Formal Alternatives Management: Problem Solving through Corporate Memory

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Abstract
Our work concerns the development of a corporate memory with pro-active support for problem solving. It is based on a concept of knowledge recycling, which is the systematic application and evolution of an organization's best practice. In this approach, one solves a problem by looking for existing artifacts that represent all or part of a potential solution, perhaps with some adaptation. Having solved the problem, one records it in the corporate memory so that it will be available for similar tasks in the future.

Alternatives Management
Typically, there is no one perfect way to solve a business problem. Instead, there are alternative solutions, each with its strengths and weaknesses. We have been developing technology that allows a problem solver to define and evaluate alternative solutions. Our work is therefore closely related to decision support systems. Our contribution is to situate decision support in the context of a corporate memory, and to connect the two ideas through rationale capture.

Tradeoffs and rationale capture play an essential but frequently unrecognized role in a corporate memory system. The motivation for "remembering" things in the system is, after all, to make use of them in the future. The purpose may be to reconsider past decisions or to apply previous successes to new situations. In either case, it is important to understand why things were done as they were, and to evaluate potential alternatives. This relationship between corporate memory and rationale is the core idea of the Formal Alternatives Manager (FAM), a tool that we have developed precisely to "bring knowledge to business processes."

The presentation of rationale is as important as its capture. We have experimented with the use of narratives, or problem-solving stories, as a means of communicating the context as well as the content of past successes (and failures). The purpose of such narratives is to immerse the potential re-user of an existing solution in the information-rich context for which the solution was first developed. In complex, multi-dimensional problem settings, the problem solver must have such a level of understanding in order to evaluate the suitability of existing solution building blocks.

General Description of FAM
FAM models evolving knowledge as a collection of interrelated hierarchies: goals, alternatives, features, and components. Goals represent the objectives of the task currently being performed. Each goal has a numerical importance assigned to it in relation to other goals. This information allows FAM to provide decision support to the user in choosing among alternatives. The alternatives hierarchy is a taxonomy of solution approaches. Moving down the hierarchy leads to more specialized knowledge. Features are the dimensions along which alternatives differ from each other. Because any complete solution will likely be a combination of many aspects, the feature hierarchy provides a way to compare and contrast aspects of the alternatives. Features also allow one to perform "what if" analyses by changing some aspects of a solution while keeping others constant.

Each alternative may be composed of several components. Each component comes from its own domain, and it may be just one of several alternatives in that domain. The component's distinguishing features have an impact on the features of the containing solution. FAM maintains these interconnections, propagating changes so that the hierarchies remain mutually consistent, providing the user with a simple means of viewing the knowledge interconnections relevant to a given task. In this way, FAM provides value beyond a simple Web-browser interface to hierarchically organized information.

While FAM provides a front-end for organizing a team's knowledge, the knowledge itself — specific goals, solutions, or feature documentation — is maintained on the
Detailed Description of FAM

FAM models the space of alternatives through four interconnected models:
- Goals
- Alternatives
- Features
- Components

Each of these is structured as a tree, the first three of which are is-a hierarchies. The component tree is an aggregation hierarchy. The Alternatives, Features, and Components models are not orthogonal: they constrain each other in a number of subtle ways. Before describing these inter-relations, we explain what each model represents in its own right.

Alternatives

This is a taxonomic model of possible solutions, or solution techniques, for a given type of problem. The solutions need not be complete. Those that occur at non-leaf positions in the hierarchy are partially specified, representing an incomplete set of commitments, to which further commitments must be added in order to put the solution into practice. Leaves in the hierarchy may also be partial solutions, or they may be relatively complete, meaning that they address all of the questions currently considered significant.

The Alternatives model is intended to provide the problem solver with a guided path towards a solution that best meets the goals of the current task. The root node of the hierarchy represents the task itself. Each step down a path in the hierarchy represents a decision to adopt one approach over others. This "decision" may in fact consist of several fine-grained decisions, binding (or constraining) several degrees of freedom at once.

For each step down a path in the Alternatives hierarchy, there is a rationale: a reason for adopting this approach over its alternatives. There may be several such reasons, such as:
- Recognized advantages (or disadvantages) to a given approach
- Distinct stakeholders applying different criteria but arriving at the same choice

The meaning of the rationale may depend on the context in which the model was created. For example:
- Here is why we adopted this approach over its alternatives
- Here is why we considered this approach
- Here is why we rejected this approach

Features

Each node in the Alternatives hierarchy represents a distinct, possibly incomplete, solution to a certain type of problem. The solutions are distinguished from each other through features.

The Features model is a forest representing the different dimensions of variability (degrees of freedom) of a solution. Each "dimension" is an aspect of the design about which decisions can (or must) be made. Although the dimensions are distinct from each other, they may not be completely independent. Commitments and restrictions, such as "Selecting feature X commits you to selecting feature Y," or "Selecting feature U prevents you from selecting feature V," are a frequent and important consideration in the solution development process.

Each step down a path in the Features model represents a constraint on the solution dimension being considered. The implied constraint is one of two things:
- A limitation of the scope of the dimension, as in the following features of Automobiles:
  - Color
  - Body color
  - Interior color
- A limitation of the admissible decisions concerning this dimension of the problem; for example:
  - Color
  - Pastel color
  - Neon color

The two types of constraint correspond to "and" and "or" branching, respectively. In the first case, the meaning of the dimension is made more precise; in the second case, the meaning stays the same, but the available values to which the solution may be bound are reduced. The former type represents a definition, while the latter type represents a decision.

Relationship between Alternatives and Features

Features are assigned to alternatives. The assignment is understood to mean that the alternative "has" that feature. This is the primary means of distinguishing between one alternative and another.

Since a solution corresponds to a set of features, the semantics of the Alternatives taxonomy and the Features taxonomy are distinct but related. Specialization of an alternative consists of specializing one or more of its features, or adding new features. This is a constraint on the mutual consistency of the Alternatives model and the Features model, and it is enforced automatically by FAM.

Features and Tradeoffs

Since "or"-type features represent commitments, they may contribute to or detract from the realization of goals. Commitments typically involve trading some goals against
Engines. FAM flags the fact that sports cars contain V8 because "V8 Engine" occurs in the Alternatives model for design of engines. The decomposition for Sports Car only V8 engines, which are a specialization of the general component designs. For example, Sports Cars may contain override some of these components with more specific components of the general car design. They may, however, a Car.

These constitute the component model for the general design of Automobiles. Each of these components defines a role that the component plays within the overall design of a car. Specific types of cars will, by default, inherit the components of the general car design. They may, however, override some of these components with more specific component designs. For example, Sports Cars may contain only V8 engines, which are a specialization of the general design of engines. The decomposition for Sports Car would then contain "V8 Engine" in the role played by "Engine" in the general car design. This is admissible because "V8 Engine" occurs in the Alternatives model for Engines. FAM flags the fact that sports cars contain V8 engines as a feature of sports cars, which serves to distinguish sports cars from cars in general. Similarly, station-wagons may require 8-cylinder engines to support their size and expected load. They need not be V8 engines, however. In the decomposition model for station wagons, therefore, the role of Engine will be played by the design called "8-cylinder Engine" and this fact will appear as a feature of Station Wagons.

The Features Model for Automobile now contains features that distinguish between Sports Cars and Station Wagons. The distinction between the two types of Automobiles is represented in the Features model for Cars. This is true even if the distinction concerns a still lower-level component, such as type of valves used within the engines. In this way, FAM helps the problem solver coordinate tradeoffs and decisions at different levels of the solution design.

**Components**

The fourth type of model that FAM uses to represent the space of solution alternatives is an aggregation hierarchy. Solutions, whether they are plans, systems, or other types of artifacts, are composed of subparts, which are composed of smaller components, and so on to arbitrary depth. Each component of a larger solution has features in its own right, about which tradeoffs must be considered and decisions must be made. For this reason, FAM situates a component within the space of alternatives appropriate to the component's domain. An Alternative decomposes into components, each of which is, itself, an Alternative in an appropriate domain, and so on, recursively down the decomposition hierarchy.

Decomposing a solution into components is a type of decision. Alternative decompositions are one way to distinguish one solution from another. FAM automatically enforces certain relationships between the Alternatives, Features, and Components models. For example, consider a set of alternative designs for Automobiles, which classifies cars into Sports Cars, Family Cars, and Utility Vehicles. Family cars are further classified into Sedans and Station Wagons. Certain components are found in all cars, e.g., Engine, Transmission, Fuel System, Cooling System, etc. These constitute the component model for the general design of Automobiles. Each of these components defines a role that the component plays within the overall design of a car.

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Related Work

FAM is situated at the intersection of Decision Support, Case-Based Reasoning (CBR), and Rationale Capture tools. The tradeoff algorithms currently implemented in FAM are rather simplistic, and we intend to replace them with sharper algorithms found in the decision support literature, such as the Analytic Hierarchy Process. The knowledge recycling process on which FAM is based is essentially a CBR paradigm. The emphasis in CBR tends to be on automated techniques for matching solutions to problem statements, while FAM currently applies only a simple text-search function and relies on user intelligence to identify relevant cases. The path to employing more automated CBR algorithms is, however, clear. Finally, rationale capture has been explored in contexts such as cooperative work, concurrent engineering, and related fields. Methodologies such as IBIS make the connection between rationale capture and corporate memory, but not with corporate memory structured as a case base. When these three disciplines are combined, certain knowledge management issues arise, which the FAM structures (described above) attempt to address.

**References**

