TANGIDESK: A TANGIBLE INTERFACE PROTOTYPE FOR URBAN DESIGN AND PLANNING

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Abstract. This paper describes the design and implementation of TangiDESK, a tangible interface prototype to assist in the design and planning of urban design projects. The prototype derives from the need for an intuitive user interface similar to a designer’s or architect’s CAD system but also simple enough for non-designers like city planners and developers who are not accustomed to CAD interfaces to use and understand easily. Users can manipulate the objects or modify its relationship with other elements in the site while making preliminary design decisions together in a single environment. With TangiDESK, designers and planners can collaborate and make informative decisions more effectively and accurately in early stages of an urban design project.

Keywords. Tangible user interface; urban design and planning; computer-aided design; collaborative design; project feasibility.

1. Introduction

During the early design phases of any urban construction project, specifically in schematic planning, the main task of the design team (architect, engineer, interior designer, etc.) is to gather as much project requirements as possible from the development team (owner, planner, advisor, etc.) and devise working schematic designs that can be studied further for project feasibilities in later phases of the design process (Wuthikosithi, 2003). These schematic designs can be presented in various formats or produced in many types of medium in which are determined by what is considered the most effective communication method between both the design and development teams.
For the design team, the most common communication method is to use two-dimensional drawings produced by Computer-Aided Design systems (CAD) to convey design information by means of representing three-dimensional buildings and surrounding elements (road, pool, landscape, infrastructure, etc.) and depict their relationship on the project site. On the other hand, the development team communicates their planning information regarding costs, schedule, management hierarchy, and feasibility studies in forms of tables and diagrams generated by spreadsheet software that may or may not be easily transferred into designs and drawings.

In both cases, it may be difficult for each team to easily comprehend each other’s information due to the fact that their information may be incoherent or are typically viewed in separate working environments. Also, the level of expertise and experience in the use of tools and of their analytical thinking are very different and are not effectively integrated in one seamless medium or environment.

2. Related Work

The problem of information transfer between the design and development teams may result in certain delays of decision-making efforts agreed by both teams and eventually the lack in feasibility of the schematic design. In past years, there have been several attempts to eliminate this problem by integrating familiar analogue techniques with efficient digital environments that allow designers to interact with digital information seamlessly and intuitively during early design processes. Some of these include Tangible User Interfaces (TUI) for urban design (Ullmer and Ishii, 1997; Underkoffler and Ishii, 1999), Augmented Reality systems (AR) for urban planners (Billinghurst and Kato, 1999; Buchmann et al., 2004) and 3D simulations for feasibility studies (Freeman and Steed, 2006; Keawlai, 2007).

MetaDESK and Urp are TUIs that have urban design and planning applications developed for designers who need to collaborate with many parties simultaneously in a single environment. However, the main purpose is to view existing designs and not to assist designers in making informative design decisions along with city planners and urban designers. FingARtips is an AR project that requires users to wear heads-up displays or virtual glasses to be able to view digital information that is overlaid onto physical objects in the real world. However, this feature is limited by the amount of concurrent users the system can handle at a given time and the cost of equipment per user may not be feasible for many participants.

This paper intends to explore new applications with TUI technologies by assisting design decision-making tasks that designers and developers face...
The proposed system consists of a tangible user interface as its primary means of user input and a semi-intelligent system to interpret user interactions that provides useful information to users in real-time in order for them to make better-informed design decisions.

3. Early Design Phase in Urban Design and Planning

During the schematic design phase of an urban design and planning project, the main participants of this phase are architects, owners, city planners, real estate developers, and financial analysts who contribute their specific expertise to make collective decisions for the project (Wuthikosithi, 2003). Some of these tasks include planning building zones, infrastructure, public common spaces, green area, and number of buildings. Also, they need to consider the design in conjunction with local building codes and estimate construction costs in order to conclude the project feasibility study.

It is during these tasks that both designers and developers need to exchange information back and forth in a linear fashion until a final compromise is met leading towards an agreeable and effective design. However, due to the problem of incompatible work environments of both teams, information cannot be easily transferred or modified simultaneously by both teams to compact the time spent in this phase. The ideal solution for this problem is to have an integrated environment for both designers and developers to use concurrently and be able to manipulate, modify, or make changes to either the design or the building information with great ease. As such, many decisions that need input by each party can be resolved at the spot and changes in the design can then be updated instantly.

In summary, we have concluded that the four main issues that have the most impact in the decision-making conducted during the project feasibility study are building types, building area, building codes, and cost estimation. As for the ideal interface for the system, it must be flexible and intuitive for both designers and developers to use together with applications for both parties to utilize in a single environment.

4. Design Tool for Urban Design and Planning

4.1. APPLICATION FRAMEWORK

The main application of this system lies in the interpretation of user feedback and providing the user with both an intuitive interface and instant feedback of
relevant results. The process starts from the user interacting with the physical objects as if he would do so with an actual physical model of an urban project. Information is then calculated on the fly and results are projected immediately in the corresponding location where the physical object is located on the tabletop (Figure 1).

Users can reiterate the process of manipulating objects, adding or removing objects until both designers and developers have agreed upon a satisfactory design. The system can then output the building types, positions, basic properties, and costs into a working drawing for further detail developments.

Figure 2. Overall Components and Process Diagram.
4.2. SYSTEM COMPONENTS

The system is comprised of four main components: the Tangible interface, the Object recognition component, the Graphic presentation component, and the Database component (Figure 2). Users will interact with the system from a tabletop surface while all computations and feedback will be provided from beneath the table surface.

4.2.1. Tangible Interface

For this system, the tangible interface is the most crucial component for the user since it represents both information and manipulations to physical objects. The tabletop is also important for completing design tasks such as moving and removing objects that is most familiar in design tasks of designers and developers. With the tangible interface, the input and output sources are integrated in the system. The CCD digital camera as means of input is attached to the bottom of the table. The projector as means for output is used to project information by overlaying it beneath the physical object. Whenever a marker is moved, rotated, or removed altogether, the camera will detect all changes, make calculations, then project the results onto the current marker wherever it is in its present location.

4.2.2. Object Recognition Component

We have explored designated reacTIVision as the main object recognition system due to its robust processing capabilities and flexibility in integrating popular programming environments. reacTIVision works by acquiring images from a CCD camera and searches the video stream frame by frame for specific fiducial symbols or markers that are attached underneath a physical object (building object). Once a fiducial symbol is identified, it is matched to a library of unique fiducial ID numbers and its corresponding data in which can then be displayed or projected as user feedback (Figure 3).

![Image](image.png)

*Figure 3. reacTIVision fiducial ID recognition diagram.*

reacTIVision includes several unique fiducial symbols with its system for users to attach to a single object or multiple objects according to the users’
main application. The fiducial tracking algorithm is also highly efficient due to its well-designed marker geometry. This allows the system to minimize the size of its fiducial symbols, speed up its recognition process, and enable the system to handle the tracking of many fiducial symbols concurrently.

4.2.3. Graphic Presentation Component

Once a fiducial ID has been retrieved, the system will need to generate the graphic representation to be displayed on screen or on the tabletop. This representation is generated by Processing (www.processing.org: Aug 2008) which is an open source programming language and environment working in conjunction with reacTIVision. When a fiducial ID has been detected, Processing will retrieve the ID number and find a match in an existing database in order to execute further commands such as calculating cost estimations or generating graphic images to be displayed back to the reacTIVision enabled tabletop.

4.2.4. Database Component

Currently, the database is developed with MySQL for ease of use and its scalable database. Most importantly, Processing can interface directly with MySQL to obtain data such as building types, building area, construction cost, etc. that is embedded within each fiducial ID or physical object on the tabletop (Table 1). The database component can also be updated when more fiducial IDs or new building objects are introduced into the system. A wider range or general properties can also be added if further analytical tasks are needed for complex calculations as well.

<table>
<thead>
<tr>
<th>Fiducial Symbol</th>
<th>Fiducial_ID_1</th>
<th>Fiducial_ID_2</th>
<th>Fiducial_ID_3</th>
<th>Fiducial_ID_4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fiducial ID</td>
<td>House I</td>
<td>House II</td>
<td>Garden</td>
<td>Pool</td>
</tr>
<tr>
<td>Building Type</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cost per Sqm.</td>
<td>8,973</td>
<td>10,356</td>
<td>100</td>
<td>10,000</td>
</tr>
<tr>
<td>Total Area</td>
<td>200 sqm.</td>
<td>300 sqm.</td>
<td>2500 sqm.</td>
<td>400 sqm.</td>
</tr>
<tr>
<td>Coordinates (x, y)</td>
<td>70m, 20m</td>
<td>100m, 20m</td>
<td>130m, 20m</td>
<td>160m, 20m</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Amount</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Construction Cost</td>
<td>1,794,600</td>
<td>9,320,400</td>
<td>250,000</td>
<td>4,000,000</td>
</tr>
</tbody>
</table>

TABLE 1. Database of the fiducial symbols used in the system.
5. TangiDESK Prototype Design and Implementation

From our many observations in urban design projects, we think that the best and widely accepted means of design and planning a project should be a collaborative effort between designers and developers. All main decision makers must be present to gather around a large tabletop surface covered with models and large master plans. Changes and modifications to the models or drawings should be recorded, documented, and distributed among the participants for later reference.

From this observation, we decided to tackle the problem of information transfer between project team participants that occur at these tabletops and utilize a tangible user interface system to integrate design elements with spreadsheet data. The prototype system was named “TangiDESK” to describe the properties of where the collaboration effort occurs and how it is handled. Then a real-life project is carefully chosen to obtain real data and scenarios. The TangiDESK system is then designed and implemented around the required collaborative design tasks.

5.1. PROTOTYPE CASE STUDY

To better explain how TangiDESK can be implemented and used in actual urban design and planning projects, a scenario of an existing local housing project based in Rangsit, Thailand is used as a case study for design schematic development. The housing project is called “Rangsit Thanee” located about 40 kilometers from central Bangkok to the East, and has simple housing project elements such as a single main road, equally divided land parcels, modular homes, a central facility (swimming pool), and public open spaces (landscape).

The entire project is a very long strip piece of land with the main entrance located at one end of the strip. Because of this unique land feature and the size of the tabletop being limited by screen resolution, the strip is deliberately divided into three parts: front; middle; and back, to better match our equipment capacity and for development purposes of the system. This is also similar to project development phases that favor development of the inner most land plots or parcels first in order to increase the value of land plots closer to the front near the main entrance (Figure 4).

![Figure 4. Rangsit Thanee Project Master Plan.](image-url)
5.2. PROTOTYPE IMPLEMENTATION

TangiDESK consists of the four main components as explained earlier with additional building objects and swimming pool object as its physical objects. We use a hard top table and replaced its surface with a matte surface sheet of plexi-glass. The hardware we used consists of an infrared CCD camera, an infrared light source to illuminate the surface from below, a LCD projector, and a PC. All equipment, except for the building models with fiducial symbols attached beneath, are located under the tabletop surface as shown in Figure 2. The software applications used are Processing, reacTIVision, and MySQL.

In addition to the tracking of building objects, TangiDESK also employs a semi-intelligent checking system that assists the user in examining building code regulations and construction costs that impact decision-making of the designer and developer alike. When a building object is added, removed or replaced, the system will automatically check for conflicts in local building code regulations that may occur due to changes in proximity of a building object to the property line, set back line, or other building objects and display in real-time on the table surface (Figure 5).

For example, if the user were to move a certain building beyond the building set back limitation set by the code at a particular project site, then the system will highlight the building in red indicating that the relocation of this building is illegal to execute as a warning to the user. The implementation of the TangiDESK prototype has provided designers and developers a simple way to collaborate with one another and assist both parties in the process of simple design and decision-making tasks such as placing building objects in appropriate locations, summarizing individual and total construction costs, detecting any building code errors, and allowing multiple users to interact with the system simultaneously.

5.3. PRELIMINARY PROTOTYPE EVALUATION

A preliminary study of TangiDESK was conducted with twelve participants consisting of seven architects and five urban planners who were given a brief
introduction about the features of the system and the required tasks. These tasks included placing and rearranging building objects on the table, identifying any changes to the construction costs, and detecting any illegal placements of objects according the building code regulations. The participants were then allowed to interact with the system freely and in no particular order to explore its features with no prior training and guidance.

Initial feedback of the system was very positive and encouraging since all participants commented that the system was very easy to use and required no or little explanation to utilize the interface. Also, some urban planners were very eager to manipulate the physical building representations just to observe changes in the costs and feasibility of the project when moving the buildings little by little. Some architects find the system useful for uncovering effective schematic design alternatives without having to wait for feedback from developers and planners.

5.4. PROTOTYPE LIMITATIONS

As in any prototype, TangiDESK was not designed to be a full-featured system that incorporates all decision-oriented constraints needed for both the designer and developer teams. For instance, the current system cannot modify the orientation and direction of the existing road in the project site since the main road inside a project site is one of the first fixed costs of the project that must be predetermined before dividing individual land plots. Both designers and developers must agree with the designated road before utilizing TangiDESK for other design decisions. The prototype also lacks the output mechanism that will transfer the final design into a working drawing since this feature must be thoroughly explored in a limited timeframe.

5. Conclusion and Future Works

This paper presents a tangible user interface prototype called TangiDESK designed to assist designers and developers in decision-making tasks during the early schematic design phase of an urban design project. The prototype consists of four main components, which are the tangible interface, the object recognition component, the graphic representation component, and the database component. Initial evaluation of the system was encouraging but we need further system adjustments and more user studies to improve user feedback.

However, there is much room for improvement in TangiDESK. For example, adding more useful features and design tasks, recording all activities that occur, employing an output mechanism, providing continuous scrolling or panning to
the interface, and adding 3D walk-through simulation features. In addition, the hardware could also be upgraded, industrial grade USB2 or FireWire cameras will provide higher resolution images and frame rates, and more variety of building objects specifically road objects would improve the quality of user interaction for all participants.

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