A Service-based Approach for the Support of Structural Change in Workflow Management Systems

Jürgen Klarmann, Ottokar Kulendik, Kurt Rothermel

Institute of Parallel and Distributed High-Performance-Systems (IPVR)
University of Stuttgart
Breitwiesenstr. 20-22
70565 Stuttgart, Germany
{klarmann,kulendik,rothermel}@informatik.uni-stuttgart.de

Abstract

In today’s rapidly changing markets companies repeatedly change their organization and process structures. Existing workflow management systems reflect these structures in a separate organization model and a process model containing workflows. However, these systems cannot cope with repetitive and frequent change of organization and process structure and thus hamper continuous operation and quick reactions to turbulent markets. Change may have an influence on the internal structure that consists of an internal organization and process model, or on the external structure of companies consisting of the network with other cooperating or interacting companies. Change of the internal structure in the organization model can cause orphaned references in the process model which leads to inconsistent workflow specifications. Change of the external structure is hampered because the systems are not able to reflect business processes that are offered as services by autonomous organization units on a service market; they lack suitable modeling concepts for specification and selection of exchangeable workflow parts with complex interactions.

We describe some scenarios of structural change to explain both of these problem domains and derive requirements for structural change in organization and process model. We then extend concepts of the organization model and propose a new integrated model for these requirements by introducing services that are related with each other according to type hierarchies. Furthermore, we adopt institutional workflow participants and concepts for modular workflow structures. Finally, we show how our model is able to deal with the identified requirements.

1 Introduction

In today’s rapidly changing markets, companies have to be able to change their organizational structures, their size and to some degree the domain of their business. An adequate treatment of these changes is necessary for survival on the market. It is the aim of the joint research project SFB 467 “Transformable Corporate Structures in Multi-Variant Serial Production” [1] supported by the Deutsche Forschungsgemeinschaft (DFG) to acquire theoretically well-founded and interdisciplinary approved knowledge to describe, to understand and to build transformable corporate structures for the production domain.

Our subproject examines how business processes can be managed in a turbulent environment [2, 3]. A major drawback of existing systems is their lack of adaptability to structural change. By structural change we mean modifications concerning the more static parts of organizations, in contrast to ad-hoc-changes like adaptations of processes that are not considered in this paper (cf. [4, 5] for an overview). Change may have an impact on the internal structure that consists of an internal organization and process model, or on the external structure of companies, consisting of the network with other cooperating or interacting companies [1]. Both kinds of change are obstructed by limitations of current workflow management systems (see Figure 1).

![Figure 1: Domains of Structural Change](image-url)
1. Internal structural change

Workflow management systems reflect business structures in a separate organization model and a process model containing workflow specifications. This separation aims to isolate changes in the organization from changes in the processes and vice versa. For example, transfer of employees from one position in the organization to another does not need to be reflected in the process model, and a modification of a process part does not need to be reflected in the organization model.

However, this separation is not sufficient to deal with internal structural changes because reflecting change of the structure in the organization model can cause orphaned references in the process model, and this leads to inconsistent workflow specifications. For example, a company’s division structure has to be changed more and more often to adapt to new market situations: new scopes of duties are created and newly assigned to employees, and obsolete ones are omitted. The frequency of change is now too high for being able to adapt the process models to the new organization model manually. Nevertheless, former specified process models should still be executable under these circumstances to reduce the cost of changes.

2. External structural change

Today, companies are more and more involved into networked organization forms like virtual corporations or tight, efficient interactions with suppliers. At the end of trends like virtual marketplaces, there is the vision of a service market where companies do not just offer their products but their business processes as well. To support this, workflow management systems should be able to reflect business processes that are offered as services by autonomous organization units [6, 7]. It should be possible to select new cooperation partners on demand and to link their business processes easily.

But current systems lack suitable modeling concepts for selection of exchangeable workflow parts and specification of complex interactions. Selection is not supported because systems lack concepts for the specification of workflow as searchable services. To specify interactions systems might allow to use the interoperability model of workflow standards like [8] or [9]. But the interaction concept of sub-workflows [10] those standards are based on is not sufficient for complex, multi-step interactions with one process. For example, consider the interaction between production processes linked to manufacturing processes. After requesting the start of the process, several interactions concerning the progress of production, delivery and payment are needed to support the whole interaction effectively. Cases like that cannot be modeled adequately using sub-workflows.

In the following, we examine the requirements of internal and external structural change on workflow management systems in more detail by means of scenarios of each problem domain. By using one approach common to both domains, we extend concepts of the organization model and propose a new integrated model for the identified requirements. We introduce services that are related with each other according to type hierarchies. Furthermore, we adopt institutional workflow participants and services with complex interactions. Using these concepts, we show in the following section how our model is able to deal with the requirements. We finish by giving a conclusion and an outlook on future work.

2 Problem Domains

We examine the need for the support of structural change focusing first on the change of the internal and then on the external structure of an organization.

Internal structural change

Concepts for supporting internal structural change of organizations are needed because the employee’s responsibilities and task profiles change much more frequently than some years ago.

For that reason we need a more flexible detachment between organization model and process model. In already existing systems and research approaches, the relationship between the entities in the organization model and the process model is hard-coded and very tight and therefore not suitable to handle turbulent environments (see Figure 2). Thus, each restructuring of the organization model has to be reflected in the relevant process models. Therefore, we identify need for concepts that are able to treat process model specifications containing elements of the organization model which have changed in the meantime.
Scenario A

Internal change can be illustrated using two scenarios. For example, the market situation urges an enterprise to merge the competencies of a manager. For gaining a leaner management, a personal manager and a product manager are put together to one combined manager. The old specific managers exist no longer. After a corresponding re-specification in the organization model, all process models using these orphaned references cannot be assigned to personal or product managers anymore. They have to be adapted to the new structure and their references have to be changed.

Scenario B

As a second scenario, we consider a repartitioning of responsibilities. Manager A is responsible for the areas $\alpha$ and $\beta$ and manager B has been assigned to the areas $\gamma$ and $\delta$. Now, it seems to be more efficient if the areas $\alpha$ and $\gamma$ on the one hand and the areas $\beta$ and $\delta$ on the other hand were grouped to new responsibilities. It is not possible to resolve this kind of restructuring in the organization model, and a complete re-specification in all relevant process models will be necessary.

Requirements

To satisfy the changed market requirements, the organization model should allow to prevent the negative effects on workflow processes due to the changes in the environment. Hereby, we have to consider structural changes of organization units as well as training and qualification actions of human actors (see below).

We distinguish two variants of internal structural change. Both of them reflect the modification in the organization model that has to be done for considering changes in the environment:

One variant of internal structural change arises from modifications of organization units and their relations. These include the creation of new organization units, the fusion of several organization units or a complete new distribution of the company’s scope of duties. Additionally, in all these cases, involuntary modifications referring the human assignment at runtime will follow. In particular for scenario B, a more detailed knowledge about the employee’s properties is significant because in that case these properties cause internal structural change. The important knowledge for this is hardly covered in existing systems. Besides, the organization model has to contain such a degree of power that it is possible to specify the effects of structural change in a direct way. Such an expressive organization model can be seen as a necessary precondition for the ability to treat structural change.

The other variant of internal structural change includes modifications referring directly to the employee. An example for this is knowledge acquisition by training actions or by individual learning. This competence acquisition is often followed by structural modifications like acquisition of additional responsibility for extending scopes of duties. This motivates a more explicit specification of the employee’s properties. The required organization model does not only need to be able to cover information about the company’s structures and its effects on structural change but also about relevant attributes of employees and analogously their behavior on structural change.

To summarize, the organization model should not rely on specifying its entities in traditional singular terms of role, group and organizational unit models as found in classical role models like [11] because they are not powerful enough to cover information about structural change. It should be possible to realize a more flexible relationship between the entities in the organization model and those in the process model.

Performance properties of organization model entities e.g. cost, time, should be described to allow selection between similar entities. Thereby, selection goals like minimization of performance time, equal distribution of workload or avoiding work assignment to absent people could be realized.

External structural change

External structural change concepts are needed for specification and selection of exchangeable workflow parts running at different, partly autonomous organiza-
tion units. We start describing a scenario to be able to illustrate the requirements subsequently.

**Scenario C**

As an example, let us consider a hierarchical structure of a production company consisting of different organization units running production and manufacturing processes. Assume there is an established agreement on the cooperation between the production process PP run by production unit PU and a manufacturing process MP run by the unit MU. The interaction consisting between PU and MU may contain the following steps (for simplicity, we omit alternative interactions):

1. PU requests the start of the manufacturing process at MU.
2. MU confirms the processing of the request.
3. MU informs PU when the manufacturing of the parts is finished, so that PU can prepare for the acceptance and the assembly.
4. MU tells PU that the parts are shipped.
5. PU tells MU that the parts have arrived and are conform to the request.
6. MU sends PU the invoice for this order.
7. PU tells MU that the payment has been ordered.
8. MU tells PU that the order is finished.

**Requirements**

To support the modeling and execution of processes spanning several organization units as in scenario C, it should be possible to model the interaction and to select among different providers of a workflow part. Both units need the specification of the interaction to be able to integrate that with their workflow parts, and before starting PP, PU might want to select among different units that produce needed parts. Modeling the interaction makes it transparent, allows definition and checking of correct interactions and is a prerequisite for the selection as well. We can distinguish more detailed requirements concerning specification and selection of exchangeable workflow parts:

1. **Interaction interface**
   
   An explicit and externally visible model of exchangeable workflow parts describing the interaction elements for communication and synchronization is needed. To allow the change of internal procedures, the comparison and interchangeable use of workflow services, as well as to hide the business secrets of organization units, the interaction between workflows should be based on interfaces that hide the implementation [7], analogously to programming in the small. The interface should specify the signature, i.e., the typed input and the output signals needed to interact with the workflow, together with the workflow data that should be exchanged with the signal.

2. **Quality properties**

   Properties of workflow parts should be available to select between different but similar workflow parts. Examples of properties are process generic ones, e.g., process cost, time, as well as process specific ones, e.g., for describing different part variants in scenario C. Properties of the organization units implementing workflow parts should also be considered.

3. **Classification of functions and interfaces**

   The workflow model should specify which workflow parts can be selected. To distinguish between workflow parts during selection, they have to be classified. Besides a classification of their abstract function that describes what the part does, a classification of the interfaces allowing to categorize according to the supported interaction is required.

4. **Compatibility relation for functions and interfaces**

   The model should specify a compatibility relation concerning the functional classification and the interaction interface. The functional compatibility should be able to model that a function of a workflow part is a specialization of another function.

   For example, suppose that MU supports the production of a part X. If PU needs part X1, which is a specialization of X, MP can still be used for the interactions. Therefore the functional classification of MP producing X1 should be compatible with the functional classification of MP producing X.

   Interface compatibility should allow to select among workflow parts with interfaces that are extended or restricted concerning supported input and output messages. For example, to speed up the process in scenario C, another production unit PU wants to send the “payment ordered”-message (step 7) before receiving an invoice, making step 6 obsolete [12]. So PU no longer needs an interface supporting that step. On the other hand, MU just needs to ignore the message in step 7, without implementing a new interface. Therefore, MP should be specified also as compatible to the new, restricted interface.
3 Service-based Model

In this section, we introduce an integrated service model that satisfies the requirements caused by internal and external structural change.

To support the flexible participation, the selection and the interchange of different humans and organization units in a workflow, the organization should be structured as a market. In this market humans and organization units offer their potential of work in a cooperative or a more concurrent fashion, depending on the specific organizational form. As a common abstraction for the potential of work they offer, we view activities and interacting workflows as services that can be used in workflows (see Figure 3).

Figure 3: Service-based Approach

We define an actor as an abstraction of a human or an organization unit. Actors represent active participants in a workflow. Organization units are institutional actors, i.e., groups of actors, modeled by a belongs-to-relationship, that act as one logical actor. Actors are mainly described by services they offer. Figure 4 shows the elements of the organization model and their relations using UML.

Figure 4: Organization Model

Services are described by service types and attributes. To express this, we have to extend the meta model by subtype relationships (see Figure 5).

Figure 5: Service Model

Each service is an instance of a service type. Service types classify the function of the services. Service types are related to each other by their subtype relation, describing compatibility of services of subtypes with services of their super-types. This relation induces a type hierarchy with the semantics that a service of type T is also an instance of all of the subtypes of T.

A service type represents either a specific capability of an individual actor or a role describing a scope of duties. Services representing capabilities belong only to actors and are therefore independent from structural change, whereas services representing roles may be subject of change.

Services contain attributes that describe its properties and behavior. Each attribute is an instance of an attribute type of the corresponding service type. Attribute types describe name and value type of an attribute.

Interaction services are specializations of services. They are used to model services with complex interactions. An interaction service has an interface that belongs to an interface type. The interface type classifies interfaces and specifies input and output messages that can be used in an interaction.
Services offered by an actor have to be mapped on required services specified in the process model. The mapping occurs via referred services types in the process model (see Figure 6).

![Figure 6: Process Model](Image)

A workflow is described by a workflow specification. A workflow specification contains several activity specifications that describe work to be done. By specifying this in terms of service types, we are able to map their offered counterparts in a more flexible way by using trading mechanisms at runtime.

### Exemplary Model Use

We show how to use our model for coping with the identified requirements of internal and external change. For that we take up the examined scenarios.

**Scenario A:**

First, remember scenario A. In terms of our model we specify all manager types as offered services types. The new general service type manager is a subtype of the personal manager as well as of product manager. A search for personal manager or product manager is now able to find manager using the subtype relation. Figure 7 depicts the referring part of the organization and service model.

![Figure 7: Organization and Service Model of Scenario A](Image)

**Scenario B:**

Scenario B can be treated similar to scenario A. The formerly implicit information $\alpha$, $\beta$, $\gamma$ and $\delta$ are now explicitly specified as service types that can be used to find the connection between old and new scope of duties considering the subtype relations between scopes of duties.

So far, manager A was responsible for the areas $\alpha$ and $\beta$ whereas manager B was for $\gamma$ and $\delta$. After an organization restructuring, a manager A’ gets the areas $\alpha$ and $\gamma$ and manager B’ gets the areas $\beta$ and $\delta$. In existing process models, manager A still is specified although he does not exist anymore. Using the type hierarchy, we see, that area $\beta$ is a sub-type of both service types A and B’. If manager A is specified in the process model because of his competency in $\beta$, we are now able to assign manager B’. Even if $\beta$ was not explicitly represented, we are able to offer a resolution selection between the manager types A’ and B’ (see Figure 8).

![Figure 8: Organization and Service Model of Scenario B](Image)

**Scenario C:**

MU and PU agree on the interface type called Manufacture consisting of the input messages give_order, parts_arrived, payment_ordered, and the output messages order_accepted, manufacturing_finished, parts_packed, give_invoice, order_finished. For another manufacturer, MU also registers the type called Manufacture_Without_Invoice (MWI) that lacks the give_invoice message. MWI is registered as a super-type of Manufacture, so that services offering the invoice message can also be selected as services of the type MWI.

MU registers MP as service for the service type manufacture-X with a specific interface type, together with their offered values for cost and time properties. PU specifies the sending and reception of the messages in PP. PU can then select MP and interact with it during the execution of PP (see Figure 9).
4 Related Work

Although it is accepted that there is a need for providing flexibility in the workflow domain [13], existing workflow and organization models are not powerful enough to do so. Most of them prevent an adequate change behavior because of strict coupling to their process model [14–16]. [17] introduces a model with a process object for decoupling organization structure and process structure, but the model also does not cope with changed organization structures. [18] recognizes that there is not only a need for a powerful organization model but also for a powerful meta model to be able to specify significant organization models. But the described meta model does not allow to derive a model coping with structural change.

Concerning external structural change, contributions in event-based workflow management, interorganizational workflow management and trading in distributed systems are relevant. Event-based workflow models are suitable for the use in inter-workflow communication, cf. [19], but do not support the needed privacy and flexibility for inter-organizational workflows [7].

In the area of inter-organizational workflow management several approaches already exist: WAWM [20], Process Model Fractals [6], WISE [21], Interworkflow [22], CMI [23] are examples. While they provide suitable paradigms for modeling and execution of processes spanning several organization units, they lack for support of complex interactions between workflows [21] or for an automatic selection of processes [6, 20, 22, 23]. One exception is the work in CrossFlow [24], where some algorithms for matching of sets of activities have been investigated. However, the interaction is based on a request-response-like paradigm, which hampers specification of a bilateral interaction interface. Furthermore, there are no concepts described how to support exchange of different but similar processes, as the type concept.

In the area of trading, that is relevant for both addressed problem domains, a model for offer and selection of services has been developed and standardized [25, 26]. While the approach of the basic model has been extended for services exhibiting some external behavior [27], specific needs for trading of interacting processes have not been considered in the past. [28] introduces an approach that bears potential to detach organization model and process model. His approach is suited in the trading area and satisfies mainly requirements for technical services. It cannot be adapted to requirements for organization units which has been identified in this paper.

5 Conclusion and Outlook

In this paper, we have motivated that it is important for companies that permanently change their internal and external structure to be able to reflect these changes in workflow management systems. Reflecting internal structural change can cause orphaned references in the process model. This leads to inconsistent workflow models. External structural change is hampered because there are no suitable concepts that support modeling and selection of exchangeable workflow parts with complex interactions.

We have described some scenarios of structural change to explain both of these problem domains, have derived requirements and then presented our integrated approach basing on services. We have enhanced concepts of traditional organization models by enlarging the meta model with typed services, and express former singular model entities using these services. Following principles of trading, we have used subtype relations and properties for description of services. So we are able to express specialization relationships that allow resolving orphaned service specifications and specifying more detailed knowledge about actors. This makes it possible to assign activities much more flexibly. Furthermore, we have introduced institutional workflow participants and concepts for modular workflow structures by specifying interaction services that have interfaces containing relevant interaction messages.

We have shown how our model is able to deal with identified requirements by applying the service-based model to the introduced scenarios and have shown how interaction interfaces can be described in the model. Interface types and their subtype relationship can be used to classify interfaces and to specify specialized but compatible interfaces.

At the moment, we are extending a prototype to use the model for enacting services in cooperation and to
integrate it in existing workflow management systems. Therefore, we are going to enlarge the model for trading mechanisms that considers the evaluation of service quality, using attributes and attribute types of the model. Furthermore, we examine to use concept graphs for specifying the organization model. Hereby, we expect further improvements by being able to use AI-concepts like learning, less exact specifying, and representing semantic aspects. Concerning interaction services, we intend to enhance type model and compatibility relation from interfaces to protocols that specify behavior of these services.

References

[1] Joint research project “Transformable Corporate Structures in Multi-Variant Serial Production” http://www.sfb467.uni-stuttgart.de/


