CoPI: A Web-Based Collaborative Planning Interface Platform

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Abstract. In this paper we present the Collaborative Planning Interface (CoPI), a web-based multiuser collaboration interface platform for planning of complex systems. The interface provides analytical and visualization components to support decision makers. The Interface is designed using a user-centered design approach, while considering existing tools and environments in the field of decision support systems. The architecture and structure of the Interface are described as well as the flow of the user experience within the system. Finally, a case study explains the use of CoPI in collaborative policy planning for large-scale infrastructures.

Keywords: complex systems, web-technologies, collaboration, multi-user, decision support systems, visualization, HCI.

1 Introduction

The increase in the world's population has led to the increase in the demand of man-made complex systems such as transportation, water and energy systems. In planning such systems many stakeholders need to be involved. However, while each stakeholder improves their particular system, other systems could be affected negatively [2], [7]. Therefore, a collaborative planning approach is required.

Understanding the different stakeholders and their collaboration and activities during the process of making decisions is an essential element toward designing a tool that assists them in making better informed decisions. Current Decision Support Systems (DSS) used by stakeholders provide some analytical modeling or visualization capabilities. However, these DSSs do not provide mechanisms for collaborative decision making. From our user research sessions, a need for a collaborative planning tool was evident.

In this paper we will present the Collaborative Planning Interface (CoPI), a web-based platform that supports multi-user collaborative planning for complex systems. CoPI is intended as a front-end for DSSs providing capabilities for decision management and visualization. The paper is divided into five major sections. Section 1, presents existing DSS systems. Section 2, describes User-Centered Design methods

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used in designing the platform. Section 3, describes the CoPI Architecture. Section 4, discusses the user experience of the proposed Interface. Section 5, presents a case study of implementing CoPI within the Sustainable Infrastructure Planning System (SIPS).

2 Background

Different tools have been developed to support decision makers in making better-informed decisions within different domains [1], [3], [4], [6], [9]. Some Decision Support Systems (DSS) are Geographical Information Systems (GIS) based [5]. These systems are used to assist decision makers in making spatial planning decisions. They couple the spatial view with different analytical modeling techniques and tools. For example, an integrated simulation environment decision support system was developed, and used to analyze critical infrastructure [6]. The tool is used to assist decision makers in analyzing the impact of disaster propagation on national infrastructures. The amount of information involved in such activity is overwhelming and requires a huge amount of human cognitive capabilities to analyze [6], [7]. Another tool [3] was developed by integrating a GIS with Multiple Criteria Decision Analysis (MCDA) to support land management decisions. Here, the increase of the importance of land and natural resources management derived the demand for such system.

Based on what has been discussed in the previous paragraph, several of these Decision Support Systems do not support multiuser collaboration. In addition, in many of these systems the Interface is either fairly basic or designed for a specific problem or hardcoded within the DSS. This does not provide for reusability of such Interfaces within other DSSs and domains.

Given the use of decision support systems in planning complex systems [6], [10], and the different needs in visualizing, accessing and interacting with the DSS, we designed CoPI to be an interface platform to support different user needs that could be applied to different domains (Fig. 1). In designing the CoPI, we conducted a user research study of the potential users of the platform. The next section discusses briefly the different UCD methods applied in the design, based on best practices in the field [8].

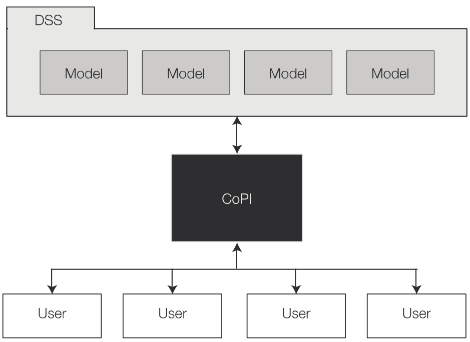

Fig. 1. The collaborative Planning Interface (CoPI) supports multiple users

3 User-Centered Design

To design an interface that supports the collaboration between different stakeholders who make planning decisions, we need to understand their process of making decisions and the tools they use to support their decision process and analysis. To collect this information, we used different User-Centered Design methods during the discovery and design phases. In the discovery phase, we observed the environment in which the stakeholders would likely use the system. We organized a set of semi-structured interviews, which were targeted towards analysts and policy makers within several governmental agencies. During our interaction with the stakeholders, the following sequence of activities was identified. The process starts by an analyst analyzing a specific case and proposing a set of solution scenarios. Each scenario is then evaluated on the basis of predefined indicators. During the analysis, Geographical Information Systems (GIS) or other specialized mathematical models are used. The set of scenarios is then reviewed and new solutions are proposed. This process is repeated until a subset of scenarios is reached whose indicators satisfy a minimum threshold. The list of scenarios is then presented and discussed with decision and policy makers for recommendations and final evaluation (Fig. 2). A popular framework that maps well to the decision analysis process is the Pressure-State-Response (PSR) framework. In the PSR framework, general drivers such as GDP and population are considered as pressures that affect the current state of a system, which is represented by a set of indicators. The response is then carried out to move the existing system into a newer state with a different set of indicator values.

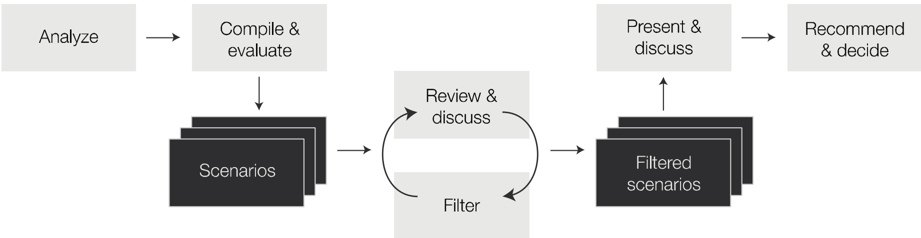

Fig. 2. Sequence of activities during a decision making process

Synthesizing all the results from the observation and user research, we designed the Collaborative Planning Interface to satisfy the expected user needs. It was determined that CoPI will be web-based to allow multiple users to collaborate remotely as well as provide high computation performance within a unified framework. CoPI should enable users to manage their cases and scenarios. To support the analysis and exploration of scenarios, CoPI will provide visualization of outputs that could be spatially and numerically presented. During the design phase of CoPI, we went through multiple iterations of the interface design and collected general feedback from non-domain field experts. The next section describes the architecture and the structure of CoPI in more detail.

4 Collaborative Planning Interface (CoPI) Architecture

The CoPI architecture is focused on the client side. The server side would include the DSS Engine, which consists of the computational server, data warehouse, and mathematical models (Fig. 3). The computational server contains the brain (logic) of the platform. It hosts the models that receive different inputs from users to evaluate. The data that feeds these models resides within the data warehouse. The communication between the client and the server is done through the exchange of messages (AJAX, JSON and XML format). The server receives inputs from the client to evaluate those inputs (decisions/scenarios) and then sends back the results to the client. Later, the client visualizes the outputs for the end users to analyze the results.

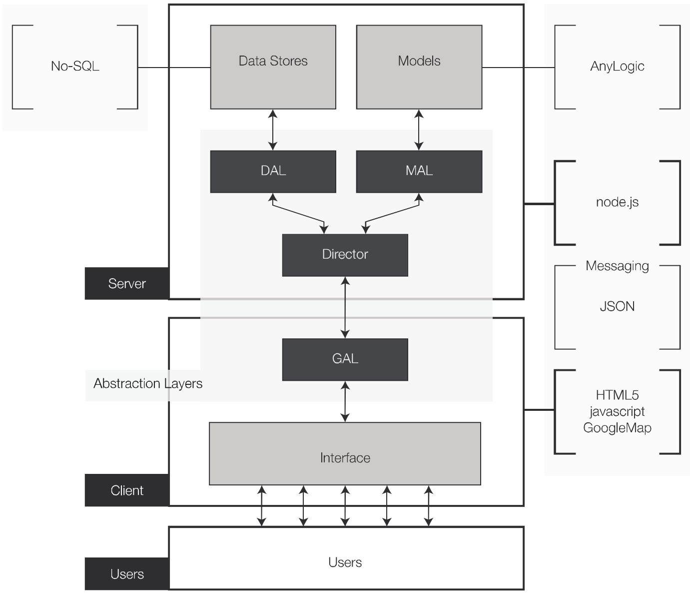

Fig. 3. CoPI client-server architecture

CoPI includes a web interface and visualization elements. The web interface is the portal for the users to interact with the system, simulate their decisions, and interact with other users. The users decisions are encapsulated within a scenario that a user would like to analyze. Charts and outputs representations are part of the visualization on the client side, which uses Data-Driven Document (d3) javascript library.

CoPI is constructed using the model-view-controller architecture. The view holds the html and css files. The controller, is a javascript file that controls the interaction within the CoPI, and the communication with the server side. The model holds the user scenarios before submitting them to the server. In the next section, the components and structure of CoPI are explained.

4.1 CoPI Components

CoPI is divided into six main components (Fig. 4). These components are: the registration system, style components, simulation configuration, real-time communication, Google maps, and visual analytics. The breakdown of CoPI into these components is to simplify the development process and to allow CoPI to be scalable for future features implementation. Each of the components is described in more detail below.

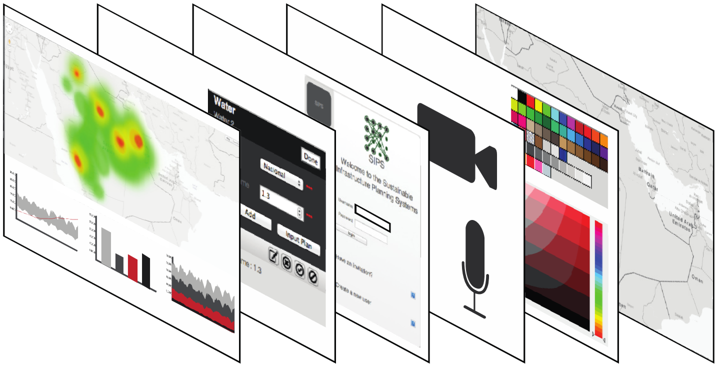

Fig. 4. CoPI Components

Registration System. All the user administration information, such as usernames, passwords, etc. is kept in the same component. Cookies management for multi-user collaboration is also kept within this component.

Style Components. To support different user preferences, we created this component to control the theme. This includes font types, background colors and sizes to be customized by the user.

Simulation Configuration. Generic simulation configuration and scenario setups are kept within this component. Such information includes the simulation time and scale, as well as the categories to be used in each case.

Real-Time Communication. This component is included to support users discussion and negotiation through audio and video channels. For that, we are utilizing WebRTC to include in our development.

Google Maps. The component controls the base map component. It has the country map, regions, and future areas that might be required. In addition, it holds the properties and methods to control the map.

Visual Analytics. This layer holds the visualization elements. Dynamic heat maps and choropleth map visualization are part of map overlays. Plots and charts, such as line, area and scatter plots, are used alongside with the other visualization components, but not as an overly.

4.2 CoPI Interface Structure

At the top level of the content structure of the interface is a case. A case acts as a folder that contains a set of simulation files known as scenarios (Fig. 5). After a case is created, the user creates one or more scenarios to simulate the impact of different decisions on that particular case. Each scenario consists of a set of decision variables (DVs), or inputs; and a set of Key Performance Indicators (KPIs), or outputs. A Decision Variable, is a set of attributes that users can control. Attributes are the smallest element in a DV, which allows the user to modify the values of that decision variable. Those attributes are modifiable before the simulation is started. After the simulation is executed, the outputs are visualized using charts and graphs or spatially on the map or even temporally using a timeline.

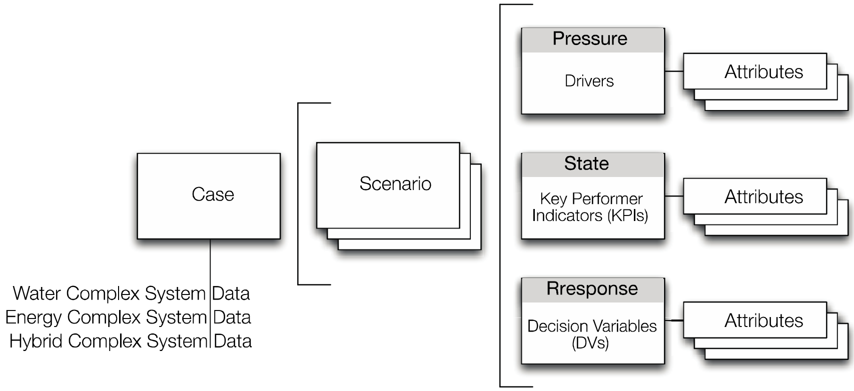

Fig. 5. CoPI interface structure

5 Platform Experience

The user starts interacting with the system by providing their credentials for authentication purposes. After identifying the user's role and authority, the user is granted access to setup, organize and manage cases. Then, the user interacts with the cases by creating scenarios. Finally, a report could be generated by the user(s) to share results and recommendations. This experience is mapped into four main screens/pages (Fig. 6). These are: the login screen, main screen, simulation screen, and reporting screen.

The login screen is the entry point to the platform. Users must be authenticated before they login to the system. The main screen is the first page users see after they

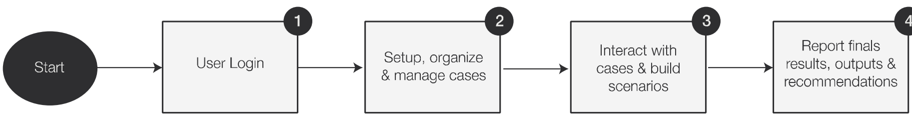

Fig. 6. CoPI overall experience mapped to number of screens

logon to the system. It includes all the cases a user created, or modified, list of shared cases as well as invitations from other users to collaborate on a case. On this screen, the user has the option to create a new case, or modify an existing one.

When a user creates a new case, they have to set it up with the initial configuration. Initial configurations include: the data for the system under study, period of the simulation and the involved users. Infrastructures data (decision variables and KPIs) are stored in the server. The period of simulation is determined to allocate memory space in the server. The user could chose to simulate certain inputs in years, days or hours. Furthermore, users choose the scale of their simulation. They could choose between national scale, regional or city scales.

After users create a new case, or after they select an existing case and modify it, they are directed to the simulation screen. In the simulation screen, users select decision variables, interact with the outputted KPIs, and observe and analyze the visualized results. This screen has four main components: inputs, outputs, temporal and spatial components. The inputs components consist of decision variables and drivers. Users can add as many DVs as required to compose a scenario. DVs are modifiable once they are added to the created scenario container. The outputs component is the list of KPIs that users can select to visualize. These KPIs are visualized after the simulation is run to assist the users in their analysis and decision making. When users specify duration for their created cases, a time slider will appear after the evaluation/simulation is completed. This slider represents the temporal dimension. Users can observe the outputs for every time step that has been simulated.

Finally, the spatial component, which is another visualization element on the screen, shows the map of the selected region of interest. The displayed map is based on the scale that the user has selected when they configured the case. It could show the specified region or the whole country. When there is data associated with geographical locations, this data is visualized on the map as well.

After a desirable scenario (or set of scenarios) is reached, the user has the option to produce a report. On the reporting screen, the user could generate a report form a specific scenario, or all the scenarios within a case. In either case, all the added decision variables, list of KPIs, are displayed. In addition, the user could add snapshots of the different visualization elements on the screen, as well as annotate those images. The users could also write their own recommendations and then export the report into a PDF document for printing. An additional feature is to share that report with other users and decision makers.

6 SIPS: A Case Study

CoPI was implemented for the Sustainable Infrastructure Planning System (SIPS), a decision support system which is currently developed as an integrated modeling framework to assist stakeholders in making informed policy decisions about infrastructure systems planning. At this stage, SIPS is looking at the water Infrastructure in Saudi Arabia.

In this project, CoPI is loaded with water infrastructure data to populate the decision variables and KPIs sections. The variables included are related to demand and supply elements within the system. The KPIs are focused on technical, economic, social and environmental indicators.

The decision variables for example include water plants related data. This group of data describes the physical plants of the infrastructures such as geospatial locations, capacity, status and the types of water it uses. Each plant component has the following variables. Plant latitude and longitude to identify the region of which the plant is located. Plant status, indicates whether it is online or offline. Plant capacity is the amount of water it holds per day, which ranges from 50 m3/day to 880,000 m3/day. Plants types differentiate between solely desalination plants and power/desalination plants. Water sources, define the type of water inputted to the plant. Currently, there are five types of water sources: seawater, brackish/inland water, pure water, river water, and waste water.

The KPIs include economic data such as costs and financial information related to plants. The KPIs could also include environmental data such as the environmental impact on the region or the nation. For example, CO_2 emissions are included to visualize the relation between plants production and capacity and their environmental impact. Users collaborate to generate different scenarios to assess how their current decisions on different inputs impact the future state of the kingdom. In addition, they would indicate policies that should be implemented and decisions/policies that could be modified.

A possible scenario could happen when two or more users such as the ministry of water and electricity (MoWE) and the Saudi Water Company (SWC) want to collaborate to decide whether or not to change water tariff for residential and commercial sectors. An analyst from SWC (user-1) creates a case with a blank scenario after logging on to the SIPS CoPI. The CoPI is loaded with DVs and KPIs. User-1 initiated the case to study the problem on the national scale and for a 30 years span, between 2015 to 2045. The analyst invites two other stakeholders from within his/her organization, and three other stakeholders from the MoWE.

Once everyone is logged onto the system viewing the shared scenario, a shared simulation screen is loaded. User-1 loads his/her decision variables container with the water tariff decision variable for each region, as well as population and GDP. At the same time, a set of KPIs is loaded on charts. The set includes change in demand and normal fractional change per capita. GDP is also included in the output for visualization.

The stakeholders analyze the change in the outputs (Fig. 7), and discuss whether that change is applicable or not. The stakeholders go through multiple scenarios before they achieve a desired result. Finally, User-1 generates a report from the scenarios including everyone's recommendations.

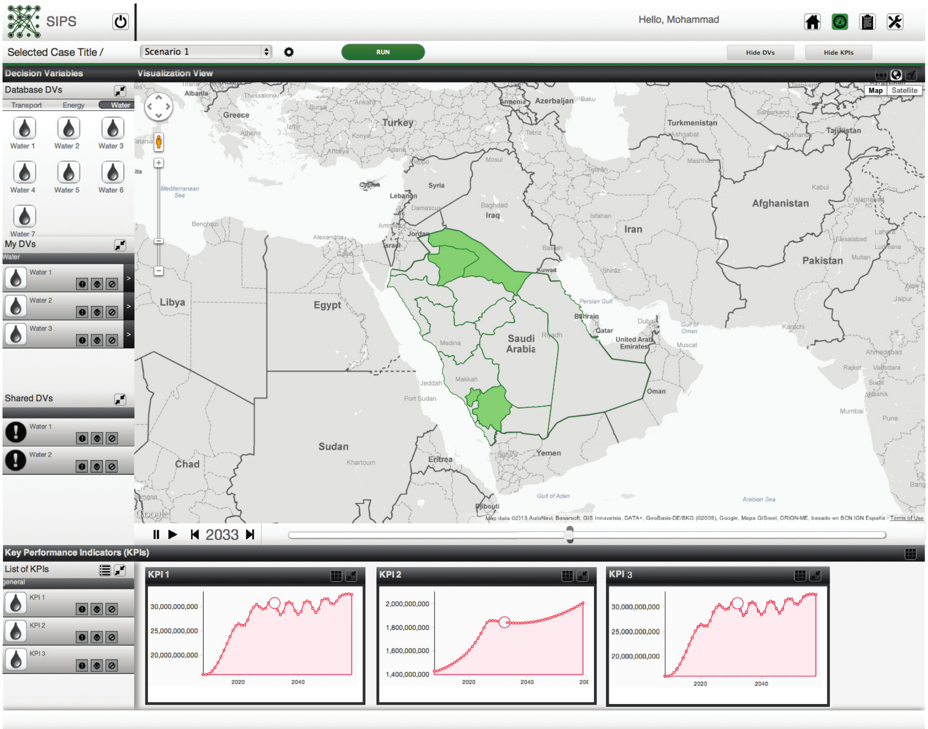

Fig. 7. CoPI prototype in the SIPS project

7 Conclusion

In this paper, we demonstrated the capabilities of the Collaborative Planning Interface (CoPI) platform. With CoPI, a simplified experience for decision management and multi-user collaboration is provided. CoPI assists decision makers in making better informed decisions by dynamically visualizing users' inputs analytically, spatially and temporally. The simple architecture and structure of the platform makes it scalable for the planning of multiple complex systems. As it has been discussed, a current DSS for sustainable infrastructure planning (SIPS) is being developed and utilizes CoPI for multi-user collaboration. We demonstrated how stakeholders utilize the platform for cross planning a sustainable physical infrastructure in Saudi Arabia.

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