Acquiring, Maintaining, and Customizing Organizational Work Process Descriptions

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Abstract

Models of work processes and of organizations' activities are an important part of workflow systems and simulation, and capture procedural knowledge stored within the organization. However, acquiring, maintaining, and customizing these models can be difficult. To assist the acquisition and maintenance of organizational models, we have developed a set of knowledge-acquisition tools suitable for use in the domain of medical organizations. In modeling medical organization processes, three areas of expertise must be brought together. Expertise in medical care, organizational structure, and modeling is necessary to describe accurately the process of medical care delivery for simulation or workflow management. We propose a method of modeling work processes that uses the Protégé suite of tools to generate organization-specific work process descriptions. We have created a set of Protégé knowledge-acquisition tools customized for medical, organization, and modeling experts, and have used a prototype system to create detailed, site-specific process descriptions. In our prototype system, we have identified a set of transformation operators that should make possible additional computer-based support. We believe this methodology will improve acquisition of an organizational model, and make it easier to maintain an accurate model in the face of changes in medical process or organizational structure.

Work Process Descriptions

There has been a recent interest in creating organization models that are predictive of organizational performance, or capable of providing insight into theories of organizations (Levitt et al, 1994). Organization models can capture the tacit knowledge contained in organizational processes, and allow organizations to evaluate and improve these procedures. However, for these computer-based simulations to be successful, builders of organization models must invest significant effort into creating detailed models of organizational structure and work processes. Building accurate organization models requires the model builders to have a detailed understanding of the organization, the work that it does, and the interactions between the work process and the organization structure. In complex domains such as medicine, organization model construction can be a particularly difficult task, and may require bringing together many different areas of expertise (Burns et al, 1995). It is only by bringing together these areas of expertise, that model builders can craft a representative description of a particular work process and organization. If the model builders are successful, their model will reflect the structure and processes as they existed when the model is constructed.

In medicine, protocols for patient care can be considered work process descriptions in that they describe the steps necessary to care for a patient with a particular illness (Field & Lohr, 1990). There has been significant effort at both national and institutional levels to create standard care plans, critical pathways, and protocols to reduce practice variability and to improve the quality of patient care. When properly followed, protocols do have the desired effect of improving patient care while reducing patient care costs (Loback & Hammond, 1994).

Unfortunately, medical protocols are not static. For medical protocols to be accepted, most undergo changes to make them specific to a clinical setting. These changes may be as simple as specifying the preferred formulary drugs available at an institution, indicating which referral forms are required to order a particular laboratory test, or designating who can schedule a procedure. More radical customizations include changing the order of guideline activities to streamline scheduling of patients in the clinic. Many institutions recognize the importance of creating medical process descriptions that are specific to their organization, and have a medical director or committees of health care providers to create these specialized protocols. These administrators transform the generic protocols into a site-specific protocols more acceptable to the practitioners in the institution and more capable of effecting change in medical practice (Gensensway, 1995).

Not only do these medical protocols change, organizations undergo a constant flux of employees and restructuring of responsibilities. Each time a change occurs, the model becomes out of date, and can no longer accurately predict the organization's performance. Updating the organization model forces the model builders to constantly accommodate for changes in the organizational and process models. To update the work process, many experts must be brought together—experts who created the original work process, experts who understand the organizational changes, and experts who understand the modeling requirements. This task can be difficult, if not impossible, and needs to be repeated each time a significant change occurs. The need to accommodate changes in the model limits the reusability of model descriptions—the incremental work to modify an existing model may be more than the cost of modeling the new organization from scratch.

There has been recent work in generating reusable work-process descriptions that can be shared among different organizations (Malone et al, 1993). These reusable work-process descriptions are intended to be used as the building blocks for modeling existing organizations or for creating new organizations. Whereas these efforts are beginning to standardize representations of processes (Lee et al, 1994), they still require significant expertise in modeling, and a clear understanding of the domain of interest. These libraries of work-process descriptions do not solve the problem of providing the needed expertise. The model builder is still faced with the daunting task of maintaining both the organizational and process information at a sufficient level of detail for simulation and workflow management.

Our work has focused on improving the methods of acquiring, maintaining and customizing these work process descriptions. In this paper, we describe an alternative way of creating detailed, customized organization descriptions. Our method divides the work of knowledge acquisition among the domain experts, applies transformation operators to the work process description, and brings them back together using the Protégé suite of tools to generate a cohesive model of both the organization and the work process.

Protégé

The Protégé suite of tools provides a methodology for the construction of knowledge-based systems and knowledge-acquisition (KA) tools (Eriksson et al, 1995). These KA tools are generated by the Protégé environment, based on a model of the domain created by a knowledge engineer. Because these tools are domain-specific, they are easy to use by domain experts who may be unfamiliar with knowledge base representation issues.

In the area of organizational work processes, the knowledge base contains information about the workflow of an organization, or information about a single process, such as a specific medical care guideline, within an organization. For Protégé to construct an appropriate KA-tool, an expert in the area of simulation and workflow management must build an appropriate domain model that captures the distinctions and terminology needs of the simulation system or workflow manager. Protégé uses this domain model to generate a KA-tool that could be used by domain experts to build a knowledge base about a particular organization or organizational work process.

The Protégé approach is well-suited for domains where the knowledge content is dynamic. Thus, if the description of the workflow changes, the domain expert can easily modify the knowledge base to reflect this change. Likewise, if the organization changes, or even if the underlying model of the organization changes, Protégé can rapidly create new KA-tools or knowledge bases that reflect these changes. However, because the generated tools are based on a common ontology of terms, they can remain coordinated in the face of these changes.

Medical Process Descriptions

Early work with the Protégé environment has been in the construction of knowledge-acquisition tools for populating knowledge bases in medicine. Recently, Tu et al (Tu, 1995, 1996), have used Protégé to assist in the acquisition of protocols for patient care. These protocols describe the steps necessary to care for patients with a particular problem and are examples of a process description specific to medicine. In medicine, protocols, clinical pathways, and clinical guidelines are examples of medical work processes that have been created with the goal to improve the efficiency and quality of medical care (Lobach & Hammond, 1994).

Although protocols can improve the efficiency and quality of patient care when they are used, they suffer from many of the same problems that detailed process descriptions have. First, good medical protocols are expensive to create. Most are created by medical experts and based on extensive review of the medical literature, case-controlled clinical trials, and consensus statements of national organizations. The expense and complexity of literature reviews, clinical trials, and consensus meetings motivates guideline authors to share protocols among different institutions so that others can take advantage of their work. It is difficult however, for creators of national protocols to anticipate all the possible contingencies that a specific organization might require. Often

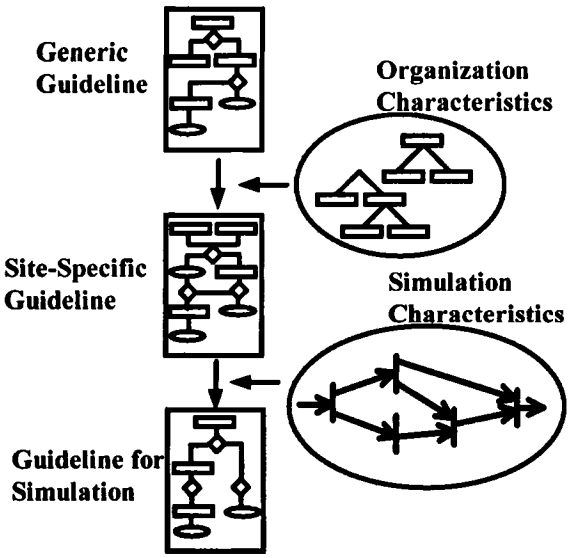


Figure 1. The process of creating protocol models. Process models require modifications for both organizational and simulation characteristics

this situation leads to protocols that are broad in their recommendations, so institutions have the flexibility to change and adapt a national protocol for use within a particular institution.

Although underspecified protocols make it easier for these protocols to be shared, these high-level process descriptions are inadequate for simulations or workflow systems. A generic medical protocol might suggest a goal condition to be achieved, but not specify how that goal should be achieved within an organization. The protocol might suggest an alternative that does not exist within that organization, or one for which there are cheaper, organization-specific alternatives.

A clinic director, familiar with the resources and skills of the organization, is responsible for taking a national protocol for patient care and adapting it for the particular resources of that organization. Thus, the experts who create the process description are often not the same ones who are charged with customizing the protocol for an organization, or modeling it for the purposes of simulation or workflow. At most institutions, it is a long and difficult process of committee meetings to customize a national protocol for use within a particular setting. As with other process descriptions, when new medical knowledge becomes available or when there is a change in the way in which medical care is delivered, the protocols are no longer accurate.

Even organization-specific protocols may not be adequate for simulations or workflow systems. Adding detail of routing or verifying processes and timing events may be required for a simulation. Organization experts and medical experts may not have expertise in the requirements of a particular simulation system. People skilled in simulation techniques must be certain that the information they require from the organization and medical experts for the purposes of simulation is included in the final model.

Thus, to create models of organizations suitable for simulation or workflow applications, three areas of expertise must be brought together: This process of creating medical protocols for simulations is shown in Figure 1. Medical experts who create the process descriptions, organization experts who map these process descriptions to the organization activities that accomplish the goals of the protocols, and model builders who understand the requirements of the simulations or workflow systems must be coordinated to create an accurate organization model. Before accurate models of medical organizations can be constructed, tools that assist in bringing together expertise in these three areas must be developed.

Making Generic Protocols Site Specific

To assist the coordination of these experts in creating accurate organizational models, we have used the Protégé system to create a series of customized knowledge-acquisition tools, suitable for use by each of these experts. We have entered a protocol used at the Stanford University Bone Marrow Transplantation Clinic into these knowledge-acquisition tools and are extending this framework to provide additional computer support for protocol specialization.

The Stanford Bone Marrow Transplantation (BMT) Clinic has recently adapted a series of inpatient medical protocols for patient care for use in an outpatient setting. These protocols were initially drawn from formal clinical trials, and were meant to be used in an inpatient setting. However, two changes have occurred within the clinic.

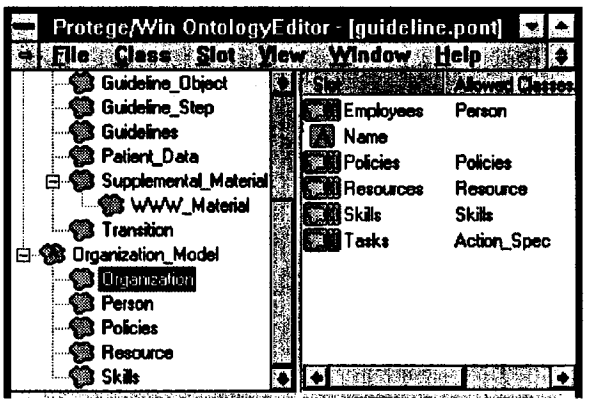


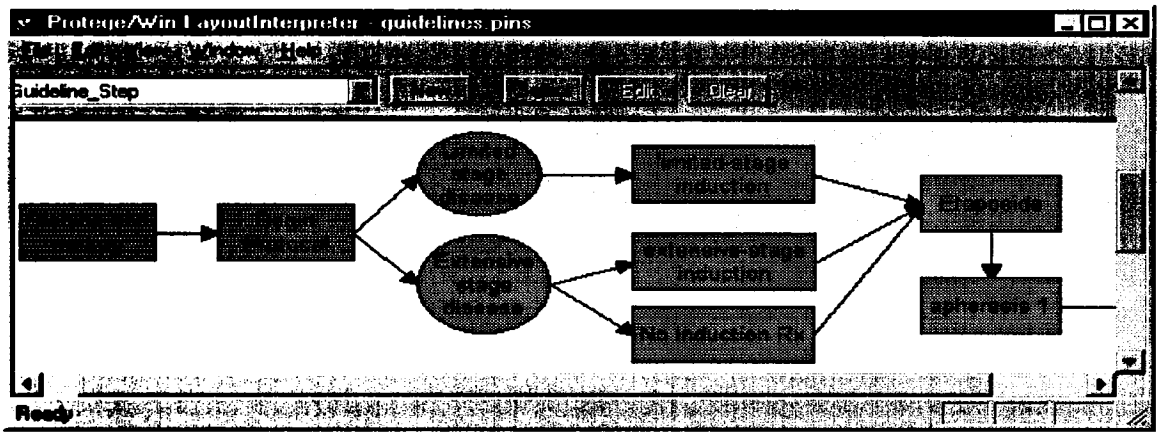
Figure 2. The Protégé ontology editor with the BMT organization ontology. The left panel shows the terms used in the model, and the right shows the details of the term *Organization*.

First, advances in medical care have made new therapies possible, simplifying the process of giving chemotherapy and bone marrow cells. Second, pressures to control the cost of expensive procedures have encouraged organizations to move inpatient therapies to an outpatient setting. Because of these changes in both the process of giving care and in the organizational structure, the Stanford BMT clinic has modified a collection of protocols for use in the outpatient setting. We have used their lung cancer protocol as an example of the changes that occur when work process descriptions must be changed because of changes in the structure of the organization.

We used three knowledge-acquisition tools in our prototype system—the first was provided by the Protégé environment, and the other two generated by Protégé. The first tool, the ontology editor allows model builders to define the information required by the simulation or workflow system. Figure 2 is a snapshot of the ontology editor with part of the BMT organization ontology. The ontology provides the terms needed for a simulation or workflow description, and the relationships among these terms. For our organization model, we used a common ontology extended to include each of the different knowledge-acquisition tools that we created. This provides an underlying common representation which facilitates bringing together several areas of expertise in a cohesive manner.

Another tool, shown in Figure 3*a*, provides the mechanism to enter a generic protocol. This sharable protocol requires additional information including intentions, goals, and requirements, not typically present in generic protocols. This richer representation allows the

Screen *a*:



Screen *b*:

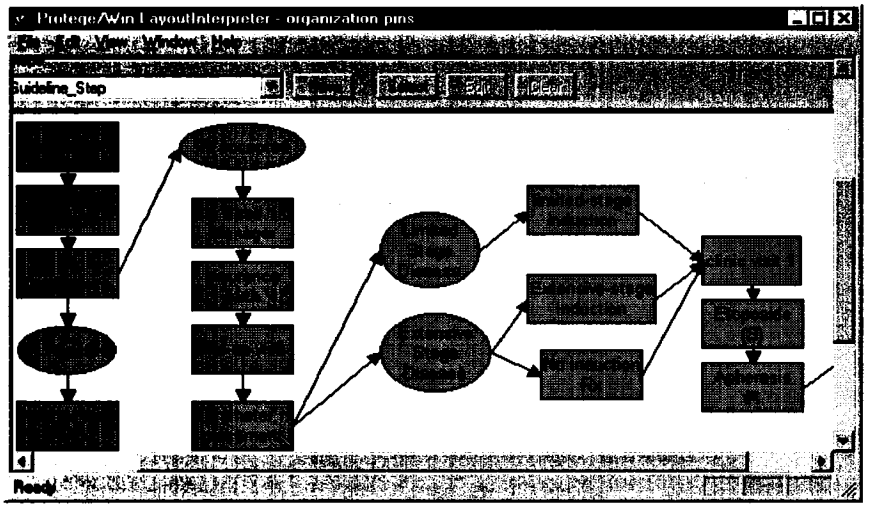


Figure 3. Screen *a* shows the generic KA tool displaying the BMT protocol prior to modification. Screen *b* shows the CAMINO tool, displaying the BMT protocol, now modified for the Stanford BMT outpatient clinic. The activity *Staging and Workup* in Screen *a* has been expanded into the first 2 columns in Screen *b*.

experts who create these generic protocol to provide additional guidance to organization experts in mapping the generic tasks to the organization.

Finally, we created a tool, CAMINO, which provides assistance to the organizational expert in (1) creating and maintaining a description of the resources, tasks, and skills within their organization, and (2) providing an editing environment to assist organizational experts in mapping these generic process descriptions to the organizational tasks that will accomplish these goals or intentions. In Figure 3, we show a portion of a generic guideline and a site-specific guideline. The generic activity "Staging and Workup" in Figure 3*a* is expanded into a series of site-specific tasks in the site-specific guideline in Figure 3*b*. Additional activities that satisfy insurance verification requirements of the organization have been added after the "Begin Protocol" step, and are shown in the left-hand side of Figure 3*b*. At present, possible mappings into the organization are chosen from a pick list of organizational activities, but we have defined a set of transformation operators, described below, that should provide additional computer-based support for intelligent mapping of generic process descriptions to organization-specific activities. This will be particularly important in maintaining accurate process descriptions in the face of organizational or process changes.

Protocol Adaptation as Plan Revision

The transformation operators used by CAMINO can be described more explicitly if we view work process descriptions as plans that require revisions to satisfy additional constraints of the organization. More formal descriptions of plans and revision strategies has the advantage of providing a shared language to describe the process of customization, and making automatic support for maintaining and customizing work process descriptions possible. Based on our experience with the BMT clinic and other medical protocols, we have defined a preliminary set of operators that can be used to modify work process descriptions.

Addition New activities are added to a protocol when the additional activities satisfy an organizational requirement (checking insurance status), or an implicit requirement of the protocol (additional testing to determine protocol eligibility) that has not been made explicit.

Deletion Activities that are not needed to satisfy organizational or protocol constraints could be removed from the protocol without damage to the revised plan. If the organization was not capable of performing a particular activity (and therefore deleted it from the work process), another activity would need to be substituted that could satisfy the post-conditions or intentions of the deleted activity.

Aggregation The protocol may indicate two different activities that the organization always treats as a unit and does not further describe sub-activities. For example, a guideline may indicate to check a patient's blood pressure and then his pulse. The clinic protocol may only be concerned that vital signs are taken, which include a blood pressure and pulse. Here, the generic protocol has more detail than is necessary for doing the tasks within the organization.

Expansion A site-specific protocol may require more detail than that specified in the generic protocol. For example, the protocol may indicate that chemotherapy should be given; the site-specific protocol, however, may specify pre-hydration requirements, monitoring tasks, and follow-up visits as part of the process of giving the chemotherapy. In this situation, the description of tasks in the organization is more detailed than the task descriptions in the protocol.

Substitution Substitution is a combination of addition and deletion. The original activity is deleted, and one or more activities are added to the guideline For computer-based support of this operator, a similarity metric must be defined, and used to determine which tasks are suitable alternatives to the protocol task that is to be substituted. For example, if the similarity metric was based on activity intention, then substituted activities would have the same underlying intention. Other metrics might involve not only intentions, but post-conditions, skill requirements, and other activity characteristics.

Temporal reordering It should be possible to reorder activities that do not have explicit temporal constraints to be consistent with the organization's procedures. For example, if the protocol indicates that one test should be done and a second done based on the results of the first, it may be more efficient for the organization (and convenient for the patient) to do these tests at the same time and then to evaluate them both simultaneously. We did not see evidence of temporal reordering in the BMT protocols, but there were much tighter temporal constraints on the outpatient protocol than the inpatient protocol, given the additional constraints of the outpatient clinic and staffing limited to business hours.

Separating the organization model from the generic work process description and using explicit transformations to link the generic work process descriptions to organization tasks has significant benefits. If there are changes within the organization, only the organization model requires updating—the generic work process description would not change, and a new site-specific protocol could be generated using this new organization

model. Conversely, if the generic protocol were to change, a new site-specific protocol could be generated using the new intentions and sites within the organization that support those intentions. In this framework, the authors of the generic protocols maintain separately their protocol from those activities in the organization model, but can be linked through the transformation operators. This makes it easier for individuals who understand the details of the organization activities to enter those activities directly, and have another person who understands the overall process arrange those activities in a way that satisfies both work process and organizational constraints.

Discussion

All organizational models require detailed information to generate reliable simulations. Often the expertise required to create these detailed models is distributed among different people who may not be located in the same place. In medicine, this problem is even more acute: Work process descriptions are often created by national consensus meetings, and it is the responsibility of the local organization to adapt these protocols for use within their own institution.

Protégé provides a mechanism to coordinate the development of these specialized work process descriptions by creating customized knowledge-acquisition tools that can be used by domain experts and brought together through a common ontology of terms. Our current research involves exploring ways of providing computer support to the process of acquiring, maintaining and customizing organization-specific work process descriptions. By dividing the work of maintaining complex organization models among experts in work processes, organizations, and simulation, no one person requires expertise in all these areas to generate a detailed model of the organization.

We are also defining a set of valid transformations and an explicit way of representing these changes. We hope that these transformations will allow better computer-based support for the process of both the initial transformation of a generic protocol to one that is site-specific, and maintenance of the site-specific protocol and organization models. Thus, if we have a protocol, a organization model of activities, and a language to describe protocol revisions, we can provide computer support to the process of protocol modification, and maintenance.

Organization-specific models are more accurate at predicting organization performance than generic models, but such models require significant effort to develop and maintain. Although simulations can be used to gain insight into how organizational makeup hinders or helps patient care, the effort needed to make these models accurate may prevent more widespread use. Protégé provides a way for a model builder to define the features that are important to represent for the purposes of a simulation or workflow system, and to use these features to create customized knowledge-acquisition tools suitable for use by domain experts. We have shown that this is an appropriate tool to use for modeling medical organizations, and can be used to coordinate the transformation of a generic protocol to a site-specific protocol based on a generic protocol and a description of an organization. By distributing the responsibility for maintaining the organization model among the experts within the organization, complex, models of the organization can be created and maintained, without the need for one person to be expert in all areas. It is hoped that these complex models will give organizations the opportunity to examine the procedural knowledge stored in their organizations, and acquire, maintain, and customize organization models—models in which the whole is better than the sum of its parts.

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