

Multi-Touch : The Future of Design Interaction

CHEN Irene Rui¹ and SCHNABEL Marc Aurel²

¹*The University of Sydney, NSW, Australia*

²*The Chinese University of Hong Kong, SAR, PR China*

rui.chen@sydney.edu.au, marcaurel@cuhk.edu.hk

Abstract. A multi-touch-tabletop instrument combined with three-dimensional digitalized models is presented for design-collaborations and - communication tasks. By using intuitive gestures, the system allows users from various disciplines to communicate and share their ideas by manipulating the reference and their own input simultaneously. Our study shows that forms are perceived and understood more readily through haptic and proprioceptive perception of tangible representations. Our system provides increased potential to compensate for the low spatial cognition of its users. The paper describes our innovative integration by combining both model-based and participatory approaches with multi-touch tabletop system setups, which differs considerably from conventional visual representations for collaborative design. Our system brings the intuitive user interaction into virtual design activities, thus going beyond the common graphical user interfaces.

1. Introduction

Objects surrounding us are formed by different geometries and all geometries are about shapes. They are based on primitives and architectural designing makes use of these forms within space. The architectural design process hence, deals with geometry from the initial stage to the final construction, operating as foundation of the process [1]. Computing provides a variety of instruments for the efficient design, analysis, and manufacturing of complex shapes and geometries that go beyond basic primitives. On the one hand, this opens up new horizons for architecture. On the other hand, the architectural context also poses challenges for geometry [2].

Around this, a research area of architectural geometry is emerging. It is situated at the intersection of applied geometry and architecture [1, 2]. Employing geometry, architects can make divisions of space and introduce orders and rhythms, which allow buildings exhibiting both good construction and fine architecture. Digital instruments have become the strategies for the architectural design [3]. However, models, images and other outputs by these tools are to certain extent isolated from the physical world. The technologies that create digital models do not replace the qualities of physical and subsequently haptic models. More over collaboration and social interaction is increasingly a factor that decided about success or failure of a project. Subsequently, the possibility of interaction, multi-touch and social interaction within the design - and workflow is crucial.

In extending our understanding of the design process in the context of computational design instruments, this paper shall first presents case studies of computational supported designing and interaction that try to overcome the physical-digital divide, before then presenting a prototype for multi-touch design interaction. The paper closes with a discussion of benefits our system provides for multi-user interaction.

2. The Gap between Physical and Digital worlds

There are some recent attempts which have been made to merge the physical and digital worlds, using computational architectural methodologies. Due to the emerging nature of the field these are innovative, experimental and focusing on certain parts of the design process. The following case studies illustrate the development in the field whereby designers transient from one realm to the other, or whereby the artwork bridges between the realms. They form the base of our prototype that is presented in the second half of this paper.

8448cubed [4] (Figure 1) is an architectural design exhibitions displaying creative digital design techniques. It explores how the coupling of architectural designs with digital modelling and manufacturing methods allow for a deeper comprehension and experience of physical and digital space and form. The core of this collection is held together by the idea of spatial concepts within constraints of a cube 8448 cubic-millimetres in volume. Materials are creatively cut using CAAD modelling techniques, parametric design systems and digital manufacturing processes (CAD/CAM and CNC). If a model is required to connect to others models at the interface however, creating such models is time-consuming. Although the models were designed and manufactured soli in a digital environment, the ways of connecting the physical together with the virtual reams without and seams can not be experienced; hence the gap between these two realms.

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Fig. 1. Models from 8448cubed Exhibition [4].

Akin to 8448cubed two other exhibitions also explored digital technologies in relation to the modelling and communication of architectural design : *Portal* [5] (Figure 2) – a space between reality (the gallery, where there artwork is displayed) and the virtual world (a *Second Life* environment) – explores the interface and the transformation of users when they leave one realm and enter the other as well as the perspective and perception of oneself from the two realms. Users have an experience of both virtual and physical world in which they immerse synchronously. The duality and the paradox of being in both realms are highlighted.

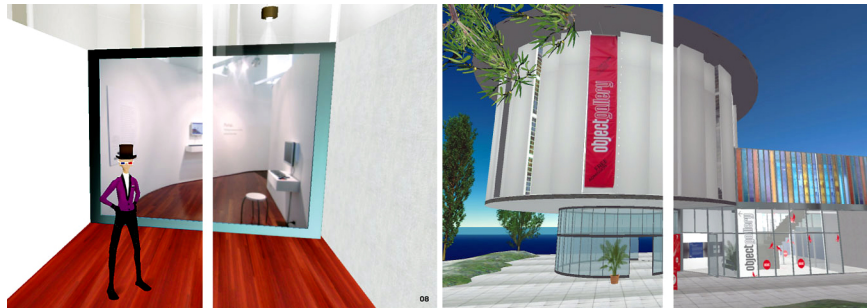


Fig 2. Images from Portal [5].

The *Immersive Virtual Design Studio* (VeDS) [6] allowed architects to jointly design within a Virtual Environment (VE) using intuitive gestures in space akin to drawing and sketching (Figure 3). This enabled designers to explore strategies that are not possible in screen based virtual or paper based physical realms. Subsequently they made more extensive use the three-dimensionality of the virtual realm and developed proposals that were unique to the virtual space. Despite the intuitive gestures designers had only visual feedback of their design and lacked any haptic feedback. This issue was addressed by the "Augmented Reality Urban Design Studio" [7].

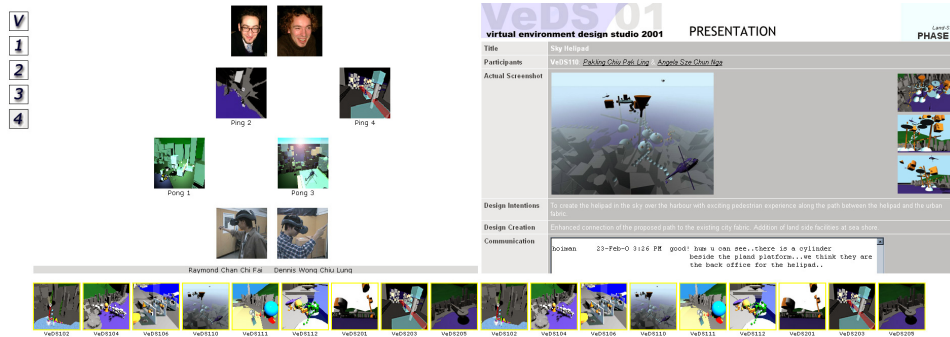


Fig 3. Images from Immersive Virtual Design Studio (VeDS) [6].

This collaborative design studio (Figure 4) was an early attempt to use a tangible interface as means to collaborative design within Augmented Reality (AR). Participants could interact on a design and discuss details of it. They were able to directly manipulate the design objects as well as load library models into their scene. This studio demonstrated how the ability to establish a unique combination of collaboration and communication of an interactive design process can be transparent and immediate. Using an AR system designers gain a more complex understanding of relationships of their design and engage in a richer communication with their partners about their design proposals.



Fig 4. Images from Augmented Reality Urban Design Studio [7].

Although these samples have shown that designers access VEs and use a variety of comprehensive instruments to express their ideas for contemporary art and architecture, people still seem to be "trapped" in either the physical or virtual realm without a seamless transition between both of them. In *Second Life* for instance, people use another identity, an avatar, to represent themselves exploring their environment often from a "third eye" point of view; hence increasing the gap

and reducing the direct interaction between the object and participant. Usually design applications allow users to manipulate and interact with the VE with their fingers and through gestures mimicking physical interactions; yet the possibilities are limited and differ greatly from interactions within the physical environment. To close the gap between the two realms, it seems that blending over one realm to the others seems feasible. This would not only aid architects in their workflow but also allow laypersons to communicate and participate in the process.

These samples above have shown that there are needs to address the disconnection between the digital and physical environments [8] during the design process. And also the issues of how to bring users together and engage them to be interconnected within the same 3D space through effective human interaction techniques. Current approaches of digital tools are no longer sufficient to match the need of refined interaction in design processes. Traditionally, two forms of design approaches can be found in the field of interactive systems. The first one focuses on a human-centred approach and aims to understand the user's needs in a comprehensive way. The second one is more formal : it focuses on structuring the design space and generating conceptual models in order to assist the transition between the requirements of the analysis and the development phases. However, these approaches both emerged from the field of software engineering rather than from designer's point of view [9].

The multi-touch table top system described in the next section tries to bridge the gap between digital and physical spaces. It engages the physical interaction of the users and integrates it with model-based and participatory approaches. Participatory approaches support the elicitation of the user's requirements by promoting the role and implication of the user during the design process. The user may express a requirement, take part in the elaboration of design solution, test the solutions and identify new requirements [10]. Existing systems for design approaches adopt either a model-based approach or a technology-driven development process [9]. In order to take advantage of the user's participation and outcomes of design models and software instruments, combining these two approaches seems inevitable. In the next following section we present a system that shall enable designers to collaborate and interact with each other as well as with the design whereby the design itself bridges the physical-digital divide.

3. Multi-touch tabletop

A study using a multi-touch tabletop combined with 3D digitalized models has been used for design collaboration and communication tasks. Using intuitive and natural gestures, designers can communicate and share their ideas by manipulating the same references, simultaneously, using their own input. Further studies have showed that 3D shapes are perceived and understood more readily

through haptic and proprioceptive perception of tangible representations - versus through visual representation alone [11]. Chen and Wang [12] subsequently established a framework to integrate 3D visualization and tactile sensory in design learning.

The next logical step in this development is to bring the natural user interaction into design activities [13]. Graphical User Interfaces (GUI) brought a new approach that was more effective than their conventional predecessors. In recent years, Natural User Interfaces (NUI) has advanced user experiences, and multi-touch and gesture technologies provide new opportunities for a variety of potential uses in design activities. Much attention has been paid to leverage in the design of interactive interfaces. The mouse input and desktop screen metaphors limit the information sharing for multiple users and also delay the direct interaction for communication between each other.

At the multi-touch tabletop for instance, more than one designer can manipulate the objects on the tabletop, and can communicate his or her ideas freely without having to wait for another's response. It makes the work more effective, which increases the overall efficiency. Designers can also collect real-time data by any change they make instantly. Our multi-touch tabletop system has integrated the *Unit3D*-tool [14] into the platform. The possibilities of Unity3D make designing very flexible, direct, instantaneous and enjoyable; it is deeply engaging and expressive. Unity3D is not only revolutionizing the game industry development, but also it is a breakthrough development for creating highly interactive 3D content as the interface of modern multimedia devices such as mobile phones, pocket-computers, etc. It allows the designers to work remotely in a collaborative way to integrate the design process by using the individual mobile devices while interacting in a common platform.

3.1. Model -based approach integrated into the system

All 3D architectural models can be built in Unity3D or imported into it. Users can choose from the various components from the built-in menus. However, in the past these objects are usually used to build game environments for the Unit3D application. The innovative idea is to build 3D architectural models instead. Since 3D architectural models have been largely applied to present the design proposal and range in detail from very simple formal massing models of just a few cubic blocks, through to basic interior/exterior walkthrough models, on to detailed models complete with furnishings and landscaping. This offers stakeholders an immediate and three-dimensional access to the design.

Digital architectural modelling is an essential part of the process towards creating an accurate building [15]. The architectural concept is reflected in, communicated through and expressed with digital models – hence it forms the crucial stage for all types of architectural building design, no matter what type of

building. Since (digital) architectural models are those elements that enable users to view an interior as well as the external appearance, the making digital models for an architectural concept is known as architectural concept modelling [15]. It is a technology allowing the user to apply their imagination and thoughts in a variety of ways, and to examine or reflect on the outcomes.

These models assist users to pursue a particular line of thoughts to intersect idea with tactile reality, satisfying for example combinations of furniture arrangement, floor plan layouts, spacing and massing. By changing the variables, a user of a digital model gets instantaneous representation, iterating towards a final design.

3.2. Participatory approach integrated into the system

Naturally our multi-touch tabletop system benefits a variety of users such as developers, builders, or contractors; all stakeholders of a building process form idea to realisation.

Some of the reasons for all stakeholders to be involved in participatory design are :

- ***Inclusive*** opening up the design of the process to include multi-disciplinary requirements; from direct and indirect intentions, and giving the beneficiaries the chance to voice their needs at the earliest stage.
- ***Negotiation*** between the different stakeholders to reach agreement about what is to be monitored and evaluated, how and when data will be collected and analysed, what the data actually means, and how findings will be shared and action taken [16].
- ***Learning*** - a focus on cumulative learning by all the participants as the basis for subsequent improvement and sustained action. This action includes local institution building or strengthening, thus increasing the capacity of people to initiate action on their own.
- ***Flexibility*** in adapting the evaluation to the wider external environment and to the set of different conditions and needs from multidisciplinary, as these factors change over time.

In architectural design, the participatory approach offers to bridge between architects, builders, developers and everyone else who needs to participant in the building and design process. This collaboration through out the building process can benefit both each stakeholder as well as improve the overall outcome. Architectural and building design solutions are richer when end-users are involved early on in the design process [16]. Therefore there is an increasing need for the building and design/production process to engage collaboratively between teams of architects, between architects and engineers, and architects and builders

as well as clients, users, and general public. Subsequently we see it as essential that our system integrates participatory possibilities in order to make use of these benefits. In the next section we describe our prototype with its technological elements and set-up.

4. Prototype

The prototype setup is described in Figure 5. It shows the interaction between the participants (actor), system hardware, and Unity3D. The designer uses multi-touch gestures to interact with a device (e.g. multi-touch tabletop, smart phone, etc.); the multi-touch gesture events are passed to Unity3D via TUIO (event handler and proxy) [17]. Unity3D then takes the user input, and acts upon it according to the game logic and creates a representation of the 3D world database on the user's device (visualization). The designer, seeing the visualization, makes decisions, and uses gestures to signal them. Stakeholders can then jointly interact, view and access the design and discuss elements they see in front of them. The multi-touch is then extended not only to the gestures of one person, but to the whole participating group. Hence the design becomes the connecting element between the designer and its stakeholders as well as between the physical and virtual realm.

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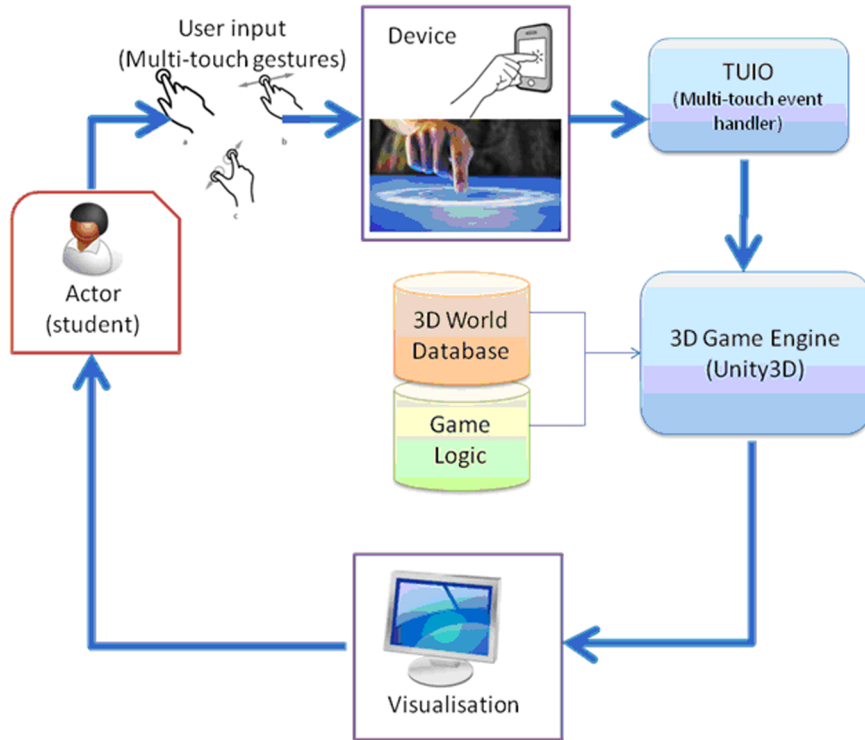


Fig. 5. Interaction diagram between participants (actor), system hardware, and Unity3D.

4.1. System setup

Detailed instructions of system setup are as follows. Every user has to install the free available Unity3D application on their devices. All users or collaborators can model their desired 3D objects according to their needs helping them to represent their ideas. Since Unity3D allows for different modes of representation, designers can develop their models from rough ideas or sketches to detailed representations.

In order to set up the TUI systems, users can also install a Community Core Vision (CCV), which is an open source/cross-platform solution for computer vision and machine sensing [18]. It takes a video input stream capturing the gesture movements by users, such as finger down, finger moved and finger released, on the screen as events sending them to the system as source images and outputs tracking data which coordinates. Users can adjust their settings to change background, smooth levels, brightness, etc. allowing to calibrate the system as the example shown in Figure 6.

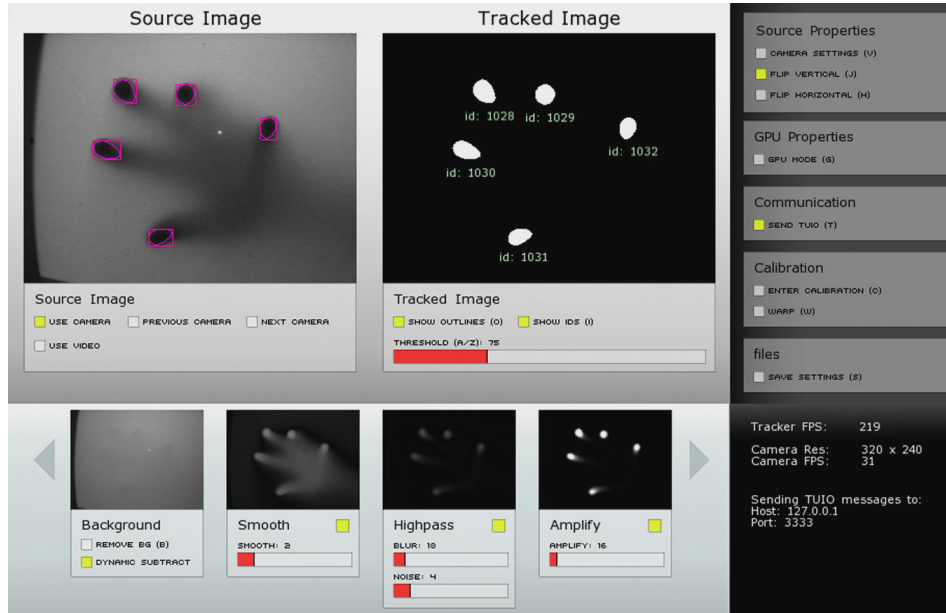


Fig 6. Good calibration from Community Core Vision [19].

The benefits of CCV is its use as an interface, with various web cameras and video devices, as well as its ability to connect to various "TUJO/OSC/XML" enabled applications and to support multi-touch lighting techniques including: FTIR, DI, DSI, and LLP [18]. Users just need to calibrate following the instructions to ensure the movements from users can be recognized by the systems precisely. Users also need to install the appropriate video drivers according to the video camera they use. The *Sony PlayStation* camera is used in our system for reasons of quality and ease of use.

The last application that needs to be installed is the TUJO as described in the previous section; it is the bridge between the hardware and the other underlying applications so it allows all applications running to be interoperable. Then users just need to connect their mobile device, video cameras and the multi-touch tabletop and run the applications. Once models are loaded or imported users can not only visualize but also collaborate in with their set-up.

5. Benefits

In design activities, people create an external representation of information, often of their own ideas and understanding. Our system provides a common ground for multiple users to express their ideas with immediate correspondence from the

representation showing on the multi-touch tabletop. It aids users to make their ideas more concrete and explicit, and once externalized; they can reflect how well their work sits within real context or situation or communicate and collaborate with stakeholders. During a design process, iterations and reflections refine the design itself. In collaborative setting users have a variety of reflections and ways to communicate them; often these variations lead to issues that need a clear visual representation. A conventional screen based or physical model environment restrains active communication and engagement of all users in the favour of the computer operant or model builder. The prototype demonstrates how this tabletop innovatively replaces the typical desktop metaphor.

The exploration of the relationship between human beings and the natural world and the subsequent implication on interaction has deep roots in philosophy, in particular Phenomenology, which also radiated into the domains of Human Computer Interfaces (HCI). Phenomenology is the tenet of empirical observation on events that are based on other theories but cannot be directly explained through them. From a designer's perspective the connection between the real and the virtual is a natural one, as the development of a design includes thinking in virtual realms about real objects [20].

We integrated for our system Unity3D with multi-touch tangible interfaces. Unity3D provides a game development tool as part of its application package that has been designed to let users focus on creating new games. However, it does not limit the usage to design additional game scenarios, and allows users to build their own 3D environments, per its customizable and easy-to-use editor, graphical pipelines to OpenGL [14]. It creates Virtual Reality (VR) environments which can simulate places of the real world, as well as new designed VEs, thus helping architects and designers to vividly represent their design concepts through 3D visualizations, and interactive media installations in a detailed multi-sensory experience. Stereoscopic displays advance their spatial ability to consider design aspects, from details to urban scales.

5.1. Visualization

Visualization is the key in design development. It is an important part of geometrical thinking and modelling, which allows communication of idea to one self or to others. Visualization is crucial in solving problems that lie within three dimensions [21]. Already simple translations or modifications of elements in space can be a challenge for designers. Generally, people have difficulties for example rotating an object in their minds to see how it would look from a different angle. 3D modelling processes usually provide 3D panorama views that allow users to visualize each building element more accurately. Subsequently, it reduces time and errors of inaccurate imaginary views. Besides reducing error

during actual construction, our system assists in clash-detection and the use of certain constraints, material requirement or structural issues.

Our prototype makes use of hardware-accelerated 3D graphics and built-in shaders, visual effects, etc. [13]. Particularly, during the initial 3D modelling process, the system offers an easy visualization process for laypersons and experts.

5.2. Speed

Based on game technologies or prototype allows for real-time visualisation, animation and special effects. This makes 3D modelling, visualization, changes, and collaboration not only faster but also easier compared to current standard modellers such as *Maya*, *Rhinoceros*, or *3dStudio Max* [14]. These programs require a higher set of operation skills and considerable time to implement changes, or amendments that are not pre-rendered or modelled. The advantage of our system is that encourages users to try out different scenarios in order to reach a solution, since these tries can be carried out in real-time and with great ease of operation.

5.3. Flexibility

The core-system of our prototype offers console-like 3D graphics for any web browsers [14] providing a flexible communication- and use-environment for stakeholders: all models can be viewed locally or remote through web browsers. Collocated or remote partners are able to engage within the 3D environment either synchronously or asynchronously.

Our system allows users to switch the target platform while they work and can use a larger variety of device for visualization, modelling and communication : smart-phones, net-books, computers and game consoles.

5.4. Tangibility

The main benefit however, comes from the integration of a multi-touch device via the Protocol for Tangible User Interfaces (TUIO). This protocol is simple and adaptable designed specifically to meet the requirements of tabletop Tangible User Interfaces (TUI) [22]. TUIO provides the communication interface between the tangible interface controller and the underlying application layers bridging between Unity3D and the TUI devices [20]. With this in place users are able to manipulate sets of objects or draw gestures onto the multi touch surface with their fingertips [17]. It was designed in respect to the findings presented in the case studies above [6, 20], where users design using common gestures to generate their design proposals. The interface subsequently connects the VE of the digital model to the physical environment of the users' interaction and hence interacts directly

with both realms. Physical objects are tracked by a sensor system and are identified and located in position and orientation on the table surface similar to an AR environment [7, 20]. Physical models can easily be transferred to virtual realm and users can manipulate and explore them in both environments.

5.5. Spatiality

In order to encode spatial information architects requires skills of spatial understanding. Marshall's study [23] has showed that TUIs offer significant cognitive benefits to individuals with low spatial cognition. In a participatory approach, not all the people are expert on how to imagine and retrieve spatial information. Our prototype with its TUI provides a great potential to enable users from any background to be less challenged since the design is accessible spatially in a physical and/or virtual environment, hence offering a clearer understanding and communication of spatial issues.

6. Conclusions and summary

There is a clear advantage in collaborative design to allow users to interact with both physical and virtual objects, whereby a tangible interface enables them to construct expressive representations passively [19], while communicating with other participants during the design process. We presented a prototype that enables multiple users to actively generate, interact and communicate spatial designs that goes beyond possibilities of conventional media and interfaces. Users can manipulate the same reference synchronously and asynchronously within the same scene with physical and virtual objects.

Our multi-touch tabletop system offers real-time visualization to process information and ease to use by any user laypersons or experts. The flexibility and tangibility means that our prototype can be used on a variety of computational devices and allows multiple users to access and interact on a design proposal remotely or collocated. The multi-touch tabletop system offers spontaneous involvement providing for an exploration of a broader scope of stakeholders. It offers a structured support by collecting data of the design development and outcomes. It integrates effectively and efficiently design-developments from the early stage onwards. Additionally our system proposes to overcome challenges of spatial cognition through its different TUI, hence aiding the communication within the design process and contributing to an integrated approach to design.

Akin to the findings of Dorta et al [24] in their "Augmented Design Studio" the implementation of hybrid technologies and design environments proves to be an efficient and effective collective ideation space. Spatial user interfaces as presented in our prototype allows the design of architecture to be "touched" by a

multiple persons using "multi-touch" gestures. "Multi-touch" extends its meaning from a technical HCI concern to a social – collective intelligence and collaborative designing. Designing is not only a technological but about an interaction, which is social, rather than technical.

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