Visualizing Situational Simulation Information

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Abstract

The Virtual Coach is a web-centric virtual environment that creates temporally dynamic clinical exercises known as situational simulations, with the intention of exposing participants to rapidly unfolding events and the pressure of decision-making. This paper focuses on visualization of information pertinent to the semantics of situational simulations in the Virtual Coach. It analyzes and classifies the information to be visualized, while addressing the broader issue of visualizing information in situational simulations in general.

An overview of the Virtual Coach

The conceptual framework as explained in Rojas & Mukherjee (2002) serves as the foundation for the development of situational simulations in the Virtual Coach. The components of this framework consist of three major models: the process model, the product model, and the information model. The process model is a representation of the building process, the product model is a representation of the physical facility, and the information model is a representation of the data environment. The conceptual framework also includes a visualization mechanism to provide process and product feedback to the participant.

Definition of a Situational Simulation

Situational simulations are temporally dynamic clinical exercises with the objective of exposing participants to rapidly unfolding events and the pressure of quick decision-making. Awareness attained through such exercises helps the participant to assimilate data from a scenario, analyze the significance of the data and to implement urgent decisions. Situational Simulations hone a participant's skills of adjudging a situation and developing an understanding of scenarios whish are often beyond the scope of classroom curriculum.

Situational simulations are often implemented through virtual reality platforms. Such platforms may be immersive or non-immersive. Virtual reality allows developers to create environments through which, they can represent complex and interesting problems that echo the multifaceted nature of real life problems. While immersive systems can help participants experience the physical feel of various situations by literally immersing them in a virtual simulated environment, non-immersive systems provide participants with a view of the simulated situation by presenting to them various audio-visual data about it.

The Virtual Coach uses a non-immersive virtual environment to develop situational simulations, which allow participants to explore 'what-if' scenarios in the field of construction management. It is based on a model, which is polymorphic and supports a multiplicity of scenarios backed by process, product, and information models.

Visualization of Information

Visualization is the graphical presentation of information with the goal of providing the participant with a qualitative understanding of the information content. Proper information visualization is extremely important for creating effective non-immersive environments that can provide the participant with a fulfilling learning experience. Efficient visualization is made of two important components. The first component is the accurate mapping of information to visual entities. This involves technical challenges of analyzing and understanding the data semantics and developing the best way to represent it. The second component involves an understanding of human interfacing with the visual information.

An accurate mapping of information to visual entities involves the following steps:

- Analysis of information to be represented. The information can be classified as raw data and/or as derived/processed data. The relations between different types of data and how they interact with each other require analysis. It is also very important to verify if the data is successfully encapsulating all the pertinent concepts.

- The next important step is to create a mapping from data sets to graphical entities. This will involve an understanding of how best to represent the data sets. The graphical entities might be simple points and lines or more complex objects like audiovisual files, image files, graphics, CAD objects, text etc. All data sets which represent 3D information is probably best represented via audiovisual files.

The second component will involve an understanding of issues of human computer interaction with the visual experience in perspective. Bertin (1983) developed the Image Theory, which deals with the psychological and perceptual aspects of visualization. He considers the *image* to be the most fundamental perceptual unit of visualization, and assumes that an ideal visualization consists of a single image, to "optimize efficiency and speed with which an observer can extract information." Even though Bertin's theory deals with visualization through a single image, some of the concepts developed in his treatise are relevant to visualization in general.

How the participant perceives the visualized information is very important. The efficiency of the simulation and the effectiveness of the developed experience is completely dependant on how well the participant interacts with the environment. A critical analysis of the graphical user interface will help developers organize visualized information efficiently and reduce noise in the presentation of visualized information. This may involve presentation of information through multiple windows and multiple techniques.

The main focus of this paper however is to investigate the nature of the information to be visualized. A study of the perceptual experience of the participant in the environment created by visualizing the information is a detailed study, which is beyond the scope of this paper.

Analysis of Visualized Information

The information to be visualized within the virtual coach is based on the information stored in a relational database on the remote server. The information is based on a Time-Activity Paradigm (Rojas & Mukherjee, 2002). The Time-Activity Paradigm divides up a project into a number of discrete time intervals of equal length. The total number of time intervals multiplied by the length of a time interval gives the total time of the project.

The number of time intervals depends on the length and nature of the project. As a result of this time segmentation each activity is divided into a number of discrete elements. An activity spanning over 'n' time intervals can be divided into 'n' discrete elements. This introduces the concept of the time-activity element. That is, the ordered pair *(i,t)* will always represent a unique element which belongs to the activity *'i'* and spans over the time interval '*t*'. The process and information models have been developed with the discrete element *(i,t)* as the conceptual basis. The following two sections deal with the logical classification and the type of data.

Logical Classification of Data

Information runs through the various components of the virtual coach and is very much like it's life-giving blood. It can be broadly divided into two parts, the Raw Data and the Derived Data. Raw Data is essentially, the properties of the time-activity element (Figure 1). The properties include material, labor and equipment requirements of the activity *'i'* during the time period '*t*'. The time-activity element *(i,t)* has associated with it, the different types of material, labor and equipment requirements of the activity *'i'* during the time interval *'t.'* Each type of material, labor and equipment used in the construction project are uniquely identified. The process model uses these data as input to calculate the derived data. It takes into account a multiplicity in the identity of materials, labor and equipment thus permitting a single time activity element to have more than one type of materials, labor and equipment requirement. While the raw data specifies requirements only for a unique time-activity element, the derived data is based on data from historical events in the simulation (henceforth referred to as historical data). At any instant of time *'t'* derived data will represent the cumulative measure of a specific parameter, which is indicative of the state of the situational simulation. In the case of the Virtual Coach the derived data will indicate total direct and indirect costs associated with an activity till the present time instant *'t'*, the efficiency with which work has been proceeding on an activity till the present time instant *'t'* and its remaining duration from the present time instant *'t'*.

The Raw Data can, in turn, be classified into the two distinct types of data: Nomological and Constitutive. Nomological data consists of time and space data for a particular time-activity element *(i, t)*. Since all the functional databases will be temporal databases, typically, the time component will consist of the timestamp on the data and the validity interval associated with it, while the space component will contain information regarding the spatial requirements of the activity. The Constitutive data will contain information pertaining to material, labor and equipment requirements of the activity *'i'* during the time interval *'t.'*

Like all real life projects, the situational simulations are not expected to run according to the as-planned layout. As events unfold rapidly during the simulation process and the participant gets involved in the process of re-allocating resources to keep the project running in spite of the events, the project will take a course, which will be different from the plan and will be uniquely dependant on the specific decisions of the participant. The aim of the visualization process is to visualize the 'as-planned' and 'as-built' information simultaneously and give the participant an indication to his present situation and comparative performance. Hence as the project progresses, there will be a requirement of maintaining two copies each of Raw Data and Derived Data. While one copy will represent the 'as-planned' data and will be static for every run of the simulation for that particular project, the other copy will represent the 'as-built' data. The 'as-built' data will be different for every run of the project and will be a function of the sequence of the events and the decisions taken by the participant involved. Hypothetically, if a simulation is run without the occurrence of any events then the 'as-planned' and 'as-built' data will be identical. This reinforces the fact that the Virtual Coach is a continuous simulation and not a discrete event based simulation.

A further analysis tells us that the 'as-planned' data is always static. For a particular time-activity element *(i, t)* the raw data can be queried from the database located on the remote server and the derived data can be calculated using the process model. This is referred to henceforth as the static data. Time sensitive data is generated dynamically during the implementation of a situational simulation and stored in a temporal format on the client's computer. The time component of the Nomological data in this case becomes particularly important, as the participant's decision will get coded in terms of the constitutive data and influence the calculation of derived data in future. The length of time till which data belonging to a particular timestamp can influence future derived data will depend on the validity interval associated with it. Based on certain temporal constraints developed based on the semantics of project control, the time sensitive data will qualify as temporally consistent or inconsistent.

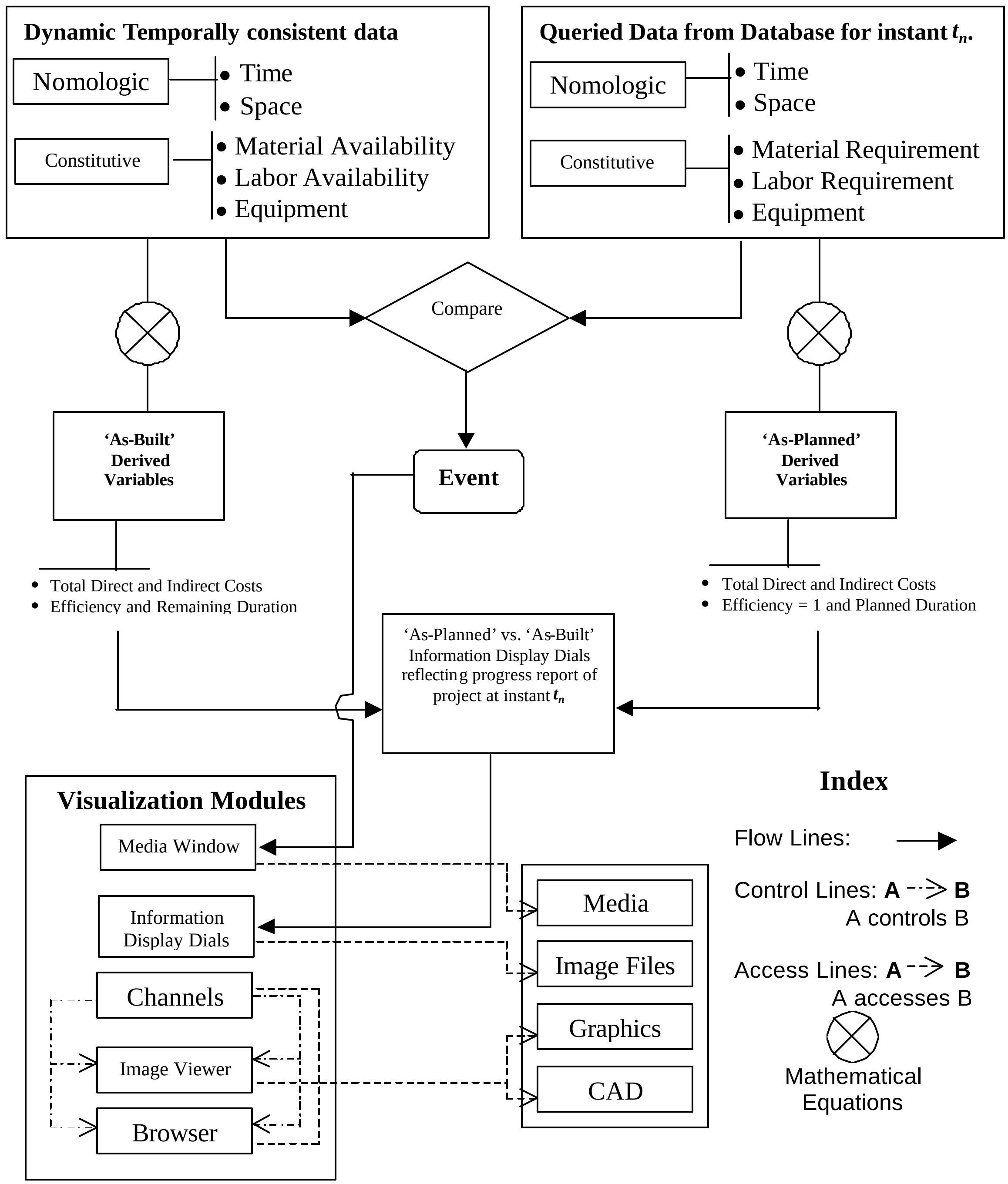

Figure 1. Information Visualization in the Virtual Coach

The time sensitive constitutive data for a particular time instant *'t_n'* will be calculated based on the decisions taken by the participant in the time instant *'t_{n-r}'*, where *'r'* is the interval of time over which the decision is valid. So if the participant comes across a situation where he is forced to cut his labor force by half for the next *'r'* intervals, the time sensitive constitutive data will project a *'0.5'* availability for labor over the next *'r'* intervals. Hence the time sensitive constitutive data is really an availability constraint while the static constitutive data is a requirement. The time sensitive constitutive data from historical time instants when applied to static data for the current time instant produces the ‘as-built’ data which is further stored in the Historical database for future reference and performance evaluation.

Type of Data

The data types involved in all transactions of the Virtual Coach will be numerical. For static constitutive data the requirements for material, labor and equipment will be expressed in terms of the number of units of a particular type of material, labor or equipment that is required, for the smooth running of the project. For time sensitive constitutive data, the availability of the material, labor and equipment will reflect the decision of the participant regarding resource allocation and will be expressed as a ratio to the corresponding requirement. Validity intervals of temporal data will be expressed in terms of number of time intervals while the timestamp will be expressed by the identity of the time interval *(t)* to which the data belongs.

Forms of Information Visualization

The information visualization process can be broadly divided into two main forms:

- The visualization of events
- The visualization of performance parameters, which keep the participant up to data with progress on the project as compared to the planned progress.

Event Visualization

An event is defined by the process model of the Virtual Coach as a time point in the simulation process when the system requires input from the participant in the form of reallocation of available resources to meet certain constraints, which are otherwise not being satisfied. The situation usually arises, when the Nomological (space component) or Constitutive requirements from static data for a particular time-activity element are not matched by the Nomological (space component) or Constitutive availabilities from time sensitive data. This mismatch in availability and requirement may happen as fallout of previous events or the Event Generator may create it. The very first event of the simulation, for instance, will have to be generated by the Event Generator. The Event Generator simply changes certain values of availability data to reflect an event. In doing so, it may override time sensitive data. Successive events may or may not require intervention from the Event Generator.

The event in the process model translates to a situational scenario in the information model and it demands interactivity from the product model in terms of participant input. The event is visualized by sending a message to the participant in a text format relating to him the nature of the constraint, which is not being satisfied. In case the Event Generator has specifically thrown in an event, then media files relating to the event will be accessed through appropriate visual modules to get the message across. For instance, an event relating to bad weather will call up a media file, which will reflect the relevant weather conditions and give the participant a feel of the situation.

Visualization of Performance Parameters

Performance parameters are visualized through comparative graphical presentations. Visually they represent *information display dials*, which will show two graphical trends over time on the same dial for each parameter. One trend will reflect performance of the parameters if the project had been running 'as-planned' and the other trend will reflect the actual performance of the parameter. Essentially, the parameters will reflect the derived data. The 'as-planned' trend will reflect the static derived data, while the 'as-built' trend will reflect the dynamic derived data. There will be one information dial for each of the derived data items. Hence, there will be four Information Display Dials showing comparative performance with respect to direct and indirect expenditures, work efficiency and remaining duration of the simulated project.

Visualization Modules

The different visualization modules, which will consist of the interface design, will include: Media Players, Image Viewers, a browser, Input Window Channels and Information Display Dials.

Each of these modules will be modeled as stand alone Java Servlets, which will query the main database for static data, query the time sensitive data and based on the mathematical equations and logistics developed in the process model calculate the derived data. There will be a single Servlet corresponding to each of the visualization modules.

Information will map onto the visual modules in a way such that the state of a visual module can be expressed as a function of the variables to be mapped. This would help in developing data flow graphs, which can be used for efficiently visualizing the information by appropriately reflecting the dependencies between the information to be visualized and the module, which visualizes it.

Conclusions

Future work involving visualization of information in the Virtual Coach will follow a two-pronged approach. In one direction, studies will need to be done to assess the perceptual effectiveness of the visualized information. In the other direction, the implementation issues and algorithms involved in visualizing information mapped onto specific modules will be investigated.

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