INTRODUCTION

The main goal of our research work is to facilitate the design of pedestrian urban space by offering a set of computational design methods and associated parametric tools that would allow for fast visualization and analysis of alternative design scenarios. The complexity of contemporary urban design projects increases with the growing pace of urban development. Large amounts of data must be collected, stored and analyzed. The use of conventional Computer-Aided Design tools does not provide speed and flexibility necessary to design in the conditions dictated by the rapid urban development. We seek ways to integrate parametric and constraint-based modelling methods into the contemporary design practice. These methods enable architects and urban designers to create, manage and organize complex (parametric) design models by integrating different types of parameters and rapidly generating and evaluating alternative design solutions (Ehran 2003; Madkour et al. 2009; Woodbury 2010).

One of the main challenges that inhibit contemporary designers from applying computational design methods within their design processes is the difficulty of converting design information into parameters of a computational model. We propose a novel method for design parameter derivation in order to foster this conversion. This research will establish an inverse method for determining the most adequate set of parameters from the local design context that are well suited for creating sustainable

Parametric Tools for Conceptual Design Support at the Pedestrian Urban Scale

Towards inverse urban design

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Abstract. This paper presents an inverse pedestrian urban design method and an initial set of parametric tools for conceptual design support at the pedestrian urban scale. Inverse pedestrian urban design concerns the derivation of urban design parameters from a local context in order to produce better informed and situated designs. The tools concern the rationalization of street network and building form. Some of the parameters that are used within the tools are view angles (visibility analysis) and distances between target points (accessibility analysis). The paper elaborates on inverse urban design, presents some case studies and tools, and touches upon design patterns and their alignment to design processes.

Keywords. Urban design; pedestrian design; parametric modelling; design tools; inverse urban design method.
urban spaces. In general, an inverse method implies converting observed information into attributes (parameters) of an artefact being designed. In our work we analyze/observe the design context and its problematic and based on the acquired information we formulate the design parameters which we use to build parametric models for design and analysis of new pedestrian urban spaces.

**PARAMETRIC PEDESTRIAN URBAN DESIGN**

This research focuses on the intermediate urban scale, with a specific emphasis on the quality of pedestrian space, ranging from urban fabric at approximately 10 hectares, to the street canyon scale (Berghauser Pont and Haupt, 2010). This provides an appropriate level of geometric and configuration detail for morphological investigations (Figure 1).

The research is concerned with the quality of urban space, originating in 1960s from the works of design theorists such as Jane Jacobs, Donald Appleyard, Kevin Lynch and some others. Their work laid a theoretical ground for a “good urban form” while at the same time the research of Leslie Martin and Lionel March at Cambridge School concentrated on the task of modelling urban design problems with accurate mathematical models in order to objectively measure urban space qualities (Martin and March 1972). In our work we investigate both aforementioned approaches in order to understand how the intangible qualities of urban space can be expressed in urban form using design parameters. In our prior work we analyzed the qualities of urban space provided in Lynch (1960), Jacobs and Appleyard (1987) and Ewing and Handy (2009) and formulated a preliminary set of design parameters. The latter were used to build parametric tools for analysis of the degree of openness of public urban space, accessibility by bike/on foot and some more (Koltsova et al. 2012). Subsequently, within a teaching exercise we analyzed several case studies (in Switzerland and Russia) to derive additional design parameters that are more context-specific. In general, we plan to conduct research on three case studies in Switzerland, Russia and Singapore. In parallel to the analysis of pedestrian areas within the three contexts, we examine relevant literature on local urban design methods, review their evolution in history, and inspect urban codes and guidelines (Koltsova et al., 2012). To succinctly obtain this information, we conduct brief interviews with local urban design practitioners. The specific details for determining pedestrian comfort might also be obtained from case-specific literature and best-practice examples in the future. Our preliminary work on the two of the case studies will be described in more detail in further sections.

The derived parameters form the backbone of a set of computational tools that we are developing within Grasshopper [1], a parametric plug-in for Rhinoceros [2]. Grasshopper is seamlessly integrated in the Rhinoceros modeling environment, a popular modeling software among designers today. The combination of ‘manual’ digital modeling possibilities in Rhinoceros with parametric modeling techniques, allows for a more gradual integration of our ‘derived’ parametric tool set into a design process. The fact that our tools can be used in parallel...
to the design process within the same modelling environment constitutes an advantage of our method in comparison to design analysis software such as Space Syntax [3] or Ecotect [4], where designers need to export their models for analysis into another software and interrupt the flow of the design process.

Our tools are targeting the early design stages, when architects develop first sketches of their design ideas. Architects often develop these first sketches based on their sense of beauty, styling, and overall vision, temporarily neglecting some rational aspects. The design outcome would greatly benefit from the use of simple tools for evaluation and analysis of the architect’s design actions at this early design stage. Using such tools the sketch design would be well grounded and drastic changes of concept ideas in the later stages of design would be overcome. Our tools can be used to analyze the design models prior to their detailing and before their further analysis within more sophisticated software such as Ecotect or Space Syntax, which would help to avoid double work.

INVERSE URBAN DESIGN METHOD
In general, a physical system can be modeled mathematically as:

\[ Y = F(X) \] (1)

where \( X \) is an input, \( Y \) is an output and \( F \) is an operator that characterizes a system. Inverse problems are defined as solving (1) for unknown \( X \) with given \( Y \) and \( F \) (Hirano and Yamada, 1988). When applied to urban design, an inverse problem implies converting observed information (urban form) into attributes (e.g. parameters) of an artifact being designed (Figure 2).

This research is based on the hypothesis that an inverse urban design method provides an improved way of creating sustainable urban environments compared to conventional design methods. The development and definition of an inverse urban design logic is an integral part of our research.

Inverse urban design is based on the analysis of the information available for a target context in order to discover a set of parameters that is most relevant to urban form design within the same context. By analyzing the information available for a target context, it is possible to discover a set of parameters that are well suited to create compelling novel urban spaces within the same context. Inverse urban design is not achieved by deriving formal patterns and rules from an existing city structure and buildings and applying these for the generation of new designs. Instead, the local context is analysed in order to derive information such as view points, view obstruction, landscape undulation, proximity to major functions, etc. This information is then used as an input for parametric tools in order to create good pedestrian urban designs by forming/shaping building envelopes and open spaces. The subsequent implementation of such parameters using the Grasshopper parametric environment would provide improved flexibility and variation to the entire urban form design process.

The main components of the inverse urban design method are the following:

- parameter derivation and ontological modeling,
- implementation, and
- evaluation.

Parameter derivation
The first part of inverse urban design at the pedestrian scale consists of observing existing examples of urban organization in use by pedestrians at (or near) the target context, and in analyzing its current problematic. Based on the acquired information we derive parameters to be used for design and analysis
of new urban forms. To better understand aspects that facilitate the use of urban space by pedestrians at each specific design context, it is important to observe the current situation. The data collection step tentatively includes the following subtasks to be performed at one or more locations near the target context:

- Identification of places with high pedestrian activity (using statistical data, literature, GoogleMaps, GIS, etc).
- Characterization of functions, landmarks, accessibility, and structural density.
- Description of user-space interactions.
- Formulation of the main types and configurations of streets and dynamics of space.

Subsequently, the data will be structured into three main categories with relations between them defined as follows:

- User-related data – pedestrian activity, use of space, etc.
- Physical data at fabric scale – density, accessibility, allocation of functions, etc.
- Physical data at street canyon scale – configuration, types, sections, etc.

These categories, their subcategories and their relationships will be further developed into an ontological structure guiding the systematic parameter derivation process in the next stage of the research.

**Case studies**

At the current stage of our research work we conducted preliminary studies in Schlieren, Switzerland and Moscow, Russia where we analyzed a number of pedestrian urban spaces, their qualities and problematic. Based on the derived information we developed a number of parametric models for the analysis of pedestrian urban space, which we applied for case study sites.

The work on the case study in Schlieren was conducted as part of a teaching exercise. The old part of the city of Schlieren was developed on the slopes of the valley and was later extended by the industrial zone built between the river and the railway running through the city. Apart from the railway there are two major traffic roads crossing the city. As a result the city is split into separate zones, which makes pedestrian mobility highly inconvenient. Therefore, we asked our students to look for ways in which the city structure can be enhanced in order to facilitate its use by pedestrians. After the introduction, students were asked to identify the design problem they would like to explore. To a large extent the choice of the students was dictated by the problems lying on the surface such as accessibility/navigation and noise emission.

One group of students developed a tool for accessibility analysis of any given location in Schlieren by various transportation modes. Architects and urban designers can use this tool to define intervention points and to develop new strategies to allow for a shift from private to public transport. It provides a method to evaluate the accessibility within a project area, i.e. it helps to visualize at an early design stage the zones that are not accessible by walking or by public transport. The basic parameters this definition uses are: the traveling speed (walking, bus and car) and the distance to the target point (in this case the distance between living areas and the local train station). In the first step, students superimposed a grid of regularly distributed points on a project area and measured the shortest distance along the traffic/pedestrian network from each point on a grid to the train station.

Second, based on the distance and the traveling mode (walking, taking bus or car) each point was shifted vertically. In the last step, these points were used to interpolate a surface through them. Figure 3 demonstrates the accessibility from points on a project area to the train station by bus (green) and by car (in red).

One of our findings was that the preliminary analysis phase did not constitute a challenge for students. They could identify and formulate design problems, however, it was challenging for them to translate these problems into design parameters and implement them within parametric software. In general, the parametric/relational thinking is not common and not a part of the curriculum in the tra-
ditional architectural design education. However, more and more students are using parametric tools in their design studios for model making, façade paneling, or complex building shape optimization.

In a next attempt to collect context-specific information we conducted a workshop with local architects from Moscow. The main goal of the workshop was to define the problematic of the local urban context at pedestrian scale and reveal the major factors that jeopardize the quality of urban space. Due to time constraints we could not acquire a comprehensive list of factors, however, our preliminary findings already contribute to the enhancement of public space quality.

One of the major negative impacts on local urban environment is created by outdoor advertisement. Figure 4 illustrates a local pedestrian street in Moscow from different viewpoints. In figure 4b we can see that when approaching the street from the (east / west / north / south) side, pedestrians are not aware that behind the superfluity of billboards that block the view, a beautiful urban space dedicated to pedestrian use unfolds. Uncontrolled placement of outdoor advertisement constitutes a serious problem in Moscow. In order to analyze the impact of the outdoor advertisement on the quality of pedestrian urban space, we developed a tool that allows to quickly estimate the view impact of such billboards. This tool takes the viewpoint and vertices of the façade and billboard surfaces as an input (Figure 5a). Additionally, user can adjust the view angle (in this example it is set to max 60 degrees). Vectors are created between the viewpoint and vertices. Vectors that have only one intersection point and are within the angle range of 0 to 60 degrees are selected and corresponding vertices/surface faces are assigned color (white for visible). The rest of the surface faces are colored in grey (not visible). The first conclusions
that can be drawn from our analysis is that considerable facade areas of the 18th century buildings are blocked by the low-quality billboards. Another issue is that the billboards stay on the way of one another and the information on them is not properly communicated to passers by. Our tool can be used to balance out the amount and placement of the billboards, in order to provide optimal view to the historic façade frontage and to communicate the information displayed on the billboards more efficiently.

**Design patterns**

By analyzing the problems of both design contexts we have derived the specific design parameters for each and implemented these within parametric software to measure/analyze certain qualities (accessibility- Schlieren; view pollution – Moscow). This process of parameter derivation from the local context is the basis for the inverse urban design method. The parameters and their relations derived through the inverse procedure constitute the design pattern that is implemented within parametric software. The combination of such patterns and their alignment to the design processes at an early/conceptual design stage is the concomitant goal of this research work. The design patterns will be the subject of a consequent paper.

In the next paragraphs we present an example of how the developed patterns can be used in a sequence for the design of an exemplary project site.
As a reference we used design process presented in Christiaanse et al. 2005 on the design project for the redevelopment of the area next to the Zurich main station. The proposed sequence as well as every individual design pattern will be presented to design practitioners in the future and revised based on their feedback.

Architects/urban designers usually start their work on design project by defining the possible road network organizations. Figure 6 demonstrates the exemplary project site inside the red rectangle, which contains some roads that form the building blocks. By using our parametric tool the blocks can be subdivided further into lots or parcels. This tool also provides a possibility to set the min/max size of the plot, which allows for testing the various lot organizations (Figure 7).

When the optimal amount and organization of building lots is achieved, the next tool can be applied to analyze accessibility on the site (Figure 8). This tool is based on the component of Giulio Piacentino [5], which we reworked in order to be able to measure the accessibility from any defined point to any other point on road network. By placing the transportation nodes (or any other major functions such as retail, parks or housing), the designer can estimate the accessibility on the design site. It is also possible to alter the road network by dragging the control points of the polylines that form the road network, and change the location of the functions and interactively receive feedback on the design actions. Multiple scenarios for allocation of functions and their accessibility can be tested.

In order to estimate a better location for public open spaces we developed a tool that takes all the major functions (set by designer) of the site and generates all possible solutions for shortest paths between the functions (Figure 9). Here we assume that the road segments where the shortest paths go through would be the most active and we allocate the public spaces along them. Undoubtedly, more parameters should be considered, such as visual qualities, presence of pedestrian facilities in the streets, etc. However, for a first estimation, this tool is sufficient.
After the building lots and open spaces are defined, we assign max heights per lot (defined by local building regulations). Another tool in our tool set can alter the building envelopes based on the defined view points (Figure 10). Based on the position and the view angle, it cuts the volume of the building to provide the view to an open public space.

The last tool that we developed analyzes the views from several “important” view points (defined by designer) and checks for the intersection of the view sections. The areas where the view points intersect can be used for the location of landmarks.

CONCLUSIONS AND OUTLOOK

In order to achieve design patterns in the sense of the term as it is applied in the software engineering domain, the inverse urban design method analyses the context data in order to derive parameters from it. An ontology will be developed within this method, which will be used to propose a best set of parameters to make novel and useful urban designs for the context. This ontology will be developed for global (relevant for any context), context-specific, and site-specific conditions, in order to express parameters unambiguously, define a familiar hierarchical structure of terms, and ensure the consistency of the parameters (especially the global ones), their attributes, and their relationships in the context of their use for different locations and projects by urban designers. Such an ontology will be very useful to the designers during the inverse design process (i.e., parameterization process). Clearly, the balance between extensibility, flexibility, and sufficient structure will be a key point of attention in this step.

The design patterns will be presented to design practitioners at the joint workshops and revised based on their feedback.
REFERENCES


[1] www.grasshopper3d.com/group/geco