DESIGNGHOSTS

Mapping occupant behaviour in BIM

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Abstract. For architects, a database of typological specific occupant behaviour patterns could help in the design of buildings, through a typological specific insight into the previous use of buildings. In addition, appropriately represented occupant behaviour data in commercial buildings represent an important factor for facilities management (FM) and business information (BI) teams in the assessment the operational performance of the enterprise. Building Information Models (BIM) could provide an appropriate reference for this user data. However the mapping of user behaviour data to the BIM models is unclear. This paper presents a ‘designGhost’ information system to support the mapping of occupant behaviour to BIM models, so that the user data can be represented to the different stakeholders. To test the information system a prototype tool is presented to enable the mapping of the building use (designGhost) data to the building’s spaces in order to support architects in the design stage and to support navigation from an operational (FM/BI) perspective. This paper addresses the challenges of developing such a system and proposes directions for future work.

Keywords. Post occupancy evaluation; BIM; visibility graph analysis; designGhost; occupant behaviour; design science; building design and operation.

1. Introduction
The financial and environmental cost in the creation and occupancy of architecture, means that the architectural design team are under pressure to deliver high performing buildings. At the same time, from the perspective of large commercial clients, facilities management (FM) teams are under pressure to
optimise the use of their estate as a component of enterprise analysis performed by business information (BI) teams. These stakeholders, in a building’s life cycles, are interested in capturing, understanding and influencing building occupant behaviour in order to assess and ultimately improve building operational efficiency from a design or operations perspective.

If the operations perspective of FM and BI could be captured and provided to architects in a typology specific format, it could help architects analyse the performance of their own buildings which would help them when developing new designs as well as evaluating previous designs. In the UK building industry, schemes such as soft landings have been introduced to address the performance gap between design intent and operational outcomes. Soft landings could include many factors, for the purposes of this paper, user navigation is identified as an appropriate factor that is relevant to both the design and operations perspective. Therefore using a university campus building as a case study this paper aims to develop an approach to map user navigation data to BIM models called ‘designGhosts’. These designGhost graphs will support the organisation and representation of post occupancy evaluation (POE) data that, when taken en masse, will provide typology specific spatially referenceable user data for architects to analyse in the building design process. Therefore this paper proposes a plugin to the BIM tool Revit in order to test the proposed mapping of user to BIM data.

2. Background

The challenge of this paper can be framed from the perspective of case based reasoning. Case based reasoning (Aamodt & Plaza 1994) describes situations where practitioners solve problems based on an analysis of previous approaches to similar problems. More recently this has been described as case based design (Langenhan et al. 2013). Aamodt & Plaza describe 4 stages to this approach: case retrieval; reuse; solution testing and learning. Similarly this paper tries to support the presentation of previous use data to support the design and operation of existing and proposed buildings. A BIM system ‘enables users to integrate and reuse building information and domain knowledge through the lifecycle of a building’ (Lee et al. 2006). BIM systems could therefore support the capture of the occupant data. There are a series of issues that need to be addressed in order to achieve this. Such as, how can the data be captured and analysed? (Coates et al. 2012). Previous approaches to address the challenges of capturing, analysing and representing previous design performance data are discussed in the following sections framed by the stages of case based reasoning.
CASE RETREIVAL AND REUSE

McGinley (2014) describes a scenario in which post occupancy evaluation (POE) data is combined with ‘pattern of life’ behavioural pattern analysis technologies to inform the design of buildings. In such a scenario, user behaviour patterns (user ghosts) from buildings with a similar typology could be overlaid onto a proposed design and represented to the architectural design team. This approach could use current building industry interest in BIM to launch a user centred, empirically based approach to support the design and operation of buildings. This would require behaviour to be captured in an appropriate format which could then be used in the design and operation of buildings. Langenhan et al. (2013) have created a database of graphs for architecture. They propose a method of ‘semantic fingerprinting’ to support the matching of an architect’s sketched graph to similar graphs in a database.

Architectural design teams typically do not model user behaviour. The greatest danger with this in architecture is that buildings can be designed to the requirements of the architect, rather than the needs of the users of the building. Therefore an approach that requires designers to consider the ‘ghost’ behaviours of (lots of) real users of previous examples of that typology could be beneficial to the design and operation of the building. It may be desirable to build these user stories or ‘ghosts’ based on real behaviour from users in a building of a similar typology. It would therefore be necessary to capture user data. Capture methods include WIFI machine addresses and RFID tags (Coates et al. 2012). There are significant ethical issues regarding the capture of the data which would need to be considered prior to conducting the capture. The best scenario might be to use data that is already in the public domain. However, regardless of the format used to capture the data, the next question is to establish what data should be captured. It is clear that no data should be able to be combined to identify a specific individual. The optimum solution could be to capture the user population as an aggregated, anonymous swarm of building users.

SOLUTION TESTING AND LEARNING

Visibility graph analysis (VGA) (Turner 2001) offers an example of an analysis opportunity to measure how easy it is to navigate built environments. In this way VGA could offer an opportunity to simulate the performance of buildings. This would be useful to compare against real use data to provide solution testing as required by Aamodt & Plaza (1994), however it is unclear how this data could be mapped to existing BIM models. The uptake of BIM technologies by themselves have technical, legal, regulatory, organisational and training barriers (Elmualim & Gilder 2013). There are therefore two
main challenges to this research; how to map the designGhosts into the BIM and then how to represent this data to the different stakeholders.

Motawa and Carter (2013) propose a framework to support the mapping of POE data into BIMs. However, this framework is limited to energy performance of buildings and it is unclear how this performance data could be represented to the user in their CAD environment. They propose an energy system ontology that incorporates both information about the building’s systems with its energy use and the local weather. Doherty et al. (2012) propose a user navigation equivalent of Motawa and Carter’s energy efficiency ontology. Once captured, the previous behaviours then need to be mapped spatially to the historical and proposed designs. Steadman (1983) proposed a spatial graph to represent buildings as a series of connected spatial nodes. This representation could be used in the designGhost tool to map the behaviour to the different examples and to offer the basis of a standard notation system for the examples. This would allow the integration of other tools such as those developed by space syntax etc.

CURRENT LIMITATIONS

It is clear that a tool to support the capture of behavioural data in a format that is useful to designers in the future would be beneficial to the design and operation of buildings. If the data could be captured and analysed using VGA for instance then these ‘ghosts’ could be stored in the building’s BIM using the method proposed by Langenhan et al. (2013). Therefore an information system is required to map the user occupation (designGhost) data to the design or operation BIM system is required. When the significant work has been done to capture and analyse the data and persuade the user to interface with this data in an environment that incorporates an appropriate BIM model; the main challenge is, how can this analysis be represented to the designer? The medium for this could be offered either as a plug-in to a major CAD tool or ‘as a service’ using HTML5.0 technologies for instance to deliver the representation of previous use behavior over the web in the designer’s browser. An approach to link information about the building to the designer’s design interface is presented in the following section.

3. Method

This research aims to support the development of a global database of occupancy data by typology that will enable designers to call up previous approaches for their typology of interest. To achieve this, this paper documents the development of an information system to support the mapping of occupancy data to BIM data. It can be difficult to develop information systems
for a design context, where the use of the systems could be open to different interpretations. Hevner, March, Park, & Ram, (2004) propose a design science research methodology (DSRM) for information systems which is appropriate to the development of the designGhost information system. DSRM requires: the identification of the problem(s) the design is trying to address; the testing of the design; the evaluation of the designs performance against the identified problem(s); and finally the communication (sharing) of the findings. Having defined the problem and objectives of the research, the following section defines identifies the concepts of the system, based on this a solution is developed in the form of a designGhost graph. The graph is then tested by developing a plugin to map navigation data to the BIM model, which is then evaluated and communicated in this paper.

4. The case study

In this section, the DSRM steps are used to inform the development of a designGhost schema and graph which is tested on a university campus case study in Australia. This paper reports on an ongoing research project of which the first stage explores using BIM and GIS technologies to improve navigation on campus. The project focuses on three buildings on campus and explores their navigation at an internal and campus (enterprise) level. However for this paper just one building is considered. Based on the limitations identified in the background the following objectives for the information system can be defined. The information system needs to:

- Map POE to BIM models
- Integrate with existing building design and operation tools
- Be platform agnostic
- Focus on navigation in the first instance
- Have the potential to be extended to other cases

The following sections detail the approach to develop the designGhost information system.

4.1 IDENTIFY THE CONCEPTS

The ghosts are to be developed in a platform agnostic format that focuses on the ghost’s ontological model. Motawa and Carter (2013) identified weather data, building specification, energy assessment and site details as the concepts of their ontology. In computer science, concepts are sometimes represented as entities and their relationships are described using entity relation-
ship diagrams (ERD). In this sense, following Steadman’s (1983) example of spaces as nodes, each space in the designGhost could be thought of as a node in a graph. Based on the previous discussion, the proposed concepts (entities) are: BUILDING; CONNECTOR (between spaces); SPACE; USER and their BEHAVIOUR. In Figure 1, attributes are assigned to these concepts. Entity relationship diagrams are useful because they can describe not just the relationships of the concepts but any gaps in the concepts. In the following section these concepts are used to develop a designGhost graph that can be applied to the BIM model.

4.2 DESIGNGHOST CASE STUDY

A designGhost graph was proposed for the case study building as can be seen in figure 2.
This initial example was developed by walking around the building and noting the SPACES and their CONNECTIONS, this provided an indication of the form of the graph that could be expected. In the next stage a BIM model was developed of the building. This model is represented in Figure 3 which indicates the location of the CONNECTOR and SPACE concepts as they should be modelled in the prototype.

The prototype was developed based on the mock-up in Figure 3 to map the ghost to the BIM model, it is our intention that this should be developed into an automated system in future work. The graph was mapped into the Revit BIM model developing a designGhost map using Dynamo, which is an open source software to integrate computational design workflows though a visual programming interface as a plugin to Revit.. Dynamo builds on the interface developed for Grasshopper the popular visual programming plug-in for Rhino. This software was chosen for a number of features including it native relationship to Revit and its ability to represent the 3D BIM geometry in the same canvas as the visual programming interface using the ‘show background 3d preview’ feature. Initially the Revit API was also investigated, although dynamo’s visual programming made it easy to develop the prototype. Figure 4 shows a screen shot of the prototype in development. The prototype works by:

- Identifying the (SPACE) in the BIM
- drawing CONNECTIONs between the SPACEs
Applying midpoints between the SPACES along the CONNECTIONS to describe a THRESHOLD between the SPACES i.e. door etc.

In future work the dynamo prototype should identify all rooms in the BIM model through the ‘element type’ selection filter and select ‘element of type’ node in Dynamo. Following the development of the prototype the designGhost information system will be supported by a Revit plugin that will address the design and operational requirements identified in this paper. This should be developed into a standalone system that could be interrogated by FM members outside of the Revit environment. It is also possible that a Revit API plug-in would enable the building design and or operation team to draw the designGhost diagrams directly into Revit.

5. Discussion

Figure 4 demonstrates that the designGhost could be overlaid onto the BIM model, however, further work is needed in order to assess how successful it is in supporting the referencing of behavioural performance data. This paper documents the first stage in a larger research project, which based on the work presented here will develop an app to support student and staff navigation on campus supported by operational BIM models.

From a building design perspective, the designGhosts spatial graph would overlay onto a BIM model of the building and provide user attribute data for each space in the building that an architect could use in their normal CAD software. This would enable the incorporation of occupant behaviour for previous buildings into the design of buildings. It is possible a spatial sug-
gestion tool based on a database of graphs as suggested by Langenhan et al. (2013) could suggest design configurations based on previous data held in the designGhosts using a Markov chain type analysis. The ghosts would also consist of a spatial referenceable ‘template’ that could be placed into a CAD program and stretched and pulled to match the conditions of the site. The previous use data could then populate the typological template and provide a simulation of building use. This might identify potential bottlenecks and limitations in current thinking for that typology and provide the architect with some opportunities for future exploration.

From a building operation perspective the designGhosts could be populated by the FM team in the operational BIM model. In future work, the sensing protocols for the ghosts should be investigated. Ultimately it is possible that the user navigation data could be anonymised resulting in typology specific designGhosts that can be used to inform design and operational decisions. This could be achieved by introducing a multi-dimensional designGhost for the different building design and operation stakeholders.

6. Conclusion

Based on the dynamo prototype presented here, In future work a plugin for Revit and a database of designGhosts for particular typologies will be developed. However the most pressing work is to provide a link between current behavioural research and the designGhost graphs proposed here. The graphs could then be represented to the design and operational stakeholders in disciplinary specific tools. For the architect it is hoped that this will make it possible to better understand previous approaches and for the operational from the FM and BI (business information) perspective this will support the modelling of their estate and its relationship to the whole enterprise. This paper presents an information system to support the mapping of user behaviour to BIM systems. Whilst it is possible to imagine how the tools might be built to support this work based on this paper, it is unclear the changes to the education of building design and operational professionals to apply these tools effectively.

References


