Computational Urban Planning

Using the Value Lab as Control Center

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Urban planning involves many aspects and various disciplines, demanding an asynchronous planning approach. The level of complexity rises with each aspect to be considered and makes it difficult to find universally satisfactory solutions. To improve this situation we propose a new approach, which complement traditional design methods with a computational urban planning method that can fulfil formalizable design requirements automatically. Based on this approach we present a design space exploration framework for complex urban planning projects. For a better understanding of the idea of design space exploration, we introduce the concept of a digital scout which guides planners through the design space and assists them in their creative explorations. The scout can support planners during manual design by informing them about potential impacts or by suggesting different solutions that fulfill predefined quality requirements. The planner can change flexibly between a manually controlled and a completely automated design process.

The developed system is presented using an exemplary urban planning scenario on two levels from the street layout to the placement of building volumes. Based on Self-Organizing Maps we implemented a method which makes it possible to visualize the multi-dimensional solution space in an easily analysable and comprehensible form.

Interactive Computational Urban Planning

The main intention of computational urban planning is to evolve urban designs according to specified requirements and to provide feedback about spatial configurations showing their potential advantages and problems.

As base technologies, we use data clustering algorithms like self-organizing maps (SOM) and evolutionary many-criteria optimization (EMO) based on evolutionary algorithms (EA) as technique for synthesizing designs. We use SOM because of its capability to simplify representations of complex multi-dimensional data. EMO is used as a kind of navigation system for design space exploration (DSE). The combination of SOM and EMO is used as control mechanism for the systematic generation of alternative designs. When we extend classical EA to include more sophisticated selection mechanisms that are able to consider more than one objective function for the evaluation of design solutions, we speak of evolutionary multi-criteria optimization (EMO). The EMO selectors filter the non-dominated solutions out of all generated solutions, especially if we have to deal with a variable set of contradicting and non-contradicting criteria. The generative mechanism is used to create a maximum possible variety of possible topologically and geometrically different solutions. So far, we have implemented mechanisms for generating road networks and building volume layouts.

Evaluation mechanisms are used to provide various fitness values for the objective function of the EMO. The criteria that can be calculated depends on the available evaluation algorithms. For data exchange we focus primarily on the basic geometrical input that is needed for the evaluations and return the calculated values in raw format, so that they can be assigned to the corresponding set of spatial entities represented by a chromosome. In a planning context we need an easily understandable way of presenting all solutions during the synthesis process at any time. A possibility for visualizing a multi-dimensional pareto-front is a pairwise mapping to two-dimensional pareto-front curves. As an alternative we use SOM for mapping multi-dimensional data into a two-dimensional map. This allows a planner to visually analyse clusters of similar solutions with respect to geometrical similarity, how they correspond to the objectives, and other parameter values.

With our DSE tool we can generate numerous designs within a short period of time and compute corresponding quantitative measures. Human designers, on the other hand, can draw on their design expertise and thus are able to easily identify design proposals of good or poor quality. Therefore we need to ensure that there is a good interaction between human and machine by offering an interactive DSE that integrates human design strategies with design synthesis methods. Figure 01 illustrates how the DSE is conceptually integrated into the Value Lab.

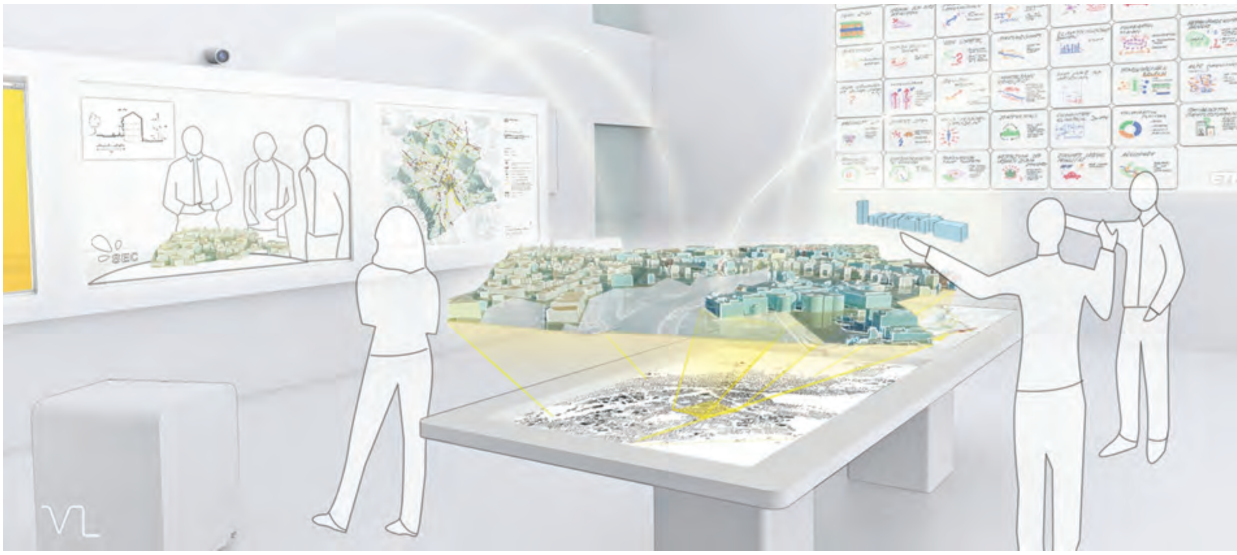

Fig. 01 Human - computer interaction concept of the evolutionary multi-criteria optimization tool adapted to the ValueLab Asia

Redesigning Rochor – A Case Study

In the following we describe a use case scenario during an imagined design research workshop using an example scenario in the district Rochor in Singapore. This exemplary area in Asia emphasizes the urgent need for fast and comprehensive planning systems. Necessary data for the existing street network was taken from OpenStreetMap, and information about neighbouring built structures in 3D was available from the Future Cities Laboratory of the Singapore ETH Centre.

The planning process starts with the empty planning area shown im Figure 03 (a) which defines the border for placing new street segments and the starting street segments (initial nodes) from which the street network is grown. The starting segments are taken from the existing network where it intersects with the planning area. The user has to initially execute the EMO for the street layouts and later for the building placements by specifying the right properties on the very right hand of the tool window shown in Figure 02 (d). The user can, for example, select the size of the population, the number of generations to calculate optimal layouts and the size of the archive to store the solutions. The user interface (UI) shown in Figure 02 is structured in three main areas for visualizing the generated spatial configurations. Figure 02 shows the archives of best variants for the building layouts (b) and street networks (c) generated so far, respectively, and (a) presents a 3D view that shows the configurations selected by a user out of the archives.

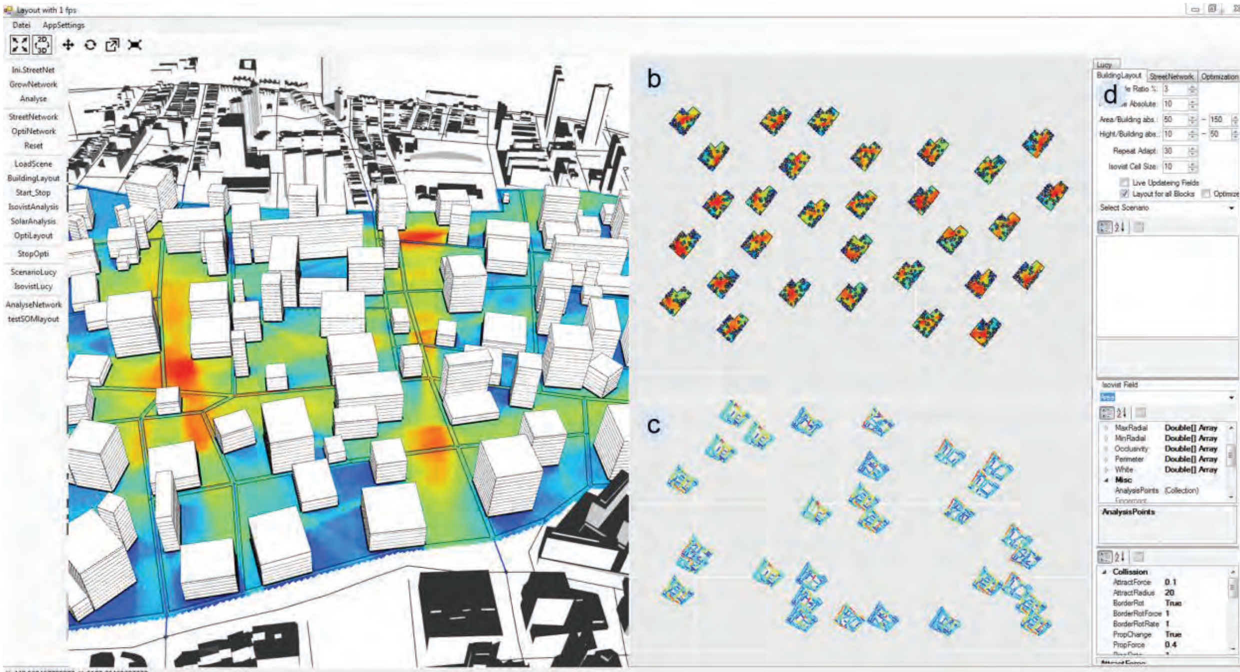

Fig. 02 Software prototype showing the main areas of the user interface: (a) a 3D view combines one solution out of each archive, design solutions of the archives for (b) buildings layouts and (c) street networks, and (d) fields for the user input of size of population, number of generations, etc.

The centrality analysis can also be run for the new network connected to the existing network in a user-defined radius around the planning site. They are combined with each other and the environment's geometry. Based on the chromosome structure, our software prototype makes it possible to move, rotate and scale individual objects (street segments and building volumes) during the planning and optimization process. Corresponding view control functions for zooming, panning and rotating the view are placed on top of the DSE tool. After some user interaction we update all chromosomes of a population, so that all genes (that represent an object such as a building) affected by the user manipulation are assigned new parameter values. This ensures that the changes will be consistent for at least some iteration. After several iteration steps, streets graphs and building layouts appropriate to the objective values are found. Figure 03 shows the results of our prototype for a proof on concept. The results can be improved by adding more detailed restrictions and objective values. We can call this kind of computational planning process evidence-based planning. It helps the designer to meet explicitly formulated design requirements and to eliminate potentially problematic solutions.

Figure 04 and 05 show a typical design workshop using the computational planning tool on the touchscreen panels and displaying the results with different visualisations on the videowall.

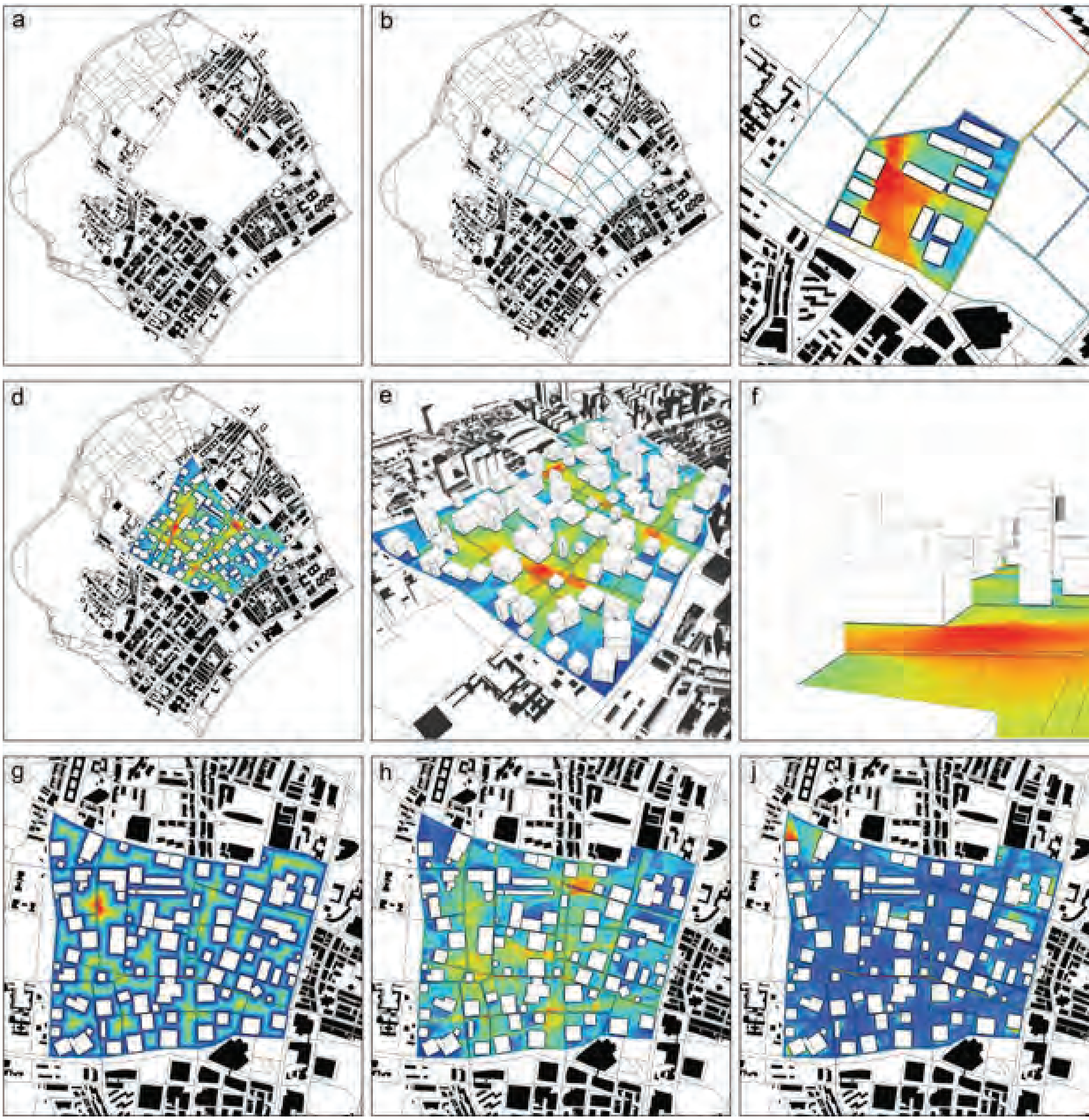

Fig. 03 Planning steps. (a) the vacant planning area, (b), the site filled with a generated street network and area Isovist field, (c) a block filled with a generated building layout and area Isovist field, (d) all blocks filled with generated building layouts and area Isovist field, (e) perspective view with area Isovist field, (f) detailed perspective view, (g) min radial Isovist field analysis, (h) occlusivity Isovist field analysis, (j) compactness Isovist field analysis.

Fig. 04 Simulated Design Workshop during the Transition Workshop. The Touchwall on the left side shows the 3D Map navigation, panels for the Selforganizing maps for street and building layouts and input panels for the optimization process. The video wall on the right side shows a planning site at Pungol in Singapore for different measurement criteria.

Fig. 05 The videowall shows a building layout proposition for the isovist, sunexposure and other measurments.

Conclusions and Future Work

We present an experimental software prototype that exhibits an advanced user interface for representing planning problems, changing them interactively, and presenting many-dimensional design spaces by means of SOM. SOM allow an understandable map for further exploration. The obvious advantage of this mapping is that we find similar solutions close to each other and that we can clearly identify the number of generally different design solutions since they form separated clusters. The software may be considered as an interactive planning support system that guides urban planners efficiently through an ever-changing search space. The search space changes at the moment when the user interacts with the DSE by adding a constraint, or by manipulating or adding geometrical elements. An important aspect is that the user always controls to which degree the design process is automated in accordance with the planner's needs and the respective planning problem. The ability for the user to interact with the generated solutions is crucial for the general applicability of the DSE.

In a future project at the FCL we want to expand the integration of urban data in the planning process, because in future, algorithmic modelling approaches will likely gain in importance as they have the potential to exploit various large urban data sources. This would enable us to achieve an even more holistic planning perspective. The architecture of the DSE framework is designed in a way that allows the integration of new urban data types by adding new generative and evaluation algorithms. The presented research approach shall be considered to develop design support tools that lead to a more evidence-based design approach.

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