ENHANCING SYNERGIES BETWEEN COMPUTER SCIENCE AND URBAN DISCIPLINES

Semi-automated applications for tangible user interfaces, a case study

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Abstract: This paper explores an interdisciplinary design approach for coupling semi-automated applications with tangible user interfaces. It describes communication methods based on parameters and diagrams, between computer scientists and urban, architectural professionals and the matching abilities to give meaning to the various parts and elements of the system. By means of the development of two rule based applications it exploits different degrees of automation and kinds of feedback possibilities and its impact on discourse and decision making. It discusses design methods for interactive urban planning applications, which integrate the different requirements and benefits from both disciplines.

Keywords: tangible user interfaces, semi-automation, decision making, urban planning

Résumé: *Cet article explore une approche de design interdisciplinaire pour coupler des applications semi-automatisées avec des interfaces tangibles. Il décrit des méthodes de communication entre informaticiens et urbanistes, fondées sur des paramètres et des diagrammes, ainsi que des possibilités de liaison pour donner un sens aux différentes parties et éléments du système. À l'aide du développement de deux applications basées sur des règles, ce travail exploite différents niveaux d'automation, des possibilités de réaction et l'impact sur le discours et les décisions à prendre. Nous discutons des méthodes pour développer des applications urbaines interactives qui intègrent les différentes exigences et bénéfices des deux disciplines.*

Keywords: *interfaces tangibles, semi-automation, décisions, urbanisme*

1. Introduction

Current status and trends in architectural and urban design practice and education use concepts and techniques of parametric modeling. The incorporation of scripting language in sophisticated CAD software allows for increasing complexity of design tasks. While optimization software and operational modeling are traditionally used in structural engineering and large scale urban and regional planning, more recently the concepts of parametric methodologies and computer simulation found their way into urban design and urban planning education (Schnabel and Karakiewicz 2007, Gaber 2007).

Architects and urban professionals are used to deal with complex design tasks and the reciprocation of different entities. The aforementioned software tools, already incorporate the interdependencies of single parameters, and allow adjusting and broadening the palette of values and characteristics. At the same time these tools partly occlude specific attributes and interrelations between single elements and diminish the traceability of arguments by detaching the designers from instant interaction within the design process.

A different approach to computer supported design tools originates from the fields of augmented reality and tangible user interfaces. Research groups explore application areas incited by their aspects of collaboration, natural interactions or hybrid representations. Architecture and urban planning are commonly the topic of such applications as they easily accommodate maps and models as often used in architectural communications and working processes. The *Luminous Table* integrates multiple forms of physical and digital representations, such as 2D drawings, 3D physical models and digital simulations, to create and discuss different proposals for urban development (Ishii et. al 2002). *BenchWorks* (Seichter and Schnabel 2005) was developed within an experiment and explores simple possibilities of positioning virtual models in an augmented environment. *ARTHUR* (Broll et al. 2004) further investigates this idea and uses an elaborate set of interaction possibilities to integrate functionalities of CAD systems into a collaborative environment.

Although some examples incorporate the planning and design process itself, such as the interactive urban design tool (IUD) (De Vries et al. 2005), most of such applications use natural and collaborative interaction possibilities to explore new forms of representation. An intense cooperation between architects, urban professionals and computer scientists can be found in the project KAISERSROT (Fritz 2008). To explore new ways of designing, the software was developed using computational geometry, which allow future inhabitants to provide criteria onto the proximity of several elements.

2. Structure of the paper

Within this paper, we seek to explore the rising possibilities from a close cooperation between urban professionals and computer scientists. We describe the interdisciplinary development of semi-automated application with a tangible user interface in order to exploit couplings of digital rule based software with a physical model of the project environment.

The following section describes the tangible planning tool *ColorTable*, which served as simplified representation of reality and allow focusing on different aspects of potential synergies between the disciplines during the design process. The forth section outlines two semi-automated applications that have been developed within the scope of real urban planning projects. The described design process includes the extraction of urban parameters, the specification of sets of *urban rules*, and the coupling of these rules with a tangible tabletop. It further reports on testing the applications in two participatory workshops, followed by a brief depiction of the impact of degree of automation on decision-making processes. Section five concludes with a summary of the different aspects of potential synergies between the disciplines during the design process, and potentials of semi-automated applications for tangible user interfaces.

3. The ColorTable

As tangible user interface, the *ColorTable* (Maquil et al. 2008) combines multiple aspects of the aforementioned planning and design tools. It is a physical game board for multi-user collaboration, which simultaneously provides the possibility of envisioning the user's perspectives, by combining two different modes of representation: the `map-space´ and the `perceptual space´ (Figure 1).

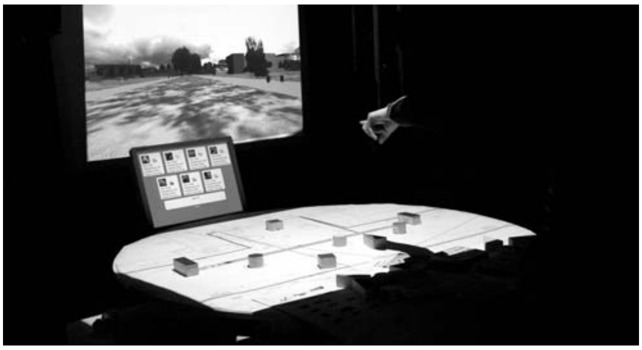

Figure 1. ColorTable components: physical, digital and augmented environment

The map space provides a top-down view onto a site and is composed of several layers combining real and virtual elements forming a common interactive space. A map can be placed on the table and is pre-registered to define the coordinate system of the interaction. This frame of reference can be adjusted when choosing a different map or a map of a different scale. Colored tokens, currently wooden cylinders of 8 different colors, can be positioned onto the map to add specific elements to the site. The tangible user interface uses computer vision based tracking from an overhead camera and detects the positions, colors and sizes of the objects on the table. Users can move and turn existing objects, while an overhead video projection on the table provides interactive feedback. The perceptual space is composed of one or more additional, vertical screens showing perspective or axonometric views of the scene being created, usually visualized as a panorama. To navigate in these views, users can change the viewing direction by rotating the panorama with a disk attached to the table.

In addition to the colored objects, we use a barcode interface to increase the number of input possibilities. This interface translates barcodes into a specific value or command and can be used to change settings of the current panorama, the top view or of the application itself. To change the content or properties of colored tokens, we use a tangible selector based on RFID. It is a small disk with representations of each object that can be rotated to select the object that should be modified. Feedback and settings of objects and applications are shown on an information screen, placed nearby the table.

The digital components being created not only help illustrating individual visions of future developments (images, 3D models, animated images etc.), but bear the possibility of incorporating additional planning information and quantifiable data about the respective sites and urban projects.

4. Developing semi-automated applications

In order to designate single parameters of the complex urban environment, the elements of the *ColorTable* served as an abstract model with two different entities: the tabletop itself is interpreted as a two dimensional territory whereas the tokens signified static or mobile objects (uses, buildings, individuals, abstract values and flows) that have impact on the territory or influence each other. We explore the given environment of the *ColorTable*, by investigating different schemes for the development of two application prototypes. Two urban projects on different sites served as the contextual frameworks each raising specific questions concerning the extraction of parameters and its reciprocal relations.

The developments of these prototypes were integrated in two consecutive classes of the postgraduate program *Urban Strategies* at University of applied Arts Vienna in conjunction with the particular course programs `density´ and `networks´. Together with the students, we exploited the potentials of *urban rules* within the given environment of the *ColorTable*.

Three steps served as conceptual guidelines within the design process. After getting familiar with the tangible user interface, each student group was asked to explore potential elements, direct or indirect forces to conceptualize the city according to the brief and the given site. Within several sessions, these factors of influence were translated into simple parameters and precise numbers to build a system that reflects their mutual relationship. Designating variables and invariants of the model and exploiting possible representation methods cross-linked to the tangibility of the interface. The students then had the chance to test the implemented prototypes and explore interaction possibilities and feedback design with the *ColorTable*.

4.1. PROTOTYPE DENSITY

Urban density is commonly measured by the relation of building land to the actual distribution of building mass on the site, which is expressed by the index F.A.R., Floor Area Ratio. Other parameters, such as the minimum allowed distances between buildings in relation to their height predefine the general physical character of built environment. These kinds of quantifications summarized in an `urban code´, partly reflect restrictions, interdependencies and regularities within the underlying complexities of urban planning processes.

According to the course program, the subject of investigation was the former airfield `Flugfeld Aspern´ north of Vienna. Enclosed by opposing rows of single-family houses on two sides of the 240ha territory and an adjacent motor-plant opposite to agricultural land, the field should transform into a mixed-use area with different types of dwelling, social and cultural infrastructure, commercial uses, a university campus and public and green spaces.

4.1.1. Design Process

Aim of the first application was to experiment with planning regulations to show consequences of different configurations on a territory. Users can explore how typologies, heights and building coverage influence density on a site. The given figures served as the initial task for the students to develop a rule based system, which explores multiple possibilities of mass distribution by conceptualizing a `dynamic master plan´.

The students were familiar with sophisticated CAAD tools and the first proposals seemed highly elaborated, as in most cases, the students tend to interpret the *ColorTable* as a simulation tool. Although it seemed to be difficult to precisely name the interrelations of the actual values being manipulated some of the approaches clearly respond to the idea of an adaptive system (Figure 2).

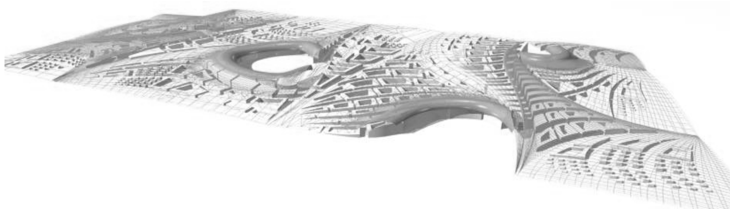

Figure 2. Miha Volgemut: Inserting voids causes shifting building masses

To correlate the rules with the tangibility of the *ColorTable* the demand for optimization and the degree of automation had to be reduced when further refining parameters.

As a starting point, we considered 5 different sizes of volumes, which dimensions correspond to various building types (single family-house, office building, plant, high-rise etc.). The footprints can be parametrically manipulated according to particular building depths and necessary exposure. Depending on those values and other global settings, the system topologically adapts the respective extensions of the buildings. To preserve the building coverage the area of the footprints decreases the more objects are placed within the territory, while the height of the buildings increases to preserve the volume. To show the consequences of distance and exposure to light we planned to adapt the positions of buildings to prevent them being too close to each other. When other urban planning regulations are broken, (e.g. exceeding the plot boundary or the recommended gross floor area), the regularly shaded building volume(s) are displayed as red wire frame.

To demonstrate more local effects on density-regulation such as the impact on property value in close vicinity to underground stations or public parks, we introduced particular elements that affect the territory in a certain perimeter and cause an increase or decrease of the surrounding volumes when positioned in-between the building masses.

For discussing with the students which of the elements are of later use, we chose a method of representation that reflects the physical environment of the *ColorTable* to communicate their interrelations and operational potential (Figure 3).

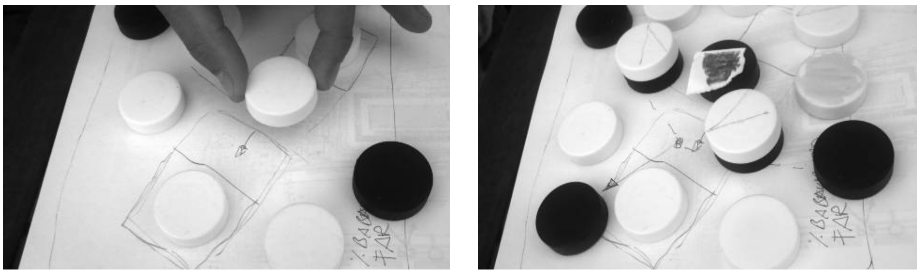

Figure 3. Automated adaptation of footprints and heights when adding elements

To control positions of buildings we connected each physical color object to one volume, whereas the position on the table is linked to the position on the site. During the implementation process, we noticed that repositioning volumes raises some problems. Since the position of a modifiable digital building volume depends as well on the position of its correlated color token as on the position of the adjacent volumes, the positions of tokens and their representations cannot be superimposed and the idea of an augmented surface is lost. In a series of sketches, we exploited the various requirements from the perspective of urban regulations and the particular requirements of the application environment (Figure 4).

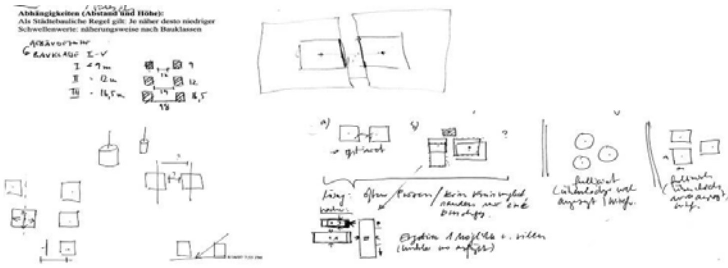

Figure 4. Sketch-Dialogue of matching digital volumes with physical tokens

We decided to reduce the degree of automation for adjusting the required minimum distances, since they can be easily re-adjusted by direct manipulation on the table. Instead, visual feedback highlights the respective situations by displaying the regularly shaded building volumes as red wire frame.

A corresponding aspect was interaction design for controlling volume and depth of buildings. Both of the variables could either be mapped to colors or be controlled by barcodes. Furthermore, barcodes could be generic modifying the variable of all colors, or specific and modify one selected color. Thus, multiple different solutions to this problem arise, whereas each provides a different set of interaction possibilities requiring different steps of manipulation. It is necessary to discuss which settings are essential, for which interactions a sequence of actions is acceptable and which ones can be simplified to facilitate the usability. We finally decided to map colors to the volumes and use a global barcode to change depth. As visual and haptic guideline for the users, we used 5 different heights for the color tokens to represent the corresponding volumes.

Since 5 colors are needed to specify the different volumes, we use the two remaining ones to manipulate building masses at specific spots. They either increase density by multiplying all affected volumes by a given factor or generate empty space by transferring volumes from an inner to an outer radius. To increase variability with the limited amount of colors we introduced a new type of tokens, which are defined by a combination of two colors, and are used to specify the outlines of the territory. Up to 6 of these tokens can be positioned onto the table and define the vertices of a polygon.

To best visualize the different impacts of the compositions being made, we had to rethink the different modes of representation. The map space shows a top view consisting of physical objects, the map with projected outlines of the territory, footprints and impact radius of the massmanipulating elements. In the perspective view, we use simple volumes of the respective dimensions to represent each building. Since this view shows an image as seen by a pedestrian we decided to work with transparencies, to avoid complete occlusion of distant buildings. Their transparency increases when approaching the viewpoint. We also introduced a third projection showing the scene on an aerial photograph to allow observing the entire area (Figure 5).

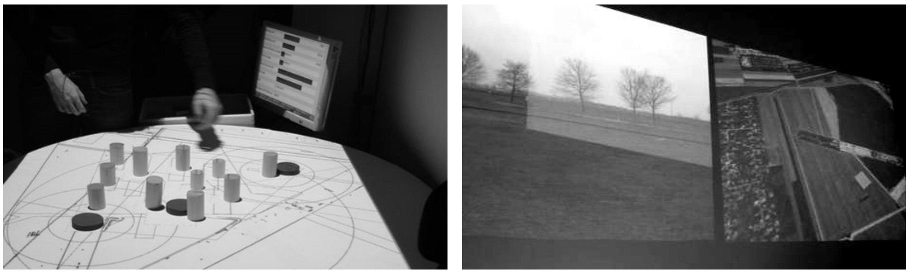

Figure 5. Tabletop with projections (left) transparency and aerial view (right)

4.1.2. Testing

The aim of a 5 hours workshop for the students to test the implemented application was to create and negotiate an urban master plan for the airfield. After a short training for the main functionalities, the students commonly defined a territory and threshold limit values (F.A.R, building coverage), placed negotiated and adjusted building masses while observing the augmented scene and the changing figures at the information screen, which shows various numbers of the building code and the calculation of an average population density.

Whereas for the students the respective functionalities of the later application were difficult to grasp during the design process, putting the application into use accelerated the understating and validity of parameters and interdependencies. Suiting the *urban rules* application with the physical appearance of the *ColorTable* thereby elucidates the complexity of a simple building code. Adjusting the size of the various tokens to characteristic building volumes eases a meaningful distribution of building masses on the site, whereas coupling the distance rule with default building depths raised controversial discussions concerning unpredictability and chance. Since building depths often correlate with specific uses, an automated setting of this parameter at first glance restricts the variability and flexibility of the master plan when discussing the allocation of functions. Although the application aims to allow negotiate possible planning scenarios and densities instead of actually designing one or various solutions, direct manipulation of certain dimensions such as volume depth and height should still be possible.

4.2. PROTOTYPE TIME AND CONNECTIVITY

The second prototype was developed in relation to an upcoming participatory workshop in Cergy-Pontoise. The later field trial, which was carried out within the IPCity project, aimed at stakeholder participation to test the developed technologies. Subject of discussion is the revitalization of an abandoned military area by which the two coalesced cities, that are separated by a highway should be reconnected: the historic city of Pontoise and the `New Town´ Cergy. A communal development plan anticipates the development of a vivid future district for the site, which is surrounded by residential areas, a private school and a university. An important issue concerns the identity and the future uses of the site to reflect local needs.

4.2.1. Design Process

In contrast to the first application, this prototype focuses on enhancing the dialogue among different stakeholders. Therefore, the students were asked to choose individual topics in relation to future users of the application and their specific points of view. The student’s projects varied from abstract approaches, specific local issues up to complex conditions in larger contexts, such as the general questions of spatial distance and actual reachability, the influence of noise or the relation of public and private properties. They particularly addressed individual patterns of daily life, responsible parties and decision makers regarding reciprocal relationships between economic values of territories, different uses and spatial organization.

From the very beginning, the students adopted the visual appearance of the *ColorTable*, by interpreting its interface as an abstract diagram, wherein the degree of complexity directly relates to its feasibility within the *ColorTable* application. After defining sets of parameters and their interrelations, the students developed possible scenarios for activating the site and reconnecting it to the surrounding. These ideas were communicated in diagrams reflecting the positioning of tokens on the tabletop (Figure 6).

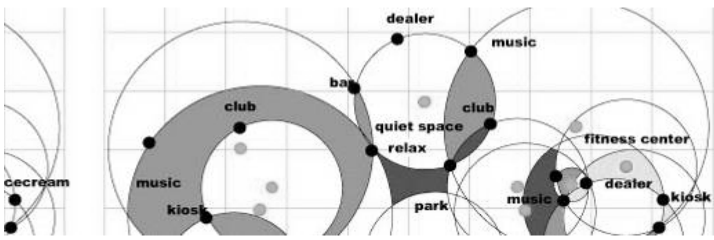

Figure 6. Stefanie Pesel: Distribution of uses

The results showed a large variety of conceptual approaches of possible negotiation scenarios for the site and offered many ideas for the use of the *ColorTable*. Some extended the site of intervention to a larger part of the city, which conflicts with the relation of token size and scale of the map. Others precisely described how to use tokens for creating patterns of usage by categorizing types of programs: punctual functions, laminar elements (paths) and territorial extension (squares). According to the uses these distributed functions could affect each other. One student classified kinds of impact and discussed feedback possibilities of compatible or conflicting uses.

To guide the design process in conjunction with the forthcoming workshop, we combined the student's projects and identified three main elements to work with; connectivity, points of interests relating to required uses and measurements of reachability. A first question to solve was how to define the respective parameters and the formation of a set of rules. We discussed if placing a program should automatically affect nearby streets and vice versa. To allow individual visions we decided to not correlate them and provide users with most freedom in allocating uses and connecting the area to its surrounding. A second dependency to discuss dealt with reachability and spatial distances. Within a sketching session we discussed the exploration of movements and various kinds of locomotion (by foot, bike, car) between two allocated uses, which requires the calculation of the closest path in-between (Figure 7).

Figure 7. Calculation of distances and correlation of programs and streets

As particular functions are intuitively associated with envelopes of specific sizes, the respective tokens would not be directly placed onto an intersection or path. Therefore, the definition of how programs are attached to the street-network affects the way distances are calculated. Although we aimed working with approximations, this choice strongly modifies the overall distance. Since it is important to define a most suitable approximation, we decided to use the closest perpendicular connection between the represented use and the nearest street as basis for calculations.

To couple the elements with the input possibilities of the tangible tabletop, we had to decide how these could be manipulated with elements of the *ColorTable*: an obvious solution for defining and positioning programs is the use of tokens, since a color can be selected with the tangible selector to associate a chosen program with the barcode interface.

Defining the different paths and streets however required a more complex solution. To achieve the most possible variety of different programs, we discussed several possibilities of how to increase the manipulation variability of the 8 different colors. One solution is to introduce two modes of manipulation that can be activated separately: in a first step, connections can be created using two tokens of the same color. Different colors could then represent different types of connection. In a second step, those connections can be saved to reuse the tokens to assign and position uses. This workflow however requires users to handle the tasks separately as they cannot position connections and programs at the same time. A second possibility is to introduce combined tokens for defining connections. To prevent the tabletop of being too crowded, we decided to use combined tokens for defining connections, and use barcodes for saving. This possibility enables users to define streets and allocate uses at a same time. Specifying a whole network of streets however requires a stepwise placing and saving of each single connection.

The third interaction to be supported by the *ColorTable* is the exploration of different distances between sequences of programs. We introduced two further combined tokens to mark the start and the end of the trip. The times for different transport possibilities (pedestrian, bike, car) can be observed on the information screen and by animated flow objects moving along the path.

Another question we had to solve during the design process dealt with the different modes of representation. As the top view shows the scene in a map space, elements should be represented in abstract shapes. We visualize streets with lines of different widths, and the dimension of functions as circles of different diameters. The perspective view however should provide an ambiance of the scene that cannot be provided by simple 3d shapes and volumes. We therefore decided to represent the different programs with pre-selected images, illustrating the inhabited space (Figure 8).

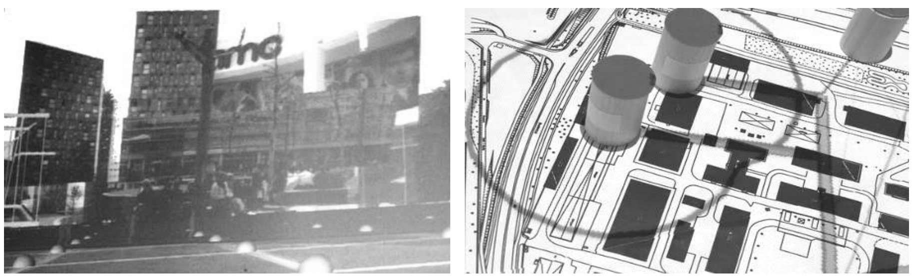

Figure 8. Images of specific uses (left), representation of dimensions (left)

One of the last steps of our development process consisted in the detailed specification of each parameter and each rule. We listed a selection of different functions and uses, connections and transport possibilities that we provide users to work with. Since several programs (such as public parks or markets) cannot be positioned onto a point, we needed an interaction possibility to define these as areas of variable size. According to the student's proposals we predefined each program either as `point´ or as `area´. Punctual programs can be placed with one token, defining the center of the program whereas its size can be manipulated via bar code; areas are defined with two same tokens marking the borders of extension.

4.2.2. Testing

For the testing workshop, we planned to picture the future scenario on the actual site in Cergy-Pontoise, by introducing a role play at the beginning of the workshop. Each student was given a specific role within which he/she should act and argue during the process of decision making (e.g. developer, resident, urban planner, architect, representative of municipality). In order to structure the overall task, we proposed to create the urban scene in three steps; first introducing the issues of connectivity, secondly discussing the allocation of various uses and finally defining individual paths along which reachability could be simulated. The table acts as a mediator for collaboration insofar as it supports simultaneous interaction and participants did not have to discuss in a confrontational way face-to-face but by means of gesturing, setting interventions, commenting, and modifying (Figure 9).

Figure 9. Selecting programs (left) and discussing their positioning (right)

The limitation of the degree of automation to default settings of the respective values of velocity and size of uses led to a vivid discussion among the students, which was mostly based on the individual ability to convince by rhetorical means. According to their respective roles, the students either focused on mere quantities claimed for specific uses or questioned the resulting spatial qualities. Although the perpetual comparison between the perspective view and the tokens on the tabletop was used as visual basis for putting the arguments, negotiation among the participants mostly related to their own perception and knowledge for arguing their individual objectives.

5. Conclusions

While developing the two different *urban rules* applications we exploited the potentiality of coupling a tangible user interfaces with semi-automated applications. The *ColorTable,* on the one hand serves as interface between the digital representation of various media and additional information that the system can provide, while at the same time constitutes the conceptual environment defining the physical framework of possibilities. Our approach addresses the matching of different abilities to give meaning to the various parts and elements of the system.

As a bridging language for communication, we chose a method of expression based on parameters and diagrams and utilized them to conceptualize, represent and discuss ideas. The designation of urban parameters highly influenced the design of the conceptual structure that guides variations and vice versa, since the set up of the system allows or rejects the adaptability for specific purposes. Exploiting the various aspects of the *ColorTable* led to a multiple revision of allocating variables and invariants in relation to interaction possibilities and feedback. Also interpretations of how to use diagrams as design instructions differed between the two disciplines. Apart from the possibility to illustrate qualitative relations and hierarchies among different elements these drawings demanded to further specification when translated into actual values and interrelations that could be implemented into the system.

The correlation of parameters and the formalization of manipulations of the tangible user interface provided decision criteria for specifying sets of rules and degree of automation. These decisions are essential factors specifying the level of the discussions being made around the *ColorTable.* We mainly distinguished between an automated reaction modifying another value and visual feedback highlighting certain aspects. The first possibility, as in the density prototype, lets the software taking the decision and skips long computations to find a valid solution. This decision, however, may not be satisfying for the user and it is equally essential to involve the users into the process of finding solutions. When leaving the degree of automation to a mere highlighting of specific aspects, the decisions are entirely taken by the users. Depending on the amount and complexity of urban rules, it is important to decide for a compromise of the two types of automation.

We experimented with abstract representations, shown on the tabletop, and atmospheric elements in the perspective view. This in turn had a strong impact on the selection of meaningful kinds of additional information the system provides and its influences on user guidance and freedom of thought in the decision making process of the later use. The density prototype, which operates with quantified figures, could easily provide data, such as an average number of inhabitants or simplified cost models that in turn correlate with the seemingly objective representation of building masses. In contrary, the second prototype allows manifold subjective interpretations of the projected images, without being directly linked to the actual layout on the table. The designation of qualities and quantities therefore lies within the ability of the users to evaluate the visible situation.

A combination of both prototypes bear the possibility to not only accelerate the production of alternative solution for specific problems, but also enable to elucidate evaluation of advantages and disadvantages from multiple perspectives. When carefully selected additional information of various kinds provide a shared knowledge, which is accessible for all participants at the same time and might compensate disparities of precognition.

Acknowledgements

The authors would like to thank all members of the IPCity project (EU Grant FP-2004-IST-4-27571), in particular, Lisa Ehrenstrasser, Michal Idziorek, Stephan Gamohn, Ina Wagner, Mira Wagner and the team of Université de Marne-la-Vallée. We also thank Reiner Zettl and all students of *Urban Strategies* at University of applied Arts Vienna.

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