener et al. 2012). Additionally, as Gärling et al. (1986) show, views of the external environment can enhance the legibility of interiors. For instance, depth of view is a variable of intrinsic interest for practitioners and researchers of human behaviour, as it relates directly to our immediate sensory perception of the environment. Consequently, manipulating visual range means making design decisions about spatial geometry (boundaries, corners), such that they influence the geometry of the scene (the scene formulated during locomotion) and facilitate users' orientation, spatial knowledge acquisition and navigation performance (Cheng and Gallistel 2004).

3.2 A Case Study at the New Parkland Hospital

In a wayfinding case study at New Parkland Hospital (Dallas), we investigated (among others) the visual range in relation to user's visuo-locomotive experience in order to reveal useful evidence for formulating design constraints. Experiments included 25 participants from the local community, between 28-83 years old. They were fitted with mobile eye-tracking glasses by Tobii and Senso Motoric Instruments (SMI), and pursued a complex wayfinding task from the 'Emergency room' to the 'Pharmacy', passing through the main public spaces of the building and also moving vertically by elevators to the first floor (approx. 15 min walk). We employed a range of sensors to measure the embodied visuo-locomotive experience (see section 2.1) and correlate it with the outcomes pertaining to spatial knowledge tasks (e.g., recall, pointing, perspective-taking, distance estimation).

The external cameras' footage in combination with the manual observations of the experimenters, pinpointed the positions where people tended to get lost, hesitated and looked around to orient themselves. These notes guided the morphological analysis to focus on specific positions, mainly decision points located in narrow corridors, at the threshold between a narrow to a wider place or in spaces with unusual geometrical features that provided unpredictable fields of view. By comparing the computational eye-tracking data analysis with these results, we were able to justify some of the detected problematic wayfinding performances. Specifically, the visual perception analysis (for each position that we analyse) included zones of interest (heatmaps), visual attractions, fixation or saccade flows (scanpaths), the scanning procedure of a new environment or the range of attention (Figure 3). It was proven that the available visual range influences the way participants scan the scene and the space around them. For instance, the zone of visual attention (the zone of the scene that concentrates the majority of the fixation points) appeared to be a thin zone parallel to the horizontal axis, but it became wider in case the ceiling of the space appears to be higher (Figure 4a).

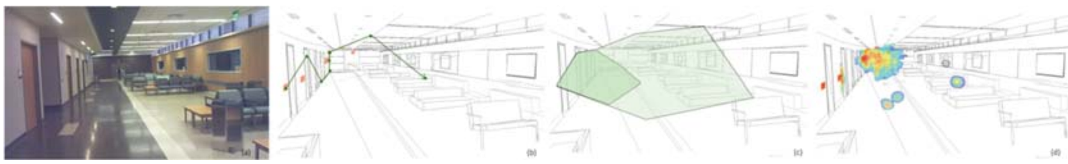

Figure 3: Visual perception analysis from the egocentric camera and the eye-tracking data: (a) Screen-shot of the egocentric camera, (b) Fixation flows, (c) Range of fixations as they change in time, (d) Heatmaps of fixation points.

Moreover, openings, glass surfaces or atriums, are known design precedents that facilitate visual connections and this was also confirmed by the visual behaviour of participants and as a consequence by their wayfinding performance. Passing through the atrium lobby, participants were able to detect the manifest cues a lot ahead before they arrive at the decision point. Moreover, glass walls and openings helped them orient themselves quicker, as they allow them to detect landmarks or previous parts of their routes. Additionally, participants passing near the glass walls tended to look outside and this had a relaxing effect on them, as they reported to their interviews. On the other hand, we noticed that a wide range of view can also be a drawback. At the final decision point, a large number of participants - while passing the threshold from the elevator to the lobby - were not able to detect the manifest cues at their first try but they got mislead by a long corridor that provides a long line of sight. As a result, many of them got distracted and followed the wrong route on their right (Figure 4b).

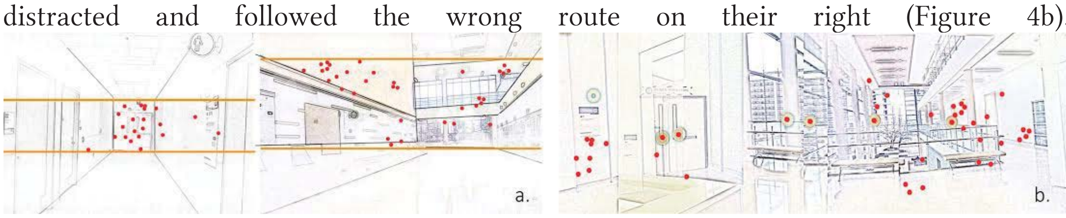

Figure 4: Findings from eye-tracking data analysis from the case study that will allow parametrization. (a) The relationship between the visual range and the height of the space (b) The fixations at the decision points shows how the visual attention is directed at the long line of sight.

3.3 Define Design Constraints about Visual Range

The results from the case study provide evidence that many of the well-known precedents about the effect of the available visual range on the wayfinding performance, as for example the role of the atrium, the distance between the detection point of a landmark and the decision point, or the use of glass. Furthermore, we concluded that the visual perception is formulated, to an extent, by the designed geometry and the affordances. Consequently, the visual range is an environmental aspect with the power to increase or decrease the rate of confusion of the user, and this can be detected and measured through his visuo-locomotive behaviour.

These outcomes constitute indicators for design parameters and we conducted further controlled experiments in Virtual Reality (VR) to clarify the rate of impact that manipulating the visual range has on wayfinding performance. The observations of our limited behavioural tests in VR were focused on different geometries (e.g., narrow corridors as decision points, the transition from a narrow to a wide space) and how the visual behaviour patterns were affected. The outcomes supported the findings of the case study. Hence, exploring multi-modal behavioural data of participants in a healthcare environment and a virtual one, we came up with some critical qualitative constraints, to be fulfilled during wayfinding design process:

- No more than three route options should be available to each decision point,
- The decision points should not be positioned into narrow places,
- The manifest cues for wayfinding purposes should be positioned in accordance with the fixation zones, which depend on the geometry (width and height) of the scene,
- The decision points should be positioned around the atrium and the atrium has to ensure visibility among the decision points,
- Glass walls and openings are useful for wayfinding performance when they permit visibility towards manifest cues, the outdoor environment or other important parts of the wayfinding route,
- High ceiling spaces enlarge the zone of visual fixations towards the vertical axis and influence the area of attention.

4 COGNITIVE THINKING FOR PRECEDENT BASED PARAMETRIC DESIGN

Our approach to define qualitative constraints for wayfinding design as an outcome of the multi-modal analysis of visuo-locomotive experience, ingrains human perceptual characteristics and morphological features into design discourse and precedent base design for the domain of large scale public service buildings. The purpose is to integrate cognitive thinking into architectural and engineering design processes. This can be possible by embedding qualitative cognitive constraints into Parametric Geometric Modelling and Building Information Modelling (BIM) that allow the quick generation and evaluation of a large number of different possibilities for the layout of a public building.

Recently a number of such BIM based design tools have been developed. These tools do not only allow the design of floor and circulation plans, but also integrate functionality to describe and evaluate user behaviour (Oh, Minoh, et al. 2015; van Amstel et al. 2015, 2016) (Figure 5). Some advanced studies have even started to develop new frameworks for designing the layout of a building together with the services this should provide (Boucherie et al. 2012). However, the problem with all of these approaches is that the representation of user activity within these models is at best crude and is not based on any type of evidence. In particular, the very important aspects of indoor navigation behaviour that defines many aspects of how a facility can offer services and how possible services are perceived as qualitative or not cannot be reasonably accounted for in all of the approaches.

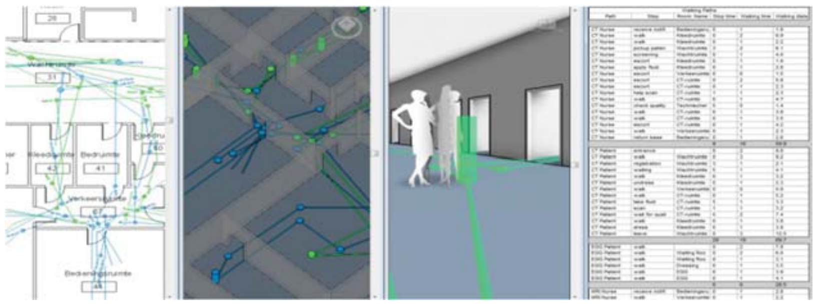

Figure 5: Impression of a BIM based parametric design tool that accounts for both, the development of floor plan layouts and the design of productive service routes.

A link between the two fields of BIM and service simulation absent parametric design with evidence based insights from an analysis of visuo-locomotive experience, would allow for the automatic evaluation of a vast amount of alternatives that parametric design tools generate using the latest results from cognitive research about human navigation in indoor environments. What is missing currently are the insights to integrate the cognitive behavioural patterns into existing computational simulation frameworks. Additionally, methods need to be developed that can clearly visualise the evaluation results to design professionals and building users for flexible and adaptable designs into cognitive thinking principles.

5 CONCLUSION

Tracking and analysing people's behaviour in large-scale buildings provides evidence about users' embodied visuo-locomotive experience during way-finding and leads to confirmation of precedents useful for design decision making. This evidence is referred to different target groups of users or to different environmental cues. In the case of visual range, our behaviour analysis led to a summarisation of users' experience and confirmed design precedents related to spatial geometry such as the atrium, the long line of sight and their impact on wayfinding performance. We examined the advantages of embedding this evidence into parametric design tools by translating the confirmed precedents into design constraints. In our next steps, we implement these constraints in open-source parametric systems and we anticipate that this approach will expand the abilities of contemporary design tools by combining flexibility, adaptability and the human dimension. Consequently, the translation of behavioural results into parametric design constraints for a range of environmental variables is a field to be explored in the future.

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