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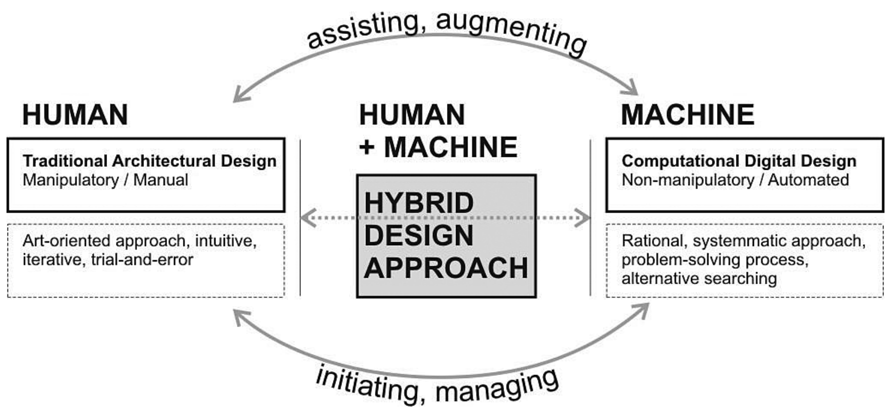

Fig. 3 Hybrid Design Approach in architectural design; source: by authors

Fig. 4. Form+Facade, Office building, Zawadzki Lukas, Sopot College

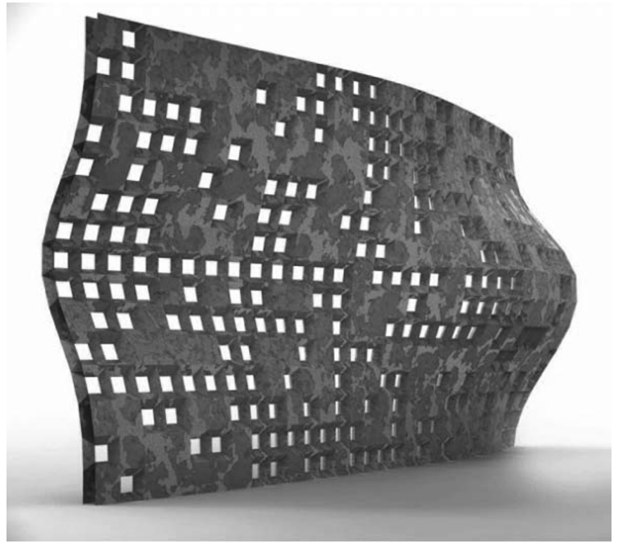

Fig. 5. Facade, Front curtain wall, Stępkowki Radosław, Sopot College

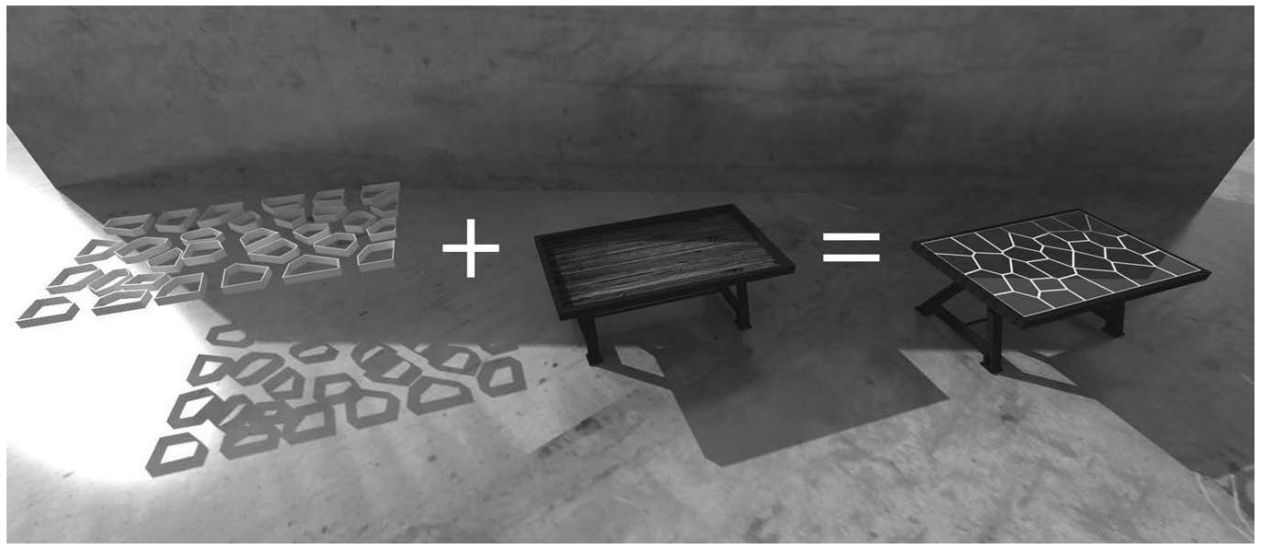

Fig. 6. Detail, Craft Table, Jurasz Emilia, Sopot College

DEVELOPING A PARAMETRIC URBAN DESIGN TOOL. SOME STRUCTURAL CHALLENGES AND POSSIBLE WAYS TO OVERCOME THEM

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Abstract
Parametric urban design is a potentially powerful tool for collaborative urban design processes. Rather than making one-off designs which need to be redesigned from the ground up in case of changes, parametric design tools make it possible keep the design open while at the same time allowing for a level of detailing which is high enough to facilitate an understanding of the generic qualities of proposed designs.
Starting from a brief overview of parametric design, this paper presents initial findings from the development of a parametric urban design tool with regard to developing a structural logic which is flexible and expandable. It then moves on to outline and discuss further development work. Finally, it offers a brief reflection on the potentials and shortcomings of the software – CityEngine – which is used for developing the parametric urban design tool.

Keywords: parametric design; urban design; building footprint; sequential hierarchy; design tools

INTRODUCTION

The overall aim of the research presented in this paper is to develop a parametric urban design tool. While the research is in its early stages of development, the aim of the paper is to present some initial results and to outline further development. Parametric design is not new, nor is its application to urban design. Yet, although different approaches to parametric urban design have been developed – from serving analytical purposes to serving design generation purposes – only few attempts (Jacobi et al., 2009) have been made to develop a design tool to facilitate stakeholder involvement.

When undertaking the task of developing a parametric urban design tool, three structural and organizational aspects must be considered: parametric flexibility, structural logic, and interaction design. While parametric flexibility is core to all other considerations and thus must be considered at all times, a structural logic must be developed at the outset and subsequently adapted or moderated according to design development. And while interaction design is ultimately important once the tool is put to use, it need not be the focus of design at the early design stages. Hence, the focus of this paper lies on developing a structural logic for a parametric urban design tool which is parametrically flexible and easy to use.

Different parametric design softwares have different strengths and weaknesses when it comes to meeting these three aspects. For our test case, we have been using CityEngine, which is a procedural design software targeted specifically at urban design. While we will not offer an evaluation of different software packages for their fit with our purpose in the context of this paper, we will, however, briefly discuss the pros and cons of using CityEngine.

BRIEF OVERVIEW OF PARAMETRIC DESIGN APPROACHES

Parametric design is a design method that allows the designer to rapidly evaluate design scenarios based on a combination of datasets and rules, in an iterative design process of defining and adjusting parameters and relations (Burry, 2005). This method can be applied to designs at any scale. However, the scope of this paper is to explore its application in urban design.

Parametric urban design as a method has been developed to involve the use of urban data to facilitate an interactive design system (Beirão et al., 2011). Using a system, or tool, geometries in a computer model are updated instantly according to changes in data or design criteria, whether it is GIS data or stakeholder feedback. This rapid production of new geometries potentially improves the quality of the design, as the design goes through more iterations than when using traditional design methods (Burry, 2005).

Parametric design has been used in various situations and industries, spanning from entertainment to urban planning (Watson, 2008); while parametric design applied in urban planning has the power and potential to be used as an outright simulation tool for urban development (Leach, 2009a), it is often used as an analytical tool for various purposes (Gil & Duarte, 2008; Chiaradia, 2009). Some designers have proposed to take the tool one step further, turning it into a distinct architectural style (Schumacher, 2009), while others only use the tool for visualization of urban data (Kroner, 2011).

Parametric design is widely used as a method of generating urban structures bottom-up, in a generative, emergent manner (Batty, 2009; Leach, 2009b, c; Roche, 2009). Using GIS data as parameters in a parametric design is a promising technical potential of the tool (Beirão et al., 2008), while the participatory aspects of a parametric design process holds great social potential (Jacobi et al., 2009). Using parametric urban design, stakeholders can be presented to actual design scenarios even in early stages of the design process (Steinø et al., 2013).

The approach to parametric urban design adopted in this research is based on the notion that parametric design is neither a simulator, nor an architectural style. Rather, parametric urban design is considered a tool to generate different design scenarios faster during the design process, as well as facilitating stakeholder involvement. It is important to note that analytical models generated parametrically are not design models, but only shapes to be evaluated by the designer (Gil & Duarte, 2008).

INITIAL TEST CASE RESULTS

In any communicative urban design process, some aspects – or parameters – are more likely to be relevant to deliberate than others. And they are not likely to be the same for different design cases. In one case, density and building style may be topical, while in another case, environmental issues or the distribution of different building programs may be relevant issues to analyze and negotiate.

When designing a general parametric urban design tool, it is therefore crucial to consider how to achieve maximum flexibility when it comes to the design aspects which should be parameterized. On the other hand, the structure of the tool should also be kept as simple as possible in order to maintain overview. The challenge therefore, is to consider not only how to design the tool itself, but also how to make it easily adaptable for specialized needs. Furthermore, designing a parametric urban design tool is a collaborative effort which is likely to involve many people across time and space. Hence, the structural logic of the tool should also be carefully considered so that contributions from different designers can be integrated with one another. As designing a parametric urban design tool, as we define it, is essentially a scripting task, this involves devising a logic by which snippets of code can be brought together to work in a unified script.

In the real world, what may be relevant to discuss and vary are those elements which determine the physical appearance of a development. These may range from land use (as office buildings are different from housing) street width, site layout, building height, building shape (setbacks, height variations), to facade design. Hence, these elements (and more/others, depending on the actual case) must be controllable and therefore parametric.

In our case study, we have focused on site layout, building height and shape, and facades, we have also attempted at defining a set of logical steps to interlink between discrete sets of operations. In a procedural logic, the following elements build a sequential hierarchy in the sense that each step is a prerequisite for the next step:

1. Terrain >
2. Street pattern >
3. Block subdivision >
4. Site layout >
5. Building envelope >
6. Facade style

For any terrain, a number of different street patterns would be appropriate, relative to existing development and landscape elements. Street patterns define urban blocks which may or may not be subdivided into smaller plots. On each plot, different site layouts – e.g. perimeter blocks, tower blocks, row houses, patio houses, etc. – would be appropriate. Site layouts determine building footprints which, in turn, form the basis for different building envelopes. Buildings may be box-shaped, have setbacks, protruding elements, etc., as well as different roof shapes, all from the same footprint. And finally, the vertical surfaces of each building envelope may have different facade styles, typically according to land use and building type.

In terms of parametric flexibility, it is desirable to be able to combine subset variations on all these levels. As an example, for each site layout, it should be possible to apply any relevant type of building envelope. And for each building envelope, it should be possible to apply any relevant facade. Thus, there should be a unified interface at the end of each step, as well as a filter to define what is relevant. In a procedural logic, each step therefore have to result in a shape with a unified name for the next procedure to pick up from. And a switch must be built in to evaluate the conditions which trigger the relevant procedure.

In our case study, we have focused on the steps 4-6 for the parametric design. Hence, the street layout was was designed manually and urban blocks were not subdivided. Furthermore, urban blocks were rectangular and of similar size (app. 0,9 ha.) in order to minimize scripting for varying plot sizes and irregular plot shapes.

In practice, we used the following shapes which, by way of attributes link on to the next sequence:

1. The site layout sequence ends with shapes for
   a) Green spaces
   b) Building footprints
2. The Building envelope sequence ends with shapes for
   a) Facades (vertical surfaces)
   b) Roofs
3. Each facade sequence ends with different constellations of shapes for
   a) Walls
   b) Openings

For each plot, different site layouts may be generated. And for each of the different shapes in the list, variation may be achieved. “Building footprints” may result in simple block shaped building envelopes or building envelopes with setbacks or other morphological variations. “Facades” may lead to different sets of facade elements, which, in turn, may contain subsets such as different types of windows or variations in wall color.

The following examples show 1) different footprints, 2) how the Footprint > Envelope sequence may lead to different building envelopes from the same footprint, and 3) how the Envelope > Facade sequence may lead to different facades applied to the same building envelope.

Facades, more so than site layouts and building envelopes, follow generic principles for their generation. On the most basic level, any part of a facade is either a wall or an opening.[1] Openings may differ by width and height. Thus, schemas of horizontal and vertical sets of walls and openings can be defined for virtually any facade. Different facade symmetries as well as random facades may thus be defined by different schemas for the organisation of walls and openings.

On the more detailed levels, the position and size of openings relative to the floor height may vary, just as walls and openings may vary in design, color, material, etc. The following diagram shows a structural logic for the composition of a facade from sets of generic facade elements.

DISCUSSION

While the initial steps towards developing a parametric urban design tool for communicative urban design processes show promising results, there are still many elements to take into consideration. For our initial test case, we have worked in an artificial sandbox. Differences in actual plot sizes (which we kept constant) would require an evaluation of which site layouts would be appropriate, as well as of how to adapt the site layouts in each case. The same is true for irregular plot shapes and for sloping terrain.[2] Needless to say, our repertoire of typologies for site layouts, building envelopes and facades is still limited. But endless variations are imaginable. Additional typologies should be added, based on case by case requirements. At some point, it may be relevant to define sets of typologies to reflect regional, land use based, or other differences.

Not all building envelopes would be appropriate for any footprint, just as not all facades would be appropriate for any building envelope. Hence, a sort of filter must be implemented to make sure that meaningless combinations will not occur. This is also the case for different land uses. Housing and offices may not

[1] In addition, protruding balconies may be considered facade parts, as they have no building parts below or above them (apart, possibly, from other balconies). Balconies, however, have not been part of our initial study. Conversely – according to our hierarchy logic – bay windows and inlaying balconies must be considered parts of the building envelope, as they do themselves have facades.

[2] For our test case we did work on an actual terrain with different slopes. Yet, our scripts are not suited for very steep slopes and thus produce meaningless results in some cases.

fit equally well into any building envelope, and not all facades may fit both housing and offices.[3]

Also, more detail is desirable. Open spaces should be more differentiated in the form of different types of green spaces, paved spaces and functional spaces. Bay windows, porches/terraces, and inlaying balconies should be added to the building envelope repertoire, along with different roof types. Facades should optionally have balcony elements.

As mentioned above, street layouts have not been dealt with in the context of our initial test case. Whether and how street layouts can meaningfully be made subject to parametric design is yet to be clarified. It would be preferable to design street layouts within an integrated process of subsequent design steps. However, they may have to be designed using software other than CityEngine, as at present it does not have very flexible tools for the design of street layouts.

Finally, once the tool is developed and ready to be put to use in a collaborative urban design process, it should offer an easy and intuitive way to interact with the project model. This is important in order to be able to use the model responsively to different interests and ideas that might trigger parametric changes to the model. This is particularly true when non-designers and lay people are involved who are not able to make abstractions about form and space the way designers are.

SOFTWARE CONSIDERATIONS

As parametric urban design makes it possible to rapidly generate different design scenarios using parameters changes, it changes the design process significantly. By traditional techniques, it would be very time-consuming to create mock-up 3D models of different design scenarios. But with parametric design software this can be done in real time by adjusting parameters and rules. Thus, the designer is able to make design decisions on a better and more well-informed basis.

CityEngine is a powerful tool for parametric urban design. It is based on a simple scripting language, making it relatively easy for architects and planners to get a grip of the tool. However, using scripting as the mediator between design ideas and actual geometry presents a challenge when it comes to using the software in a design process involving stakeholders, as this interface is unintuitive to laypersons.

Some functionalities are still missing in making CityEngine a complete parametric design tool. While the content of streets and lots can be generated freely using scripting, the street structures themselves are confined to a number of preset options. This means that street structures in real urban design scenarios have to be created manually. If the shape of streets and parcels could be generated freely using parameters like landscape qualities, line of sight or functional requirements, this part of the design would also be open for parametric experimentation and evaluation.

CONCLUSION

While different approaches to parametric urban design exist, the approach adopted in the research presented in this paper aims at the fast generation of different design scenarios in order to facilitate stakeholder involvement in communicative urban design processes. Some initial results of a test case for the development of an urban design tool have been presented. Working within a sequential hierarchy from terrain to facade, the study has focused on the sequences from site layout over building envelope to facade. Despite the modest scope of the case study, the approach holds promise for the development of a powerful parametric urban design tool.

Nonetheless, much work still lies ahead in at least six areas. The tool must be able to cater for special conditions such as variations in plot size and shape. The repertoire of site layout, building envelope and facade typologies must be expanded. Filters must be made to make sure that elements at different levels in the hierarchy will fit together. More detail must be added. An approach to the design of street layouts must be developed. And finally, the interface of the tool must be considered in order to achieve maximum ease of use.

[3] Hence, while land use is not a geometric category per se, the requirements of different land uses are. For instance, office buildings typically have larger building widths, taller floor heights and more glass on facades than housing.

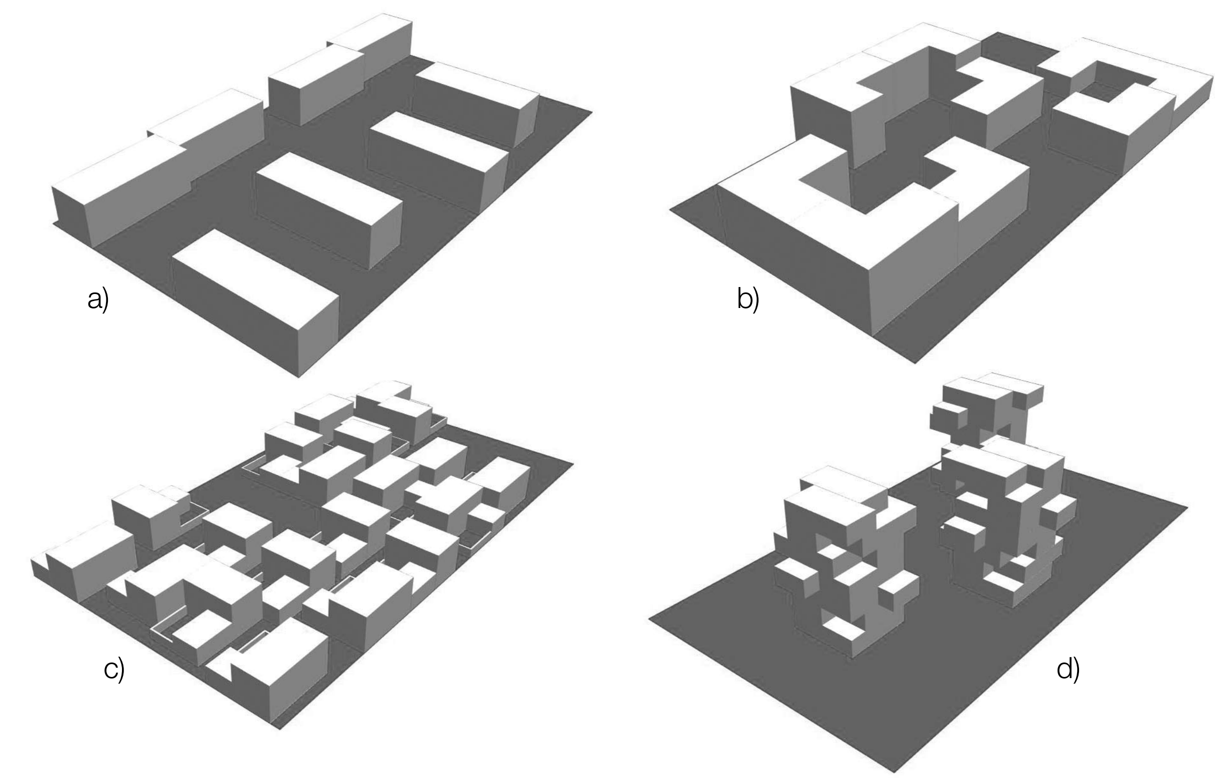

Fig. 1a-d. Different site layouts on the same parcel: a. Linear blocks, b. (semi-) Closed blocks, c. Patio houses, d. Tower blocks; by authors

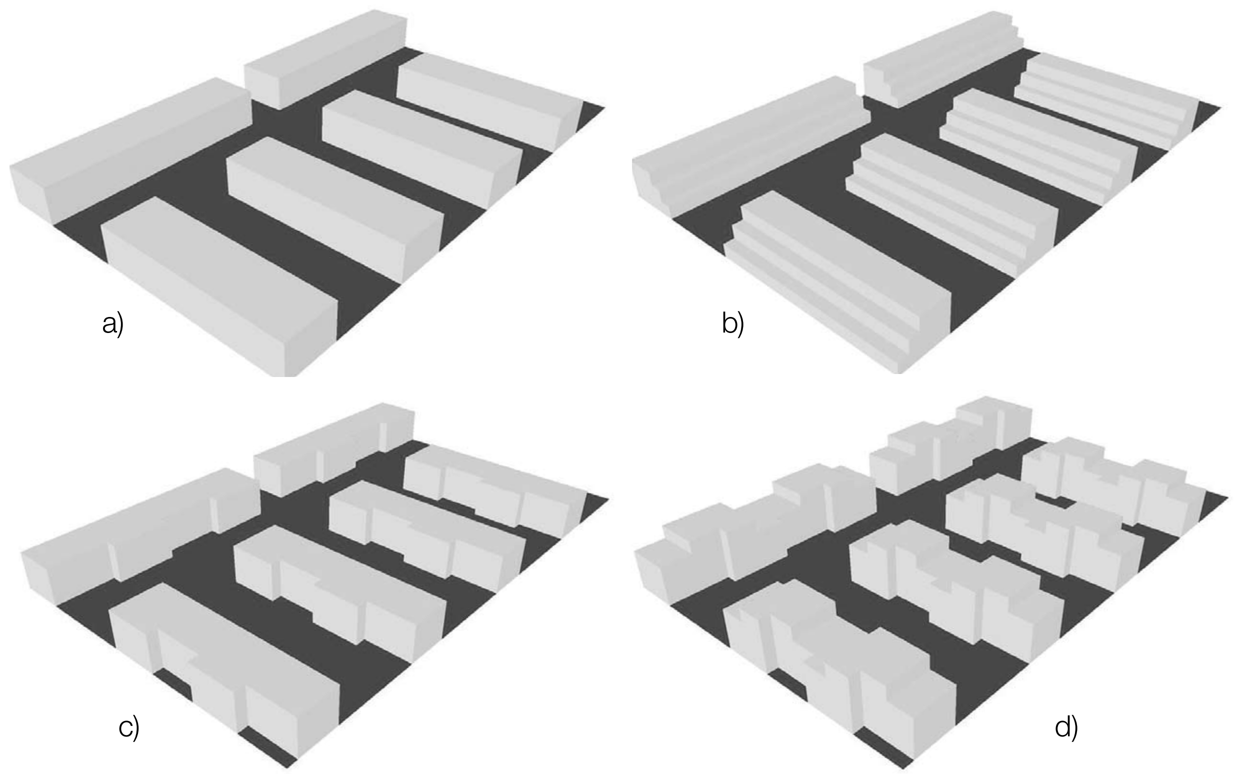

Fig. 2a-d. Examples of different building envelopes on the same footprint: a. Simple slab, b. Horizontal setbacks, c. Vertical setbacks, d. vertical setbacks and height variations; by authors

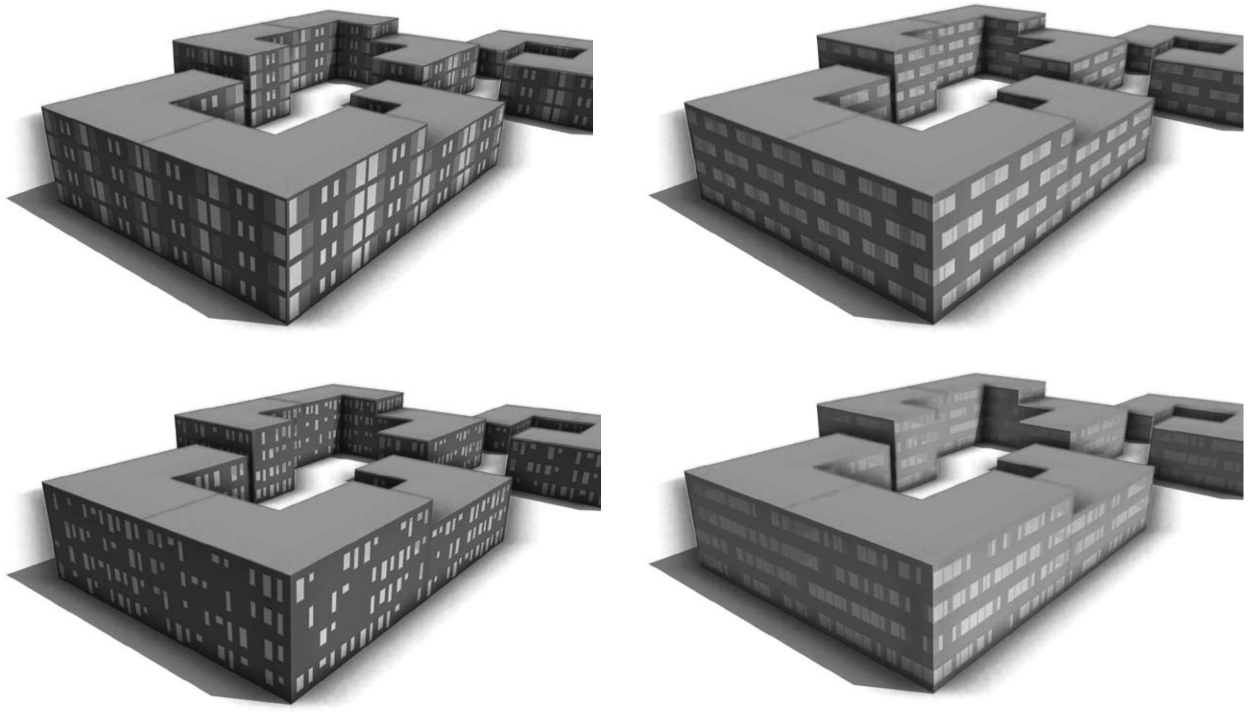

Fig. 3a-d. Examples of different facades on the same building envelope: a. Reflection pattern facade, b. glide reflection pattern facade, c. Repetitive random pattern facade, d. Random pattern façade; by authors

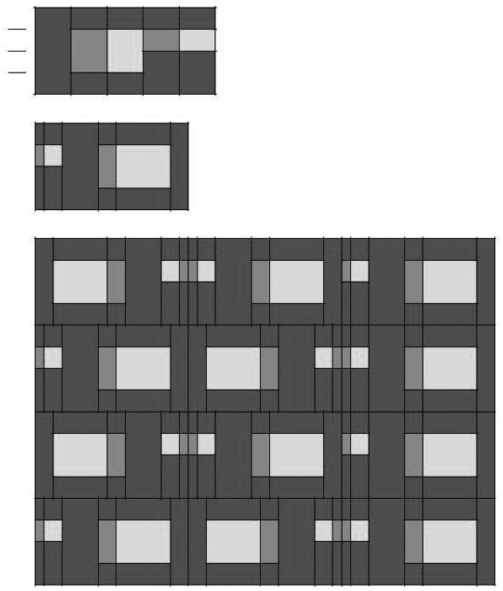

Fig. 4a-c. Structural logic for facade schemas: a. Generic facade elements with vertical splits, b. Set of horizontally scaled facade elements, c. Facade composed from the same set repeated in different combinations of reflection, glide reflection and translation; by authors

Fig. 5. Example of an urban environment generated from the elements described above; by authors

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