

Escaping Flatlands

Interdisciplinary Collaborative Prototyping Solutions to Current Architectural Topics

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The paper describes the interdisciplinary course, Escaping Flatlands, focusing on improving communication between students, who were either from the field of architecture or media informatics and human-computer interaction. There were two underlying themes. The first, the integration and augmentation of digital media and haptic models, escaping the flatland of classic architectural media such as paper or screens. The second theme, expert-laymen communication in public participation, was addressed in the contextual theme and content of the course task, the communication between students of different fields, and the presentation of robust working prototypes at an architectural exhibition. Students, in groups of four, developed three interactive architectural models enhanced with digital content. The course resulted in a number of benefits to students, the chairs, and implications for research. It also led to further collaborations between the two universities involved, including cross-over Bachelor and Master Thesis.

Keywords: *tangible interfaces, human-computer interaction, smart city, public participation, model making, augmented reality*

INTRODUCTION

Professionally, Architects take on the role of intermediary between the various stakeholders in planning projects, such as developing designs for building contractors, advising with specialist planners on details, and coordinating trade companies working on the building site. To fulfil these tasks, an Architect needs to have a basic understanding on a variety of subjects and disciplines, such as design, building legislation and regulation, and other spe-

cialist disciplines (structural engineering, plumbing, energy, etc.). This knowledge is imparted in architectural education, however, there is often a lack of opportunities to actually work in collaboration with other disciplines at universities. Convincing, sustainable and suitable solutions to planning problems do not occur through successive processes, but collaborative ones. In response to this, the new seminar, Escaping Flatlands, by which the interdisciplinary teaching method is described within this paper, was

conceived with the aim to enable architectural students to gain knowledge and experience in interdisciplinary collaborative design.

The Chair of Architectural Informatics at Technical University of Munich (TUM) has, like many other universities, a number of design courses, such as building information modelling, which focus on collaboration between students of related disciplines; in this case the Faculty of Architecture and the Faculty of Civil Engineering at the TUM. In Escaping Flatlands however, the aim was not only to create a collaboration experience for the students, but to sensitise and raise their awareness of the necessity and opportunities of co-operating with other disciplines, when it is appropriate to collaborate simultaneously and when successively, and to broaden the scope of their possible partners beyond the architectural sphere. Therefore, the course focuses on collaboration between architecture master students from the TUM and human-computer interaction or media informatics (hereafter referred to as HCI) master students from the Ludwig-Maximilians-Universität München (LMU).

As intermediaries, Architects are also ultimately responsible for coordinating public participation processes within the scope of the law and beyond. In Germany, as in other countries, there has been a shift in recent years towards transparent planning processes especially in early design phases, with the aim to increase public acceptance of development proposals, to proactively reduce the costs and delays caused by protests and public dissatisfaction, to increase the public's trust in authorities, and to enable a growing number of stakeholders (within urban environments) to gain the knowledge and understanding they seek on planning decisions effecting them. Participation is always about the communication of ideas and opinions. Architectural planning communication tools can include sketches, (CAD) plans of different scales, 3D physical or digital models, visualisations, or animations. For citizens, whose planning knowledge ranges from novice to expert [Rambow 2000], and who have diverse interests and expectations, these forms of communication can provide

both physical (access) and cognitive (understanding) hurdles.

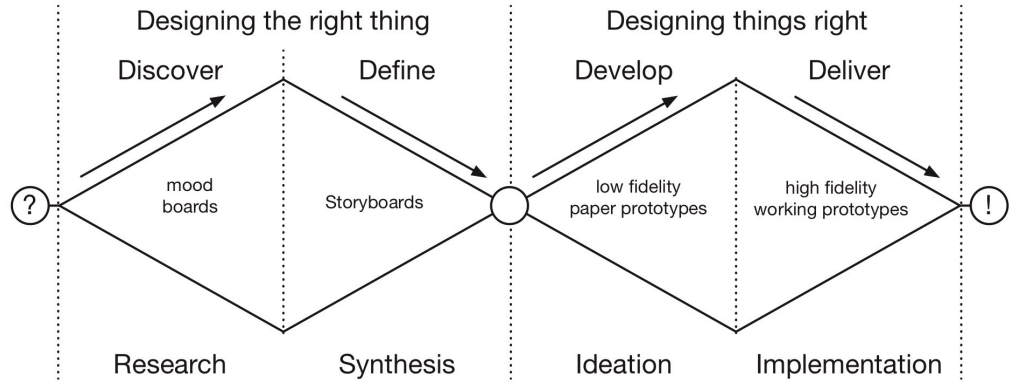
Architectural models in particular provide a significant mechanism for dialogue within this context even if each member of the conversation views the model from a different perspective [Ledewitz 1985]. Models make it possible to quickly grasp and evaluate cubature, form and spatial relationships. A significant advantage of using architectural models is that they are a potentially much richer source of information providing three dimensions and the opportunity to use a host of properties borrowed from the 'real' world for example: size, shape, colour texture, relationship between objects etc. Still, traditional static architectural media, such as models, implicitly contain information in their visual representation, whereas today's digital design methods are based on data models from which visualisations can be derived on-the-fly [Mühlhaus et al. 2018].

COURSE DESIGN

Edward Tufte is an information scientist and graphics designer who pushes the communicative abilities of the endless two-dimensional flatlands that we encounter in our everyday lives from pieces of paper and computer monitors to smartphones displays [Tufte 2005]. A haptic model is one of the simplest ways of escaping flatlands. In combination with digital content they hold great potential for the comprehensible communication of information and help us break away from the static nature of classic architectural communication media by enhancing and augmenting them with interactive digital media. The aim is to transport expert knowledge to a heterogeneous group of people using information rich, enhanced models.

Students from two disciplines were brought together to explore this topic. The challenge was to understand how information can be presented and feedback given and received. The first discipline is architecture. Architects have domain specific knowledge in this field, have design and communication knowledge and design and model-making skills.

Figure 1
Double diamond
concept overlaid
with course
elements



What they lack is hard- and software development capabilities, which is why the second discipline is informatics. Students taking part in the course Escaping Flatlands were of Master level, enrolled either in an architecture degree at TUM or in a media informatics degree at LMU.

Course Concept

The layout of the courses lectures was influenced by Buxton [Buxton, 2007]. According to his described design theories it is for any creative discipline crucial to perform multiple iterations early in the process in order to get any design right. Therefore the course was conceived around the double diamond concept [Norman 2013, Design Council 2006], whereby the design space is widened in the discovery phase, closed in the define phase, widened within a more specific context during the design phase and finally closed in the deliver phase. We referred to this design maxim also within the course Escaping Flatlands and suggested stage appropriate prototyping techniques [Rudd et al., 1996] and tools in order to provide a solid basis for revision rounds and group feedback sessions: in early stages of development, the student teams were asked to deliver sketches and storyboards on a low-fidelity (divergent phase) and produce a large quantity of ideas related to the

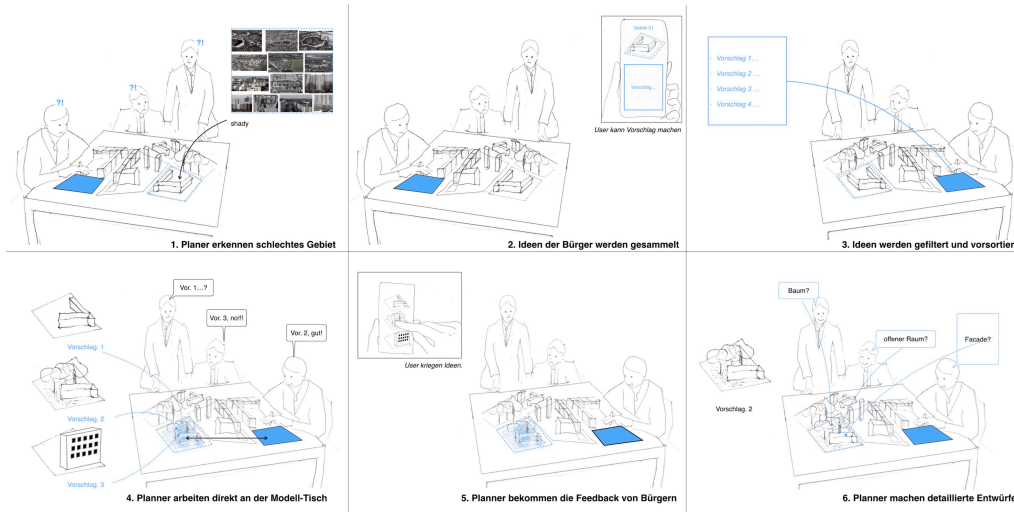
course topic. In consecutive project phases mid-review presentations were conducted in order to reduce the numbers of ideas (convergent phase) [Norman 2013, Design Council 2006]. After ideas were selected and more concrete the student teams were instructed to increase the fidelity of their prototypes by sketching-in-hardware with common prototyping platforms. The instructors were providing individual group feedback after the mid-review round and gave advice on prototyping issues. These high-fidelity iterations were performed up to five weeks before the final presentation. Subsequently a design freeze, a point where no more changes to the current concept were possible, was announced in order to reserve enough time for the final design implementation of the executed prototype.

Course Structure

The students worked together developing a solution concept to an architectural communication problem and implementing it in a robust working prototype. The course followed a structured procedure, developed to support the iterative design process and was roughly divided into four phases; problem definition, topic fixation and team-finding, low-fidelity prototyping, and high-fidelity prototyping.

1. Students prepared mood boards with which

Figure 2
Smart City Table
storyboard



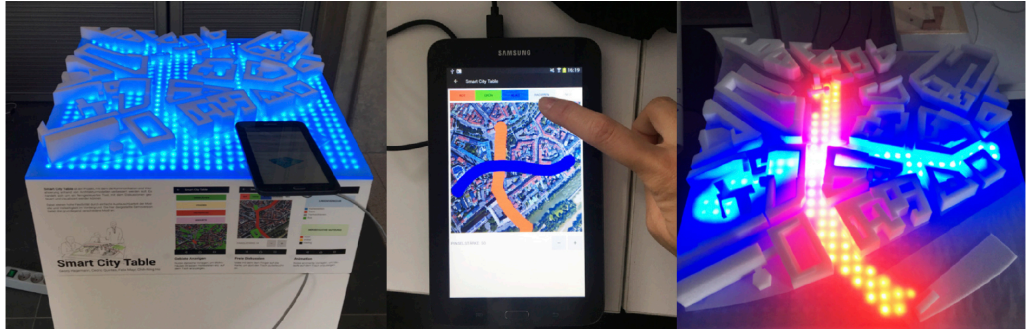
1. they visually explored the state of the art and existing solution approaches (portfolio wall, competitive analysis, state of the art).
2. They used storyboards comprised of six images (per idea) to clearly define problems and test solution possibilities and variants quickly.
3. They presented their projects at various stages using the PechaKucha style, aiding them in concisely communicating ideas and project status.
4. They designed within an iterative design process; implementing ideas, evaluating them and reconceiving them.
5. The project was developed from low- to high-fidelity, by using tools such as paper prototypes to evaluate concepts quickly without time consuming implementation, allowing a more extensive exploration of solution possibilities.
6. The final results were displayed and presented at an architecture exhibition as a robust working prototype, enabling the students to “sell” their ideas to and communicate with a heterogeneous community.

Equipment and Specifications

Each team was given access to the workshops at the TUM and the LMU, including free access to the CNC-Milling machines, laser cutters, 3D printer, etc. which students are able to use by themselves upon completion of the required use and safety introduction. They also had the possibility to use other more complex machines under supervision or guidance, if their projects required these. In order to achieve a consistent design language and to increase the comparability of the results, the prototypes followed common specifications:

- Dimensions: 50x50cm. Base (divided into two parts): top (project specific) - 20cm, foundation (uniform across groups and provided by the Chair) - 80cm.
- The base could house the technology and formed the stand for the model.
- Useful scale (e. g. M1:50, M1:100, M1:500).
- Material: left up to the students.
- Model colour: white.

Figure 3
Smart City Table
final working
prototype using the
discussion
integration



Deliverables

During the semester mood boards, 3 storyboards and a concept presentation were required of the students. Upon conclusion of the course students presented the final project where they presented their working prototype and handed in a documentation booklet and a 2min video describing the key features of the working prototype. The documentation booklet not only served the purpose of forming a basis for discussion, but also served the students reflection on their project and the team work.

COURSE RESULTS

In total 12 students participated in the summer semester 2017. They worked in three groups of four students. The groups were intended to be equally weighted, so that two architects worked with two HCI students, however the high number of HCI students meant that there was a ration of 3:1 HCI students to architects. Three prototypes were developed, “Street View Game”, “Smart City Table”, “The Muppet Show”. The process which the students went through from conception to working prototype is explained, based on the “Smart City Table” groups project documentation, within this chapter under the heading “Student Experience”, whilst the resulting prototypes themselves are described under the heading “Group Projects”.

“**Smart City Table**” (Hagemann, G, Quintes, C, Mayr, F, Ho, CN): a LED matrix to extend physical mod-

els as real-time or recorded interactive presentation tool through a tablet application.

Student’s experience during their project development is explained in more detail using the example of the “Smart City Table”, who were chosen due to the high standard of their project documentation and reflection. What follows is step-by-step overview of the different design and development stages the students underwent over the duration of the course, highlighting aspects of the concept and ending in a short description of the implimentation.

The initial phase of the course was for students to sort themselves into groups and conduct a brief (one week) analysis of the state of the art within their group. This research was presented visually on a mood board and discussed with the class. Here the aim was to widen their understanding of the topic and analyse existing solutions to *discover* deficits and potentials.

The next two weeks were dedicated to the specific problem *definition* and solution example. The was achieved through the development of three storyboards describing three different scenarios based on the initial research. A focus was laid on the exploration of the scenario and the sequence of events to test the design solution within the specific context. The scenario which was finally chosen by the group, followed the story of a group of people standing around an architectural model in a discussion round. The architect was explaining various features

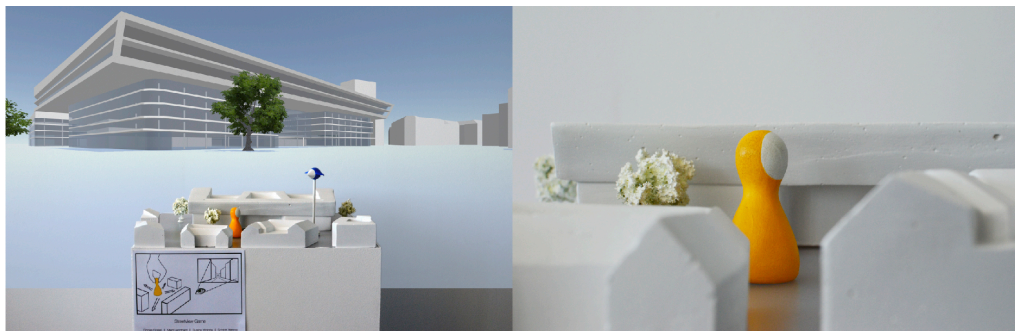


Figure 4
Street View Game
final working
prototype

of the design of their building, explaining how it fits into the existing context. Whilst some people were able to follow, others got lost as to which part of the model the architect was referring to. The solution was for the architect to highlight the relevant area on the model.

Based on this scenario the team developed a number of design criteria for their project. The technological side of the solution should be project and model independent and users should be able to generate, interact and change the information displayed on the model. This criteria limited the team in the technologies they could use as sensor and actuator technology would need to be considered whilst building the model, limiting them to optical information visualisation and interaction possibilities. In the proposed scenario projection from above made no sense, this left LED integration, LCD integration or projection from below the model. The architectural model needed to be separate from the screen and easy to make. Multiple low fidelity prototypes were developed to test the different technological possibilities with the architectural model making materials.

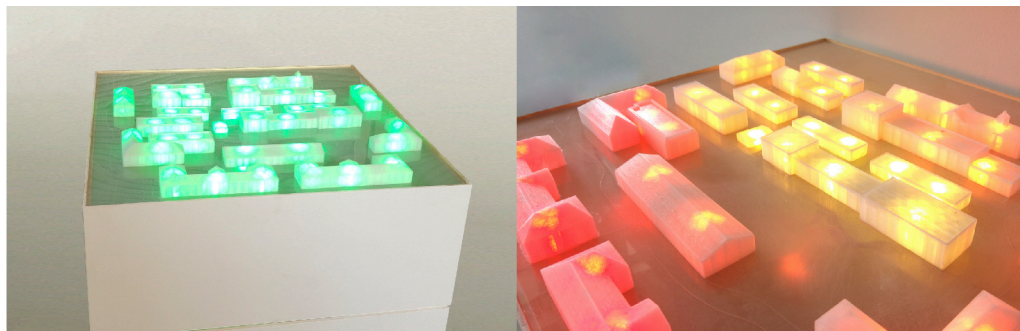
Styrofoam was chosen for the model as this is a standard basic model making material for quick model making in architecture. An LED display was chosen after tests with the model, as a higher brightness was achievable, allowing light to be visible through the Styrofoam. The LED display was delivered as a low-resolution display using standard LED

stripes as this reduced cost and supported its use in early design phases by making it clear through the low resolution that designs are not finalised at this stage. The interaction with the LED matrix was to be through a touch screen device. The app for this was designed so that no programming knowledge was needed to use the screen, it works using pixel images. This makes it possible for the designer but also for non-architectural experts to draw predefined patterns to explain problems or to generate animations through the combination of multiple patterns. Finally, the app also allows users to simply draw on a map whilst discussing and the areas light up in the colour in real-time. The students spent three weeks preparing their robust working prototypes for the *delivery*.

Initially it was difficult for the team to communicate their different competencies with each other, however over time they improved in this aspect due to the steps of opening and closing the design field and the necessity of relying on each other's competencies to complete the task. The model was displayed in architectural exhibition which the students greatly appreciated, as they were able to discuss and present their ideas to the public.

It comprised of a 28x28-LED-Matrix built from commercially available, low-cost RGB LED strips. A python server controlled the matrix and received the commands using a Json-based API. The setup allowed for smooth control with stable 25 frames/sec-

Figure 5
The Mappet Show
final working
prototype



ond via a wireless network. The user application was developed as an Android application using the Android SDK (Java). The intuitive touchscreen user interface offered different interaction modes for the Smart City Table: “Templates” (pre-defined visualisations comparable to a slide show), “Animations” (pre-defined animations comparable to GIFs) and “Free discussion” (an easy accessible drawing interface, offering different colours and strokes with real-time model interaction).

“Street View Game” (Fincke, F, Mertl, L, Rusina, V, Schlott, V): a real-time first-person visualisation controlled through a haptic avatar within a physical model.

Real models are often too abstract and therefore difficult for laymen to understand. The “Street-View Game” addressed this problem. It combined a real model with a more detailed and precise 3D visualisation of a planned structure. The interface and therefore for the interaction between the two, was a standard game piece, as found in board games. This allowed for an intuitive and easy handling of the model and 3D visualisation by all age groups and supported the translation of information from the model to the real-world perception of it.

Only three technical components were needed, all of which fit into the base of the model. A webcam (Logitech QuickCam Pro 9000) which filmed the model from below, a standard night light to illuminate the box from the inside to facilitate the recogni-

tion of the markers under the game piece and a computer to calculate the 3D visualisations. The markers on the pieces were Aruco markers, which make it possible to recognise the position and the angle of rotation of the game pieces. OpenCV, a free computer vision software library, was used for marker recognition. OpenCV was used to transmit the coordinates and the rotation vector of the markers to the game engine Unity. Unity was then used to calculate the camera position from and calculate the appropriate perspective in real time which can be viewed through a screen or projection.

“The Mappet Show” (Freistätter, R, Schneider, J, Visintini, V, Wirth, F): a physical model connected to an online neighbourhood participation platform.

The basic idea was to create an interface between planners and residents of urban areas. The Mappet Show offered a platform that allowed users to enter complaints, comments and positive feedback into a database via an intuitive app-based interface. The sum of these comments provided, in the truest sense of the word, a picture of the circumstances in the selected environment that is visualised within a haptic model. The planner (landlord etc.) thus receives an overview of the condition and the mood of his tenants and can use this directly for his planning.

The project was based on a Raspberry Pi 3 Model B located inside the base of the Model. The Raspberry Pi hosted the database (Node FS) and connected the

users (clients) to the system by providing the user interfaces via a web server (node.js, express and http). This approach made a special app on the client side superfluous, as the user interface was provided via the web browser. Two kinds of interfaces could be differentiated. The front was aimed at the residents or users, enabling them to make comments and report grievances and was optimised for smartphones. The back end was aimed at the planners and offered the tools to start surveys and evaluate results. This interface was optimised for tablets due to the more complex interface requirements. The raspberry pi also brought the model to life by controlling the LEDs located in the 3D-printed buildings of the model. The results of surveys and comments would become visible directly in the model using the colours of the buildings.

LEARNING EXPERIENCES

Students

The main learning expectations from designing the course curriculum were to provide students with a profound knowledge of processes, methods, mentality and educational characteristics of the different domains. As HCI serves as a supporting science and technology enabler within this context, the HCI students got hands-on insights into a creative domain and process steps such as, for example, presentation scale model making and creative architectural design processes, while the architectural students gained insights into the complexity of soft- and hardware development and prototyping and developed their skills in framing architectural problems for non-architectural collaborators, skills that will become essential with increasing demand for public participation, which mostly falls to the architect. The interdisciplinary setup of the course allowed the students to gain widespread knowledge from another discipline they were not familiar with before the course start, profiting from each other by gleaning insights into each other's thought and work processes. Our aim in providing both disciplines with new learning in these domain specific challenges was to foster a

mutual understanding amongst interdisciplinary design teams. As a consequence, we explicitly mentioned in the course that we did not aim at HCI students possessing high levels of design skills and architectural students possessing computer science skills after the course, instead we expected the students to gain cross-disciplinary communication skills, a learning of high value in an ever-changing professional domain. In addition, they gained an understanding in the field of expert-laymen communication, by communicating with each other and through the presentation to the public within the context of an architectural exhibition.

Chairs

For the Chair's there were two main learning outcomes. On the one hand, improvements for the course and the teaching method were identified. It was deemed important that the teams be weighted more evenly, with two architectural and two HCI students per team. For this, the advertising of the course within the architectural faculty needs to be improved. The team size of four students per team was considered appropriate for the amount of work required. For the student reflect in their documentation booklets, chapters describing project development and a description of the teamwork and what they learned from each other should be added. The duration of the promotion video students had to deliver, was found to be too long, therefore it will be shortened to thirty seconds. Although there was an external partner, who joined during the presentation, it is viewed that a further collaboration with an external partner in the architectural industry would be beneficial to the course. On the other hand, a number of crossover Bachelor and Master Thesis have been born out of this collaboration. Here the different disciplines work to their own strengths. The HCI students can work on existing, real problems and use their soft- and hardware development expertise and architects do not need to solve IT problems which have already been solved in the IT industry but can concentrate on developing solutions to domain-

specific problems where they have expertise.

Implications for Research

The resulting prototypes were also intended as starting points for future research investigations after the course. In our scientific work we are considering the field of Media Architecture, which we describe as the fusion of digital media with the built environment [Dalsgaard et al. 2016, Hoggenmueller et al. 2018]. The outcome of the course therefore served as inspiration on which topics should be investigated further. For example, the previously described prototype concept Street View Game, was perceived of being of high interests to architects and city planners to enable a deeper understanding of planning processes and the communication with citizens and city officials. Initial informal conversations with architects after the course considered the transfer of this design concept to other contexts and applying the technological framework to visualise different planned projects. The playful interplay with the different user-perspectives led to a concept of highly mobile form of Media Architecture which could serve temporary purposes such as, for example, the display of road safety information or escape routes. Additionally, the developed prototypes support research into the field of augmenting architecture using models [Mühlhaus et al. 2018] and gamification in architecture [Mühlhaus et al. 2018, Jenney and Petzold 2017].

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