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Knowledge-based scenario management — Process and support

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ABSTRACT

Scenario planning is a widely accepted management process for decision support activities. Though conventional decision support systems provide a strong database, modeling and visualization capabilities for the decision maker, they do not explicitly support scenario management. We propose an integrated life cycle approach for knowledge-based scenario-driven decision support incorporating three interrelated frameworks at different abstraction levels to support this process. The macro-level knowledge-based framework guides the Meso-level Scenario-driven framework, and these two in turn guide and inform the micro-level process-oriented framework. We develop a domain independent, component-based, and layered architecture to support the scenario management process and framework. The framework and architecture are realized through a concrete prototype.

1. Introduction

Scenarios are defined as a management tool for identifying a plausible future [10,15,24,25,31,33] and a process for forward-looking analysis. Scenarios offer a dynamic view of possible futures [22,37]. Scenarios have also been defined in many other ways: a story with a focused description of a fundamentally different future [30]; that is plausibly based on analysis of the interaction of a number of environmental variables [21]; that improves cognition by organizing many different pieces of information [7,8,34,36]; and that is analogous to a 'what-if' story [33]. A scenario can be a series of events that could lead the current situation to a possible or desirable future state. Scenarios are not forecasts [31], predictions [37], future plans [12], trend analyses or analyses of the past. They are for strategy identification rather than strategy development [30], to anticipate and understand risk [13], and to discover new options for action. Ritson [28] agrees with Schoemaker [29] and explains that scenario planning scenarios are conceived against known facts and trends but deliberately structured to enable a wide range of options and to track the key triggers that precede a given situation or event within the scenario. Scenario management facilitates the proactive decision-making process (e.g., [9]).

Decision makers have been using the concept of scenarios for a long time but, due to their complexity, their use is still limited to strategic decision-making tasks [20]. Scenario planning varies widely from one decision maker to another mainly because of a lack of a generally accepted principle for scenario management. Albert [2] proposes three approaches for scenario planning, namely the Expert scenario approach, the Morphological approach and the Cross-Impact approach. Ringland [27] describes a three-step scenario planning: brainstorming, building scenarios, and decisions and action planning. Schoemaker [29] outlines a ten-step scenario analysis process. Huss and Honton [19] identify three categories of scenario planning: Intuitive Logics, Trend-Impact analysis, and Cross-Impact analysis. Extant literature lacks a suitable approach for planning, developing, analyzing, organizing and evaluating scenarios using model-driven decision support systems. Currently available scenario management processes are cumbersome and not properly supported by available tools and technologies. They support neither the top-down approach — the breaking down of a scenario into executable and assessable component scenarios at various levels of abstraction; nor the bottom-up approach — the combining of small scenarios into the development of a high level scenario that represents a complex set of problems. To fill this void we propose a knowledge-based life cycle approach to scenario management that supports both top-down and bottom-up processes.

The generation of multiple scenarios and sensitivity analyses exacerbates the decision maker's problem. Existing scenario planning tools are not suitable for assessing scenario quality and do not fully support evaluating scenarios through a comparison process. We introduce an evaluation process for comparison of instances of homogeneous and heterogeneous scenarios that enables the user to identify the most suitable and plausible scenario for the organization.

Considering the significance of scenarios in the decision-making process, we model scenario as a decision support component of a knowledge-based DSS and define the scenario-driven DSS as an interactive computer-based system, which learns and integrates diverse

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data, models, solvers, and visualizations to explore decision scenarios that support decision makers in a dynamic environment.

Traditional DSS has been for the most part data-driven, model-driven and/or knowledge-driven [26] but due importance has not been given to scenario planning and analysis. Some of the DSS have partial support for sensitivity analysis and goal-seek analysis but this does not fulfill the needs of the decision maker. Existing scenario analysis tools deal with scenarios one at a time and are not suitable for simultaneous development of multiple scenarios. While a scenario impacts related scenarios, existing tools are not suitable for developing a scenario based on another scenario. Generation of a scenario and its analysis are inadequate for the decision support environment.

To address these issues we follow an iterative process of observation/evaluation, theory building, and systems development, wherein we propose and implement a knowledge-based, scenario-driven, and process-oriented framework and architecture for a Decision Support Systems Generator (DSSG). We develop a prototype, which we then test and evaluate using the evaluation criteria for Design Science [18], quality and appropriateness of scenarios [29], and principles of DSSG framework and architecture [6,16].

In the remainder of this paper, we first introduce a life cycle approach for scenario management including a detailed discussion of handling homogeneous and heterogeneous scenarios. We then present knowledge-based, scenario-driven, and process-oriented decision support frameworks, followed by a discussion on how they realize the scenario management process. We then present an n-tiered architecture that details the frameworks. Finally, we discuss the implementation platform and domain within which the proposed process, frameworks, and architecture were implemented and validated.

2. Scenarios and their management

2.1. Definition of a scenario

The definitions given in the previous section do not provide a complete picture of scenario modeling as they do not entail the exact scenario structure. We now discuss a proper implementation-level definition that addresses the structure of the problem situation and its dynamic behavior.

A scenario is a situation containing one or more problem instances. A change in one scenario might have chain effects on related scenarios. But the basic structure and behavior of the scenario is similar to the decision support system components model and solver respectively as a model describes real-life phenomena and solves real-life problems [14]. Hence we define a basic scenario as a complex situation analogous to a model that is instantiated by data and tied to solver(s). In its simplest form, a scenario is a complex combination of data, model and solver; it can be presented using different visualizations. A scenario structure is a template object that establishes a complex relationship for integrating various related models, solvers, visualizations, contained scenarios and related data. A scenario could be developed by factoring a high level business problem into smaller problems using a top-down approach, or it could be generated by integrating various small systems into a real-life business case using a bottom-up approach. The lower-level systems on both top-down and bottom-up approaches comprise configurable DSS scenarios that include model, solver, and data.

2.2. An example (mortgage management) scenario

A mortgage management scenario includes a series of external environment-sensitive interrelated scenarios. AMP ([3]) describes a mortgage scenario wherein the median wage and home prices increase, and the interest rate drop. What is the impact of this change, or any other changes, on an individual buyer as well as on the mortgage market? Any change in interest rate, average income, demand and supply, etc., highly influences mortgage markets.

This scenario can be broken down into several scenarios such as affordability, loan, and payment scenarios. The affordability scenario assists in understanding the borrower's eligibility to acquire a loan and their capacity to repay the loan. The loan scenario analyses the cost of financing, the loan amount, and the installment; depending on the loan type, this analysis process can differ widely. The payment scenario considers installment, interest payment, principal repayment, and loan balance, addressing the entire loan repayment life cycle. The affordability scenario is a constraint to the loan analysis scenario. Each of these scenarios can be further factored down to several smaller ones. For example, the affordability scenario depends on the income and expense scenarios while the income scenario may be sub-divided into personal income and family income scenarios. All are interrelated and the higher level scenarios are dependent on lower-level scenarios. On the other hand, lower-level scenarios can be integrated to develop the complete mortgage scenario. Sensitivity analysis and goal-seek analysis of these scenarios would greatly enhance the decision-making process.

2.3. Structuring scenarios

To address the complexity and interrelatedness of scenarios, we divide larger scenarios into multiple smaller ones with independent meaning and existence. In this context, we identify three types of scenarios, namely:

Simple scenario — This is not dependent on other scenarios but completely meaningful and usable.
Aggregate scenario — This comprises several scenarios. A top-level scenario can be broken down to low level scenarios or several low level scenarios can be combined to develop a higher level scenario.
Pipelining scenario — This scenario is an input to another, in a hierarchical scenario structure. Here, a lower-level scenario can be tightly or loosely integrated with the higher level scenario.

The decision maker may combine simple as well as complex scenarios using pipelining and aggregation to develop more complex scenarios.

2.4. Scenario management: A life cycle approach

We introduce a scenario management process that synthesizes and extends ideas from Ringland [27], Schoemaker [29], Albert [2], Huss and Honton [19] and Wright [38]. The scenario management process uses a life cycle approach that is able to address a variety of problem instances. The proposed life cycle approach for scenario management process is illustrated in Fig. 1.

The process begins with scenario conceptualization and ends with the usage of scenario for decision support. The intermediate stages are scenario planning and organization, development, simulation, analysis and evaluation. We now discuss these phases of the scenario management life cycle.

2.4.1. Scenario conception

At the outset, the decision maker anticipates the problems and analyses them to determine the influential driving forces, critical success factors, key performance indicators (KPIs), and parameters of the scenarios. The internal and/or external governing factors exert pressure on the system for various changes. The decision maker as a domain expert may predict possible changes to the KPIs to conceptualize scenarios and their planning, development and analysis processes.

In the next phase, we describe the tasks of scenario planning and development.