Interaction Design in a Tangible Collaborative Decision Support System: The City Schema DSS

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Abstract. In this paper, we introduce a decision support system (DSS) platform (City Schema) that is designed to connect a tangible interface within a 3D modeling environment (City Form) with a simulation engine for analyzing the data of the urban, transportation, energy and water systems of the city (City Analytics) to support collaborative city planning. This DSS connects two completely independent systems into one integrated system. The first system is a physical 3D model of a city with a tangible user interface that supports interactive and collaborative activities and provides users with direct manipulation interaction and intuitive interfaces. The second system is an urban modeling design tool which is a simulation engine that has several simulation modules such as operational energy, mobility, daylight, transportation and others. The DSS we present here can be used to describe a real world problem and identify possible solutions to the modeled problem through the computation of many scenarios/alternatives so that users of the DSS can evaluate, compare and select a potential solution. Our City Schema DSS consists of: database management component, simulation modules management component, and an interactive user interface with dynamic visualization and decision scenario simulations. Human factors for supporting multi-user co-located collaboration to assist decision makers in making better decisions are examined. Design implications of different interaction modalities for decision support systems and their impact on providing intuitive and engaging user experiences are discussed.

Keywords: DSS, HCI, Urban Planning.

1 Introduction

The world is experiencing a period of extreme urbanization. In the future, cities are expected to account for nearly 90% of global population growth, 80% of wealth creation, and 60% of total energy consumption [1]. The rapid economic and population growth occurring throughout Saudi Arabia is posing new challenges. In particular, problems related to planning and managing complex systems such as cities. Saudi Arabia's current growing population of 28 million is expected to double by 2032 [2].

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Therefore, developing better strategies for the creation of new "Smarter Cities" is a global imperative. Our need to improve our understanding of cities is pressed not only by the social relevance of urban environments, but also by the availability of new strategies for city-scale interventions that are enabled by emerging technologies.

Our proposition is that the livability and economic vitality of cities can be significantly improved while, at the same time, resource consumption is dramatically reduced. We believe that a new model for livable, high-performance, and resilient cities are achievable through the integrated application of next-generation design strategies, innovative technology, and enlightened public policy. This can be proven through a series of experiments using the City Schema Platform. The urban strategies to be tested using the City Schema platform will include designs that preserve and enhance the existing cultural fabric of the cities as well as new designs that capture the essence of the historic areas and bring new concepts in sustainable living/work, green transport, innovation hubs, and walkable neighborhoods.

2 Architecture of the City Schema Decision Support System

The Decision Support System (City Collaborative) component provides a way to synchronize and coordinate information and interactions between the two highly independent components City Scope and City Analytics. It provides decision support capabilities to the entire framework by collecting user input data from City Scope and feeding them into City Analytics for executing different simulations and analysis [4].

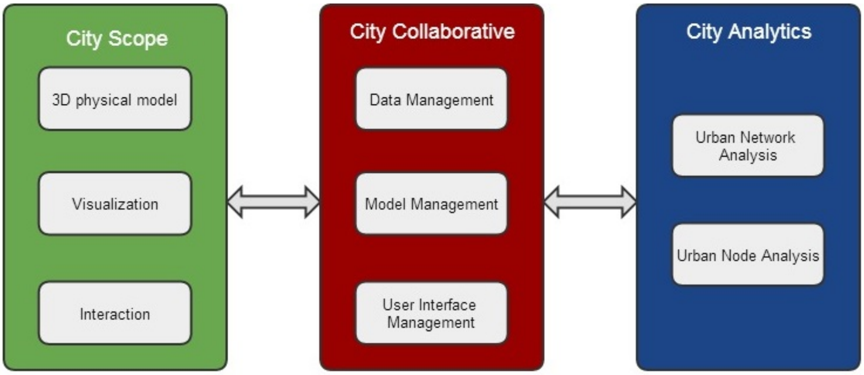

Fig. 1. Architecture of the City Schema Platform

The DSS we present here can be used to describe a real world problem and identify possible solutions to the modeled problem through the computation of many scenarios/alternatives so that users of the DSS can evaluate, compare and select a potential solution. Our City Schema DSS consists of: database management component, simulation modules management component, and an interactive user interface with dynamic visualization and decision scenario simulations.

The Database Management Component is responsible for data storage and manipulation as well as synchronization between different data stores. This functionality provides methods and techniques to manage different data sources and transform them into suitable format to be fed to the City Analytics models and coordinates between all the components within City Collaborative. It consists of multiple sub components including assigner, reporter, and conflict control manager. The assigner is the heart of the City Collaborative component where it is responsible for all the coordination between all the components as any request or change the user makes on the system and any communication between the different management components always passes through the assigner. The reporter allows users of the system to store the status of the running session including the values of the simulation's decision variables and the result of the simulation; it also allows users to conduct a comparative analysis between two simulation sessions where each session has a different input and output values. Since City Schema is a multi-user collaboration platform the system will need to control the conflict that different users might cause, for example two users entering different values for the same decision variable within a single session. This kind of conflict can be solved using different techniques. One is to take the change that is made last based on the date and time of the change. Another is to take the change of the user that has the higher priority on that decision variable, for example an energy planner has a higher priority on the decision variable of maximum energy consumption than a water planner. The third conflict control technique is to take the average of the two decision variable values entered by two users.

The simulation modules management component is responsible for coordinating the execution of different models in the City Analytics library and communicating with City Scope components for appropriate representation and visualization of the model outputs. It has three main functionalities which are data preparation, data translation and simulation execution. The responsibility of data association is to collect all the decision variables that are required in order to run the requested simulation and passes it to the data translator. The data translator translates all the data prepared by the data association into a format that is suitable for the simulation engine. The data translator also reads the results of the simulation and translates it in order for the decision support system to makes sense of it. The last component which is the interactive user interface takes care of the multiple interactions that occur between the decision makers and our Tangible User Interface (TUI). The goal of such interface is to make interaction intuitive, effective, and facilitate controlling the results that will be displayed on the user's end.

The user interface component takes care of two controlling factors in the TUI: First are the decision variables which maps to physical components such as Buildings, Roads, Parks, and Power Plants. Understanding the main physical components of a city is crucial when building the TUI of cities as it allows us to focus on the main characteristics of the city investigated when building its tangible user interface. The second factor is the Key Performance Indicators and this basically the behavioral components that infer and display crucial information regarding the city's degree of success in meeting its performance and economics objectives. These strategic goals and objectives involve (but not limited to) developing the city's economy, making the urban neighborhoods more resource efficient and reliable, enhancing transportation plans for future needs, and beautifying the city.

While the Listener part of the TUI monitors the interaction space for any triggers initiated by users, the Displayer projects the results of the requested simulation or query to the user on any interaction surface. Tracing this back to our controlling factors, the user interface for the Listener component will detect any selection or interaction that occurs with the decision variables described earlier. It will report these changes to the city collaborative component which will consequently deal with these changes by communicating with the City Analytics if needed; and the results will be sent back to the Displayer. The Displayer will visualize the corresponding information on the tangible objects or surface (e.g. touch screen surface) or surrounding walls. If the information is visualized as heat-maps or color-coded buildings, the result will be projected directly on the 3D physical model. Information such as scores, tables, and chart will be displayed on the digital interfaces for the experts to interpret and make decision.

3 Tangible User Interfaces in DSS

The interaction space in the City Schema DSS is comprised of three layers; namely, tangible objects, interactive surfaces (e.g. touchscreen), and the area surrounding the urban model and the nearby surfaces on the horizontal and vertical planes. City Schema utilizes innovative interaction modalities so that users can test alternative designs for large scale developments within the city by visualizing the implications of each design change in real time. For example, objects can be selected or activated for interaction by touch or hover; surfaces can be manipulated by touch or physical manipulation of detached or attached modes by an individual or multi-user interaction; gestures or presence of users are automatically detected to activate functionality. The urban strategies to be tested by our platform will include designs that preserve and enhance the existing cultural fabric of the cities as well as proposed designs that capture the essence of the historic areas and bring new concepts in sustainable living/work, green transport, innovation hubs, and walkable neighborhoods.

Different modes of direct manipulation will be utilized in our platform to deal with the interaction and visualization components in our platform. This include gesture recognition to interact with the system, touch screen with object detection capabilities to interact with different objects (e.g. buildings) within the system, and a TUI clock tool (e.g. position of the sun can be controlled by turning the physical hands of a clock tool) to give it a sense of reality [3].

For example, navigation gestures that can be used to interact with our system:

1. Start the Interaction mode: where actions are initiated by waving a hand with an open palm facing sensors, move the hand forearm left and right. Pointers for selection on the TUI will appear and the user can now use gestures to navigate through different objects.
2. Make a selection: Raising a hand with an open palm facing sensors and hovering over a specific object (e.g. building), and pushing it forward and then pulling it back to trigger the selection. The selected object will be visualized to confirm its selection.

3. Display an object information menu: Further layers of information can be projected by sustaining the gesture that was exhibited for selection or by a slight variation of the gesture to maintain an intuitive mode of interaction to view more from the TUI.

Interaction spaces will be implemented on the TUI surface surrounding the four sides of the physical model. Interacting with the DSS is via an interactive surface that offers a multi-user experience where multiple users can touch and share digital content simultaneously. One way of interacting with the DSS is via object recognition capabilities which captures and processes tagged physical objects that are placed on the screen (e.g. buildings) or movements that are within the range of detection (e.g. gesture recognition) by using cameras that operate in the near infrared light. Our goal is to create a collaborative and interactive interface that will help decision makers explore different scenarios with a responsive interface that provides intuitive and engaging user experiences.

4 Conclusion

In this poster, we describe a tangible collaborative decision support system that is designed to help urban planners in the context of large scale development areas. The DSS takes into consideration the complex systems of city infrastructures, to assist stakeholders in predicting future scenarios by utilizing different simulation and modeling techniques. The interaction interfaces are designed to provide urban planners with intuitive tools for manipulating data across spatial and temporal dimensions. Future work on this system involves developing the interaction modalities and evaluating them in real contexts of usage for case studies of urban developments in Saudi Arabia.

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