WorkAware
Situation-Aware Workflow Management

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Abstract: Business processes face constantly changing context factors like varying customer behavior or market conditions that force to adapt the underlying workflows to these evolving situations. Information overload induced by the diversity of context factors, however, leads to the inability to provide coherently modeled, comprehensible, and re-usable workflows, the failure to recognize relevant situations in time, and finally, the lack of provenance information urgently needed for optimizing workflows. The main goal of our research project WorkAware is to leverage situation awareness in all phases of business process management. WorkAware will be based on a generic ontology-driven framework for situation perception, comprehension and projection and will employ aspect-oriented techniques for achieving extensible workflow models and tracking of provenance information.

1 INTRODUCTION

Business process management is considered key for the overall business success, being typically supported by workflow management systems. Constantly changing business environments in terms of *internal context factors* (e.g., evolving business strategies), and *external ones* (e.g., new legal regulations) force to *pro-actively adapt workflows* to these changed situations. Workflow agents are at permanent risk of failing to identify relevant context factors stemming from heterogeneous sources in the induced information overload and, consequently, being unable to comprehend and in turn project the relevant situations workflows have to cope with. This *lack of situation awareness* endangers to timely and correctly execute workflow tasks, as well as to pro-actively prevent critical situations and escalations, potentially causing significant costs, delays, and quality losses. The diversity of context factors can hardly be foreseen to yield a comprehensive and stable workflow model, resulting also in *lack of provenance information* which would be urgently needed for workflow optimization.

The main goal of WorkAware is to leverage situation awareness during modeling, execution, and optimization of workflows. WorkAware will be based on a generic ontology-driven framework for situation perception, comprehension and projection as well as aspect-oriented techniques for achieving extensible workflow models and tracking of provenance information.

This paper describes our vision of WorkAware and is structured as follows. Section 2 discusses the three overall goals of WorkAware together with research challenges and related work. Section 3 presents the technical approach of WorkAware, while Section 5 concludes the paper with a brief discussion of the evaluation strategy foreseen.

2 GOALS & RELATED WORK

WorkAware stretches over three unique but highly interwoven key research goals as depicted in Figure 1. In the following, these goals are discussed along several challenges and relevant related work.

2.1 Situation-Aware WF-Modeling

The first goal of WorkAware aims at the modeling phase, in which workflow designers must be supported with concepts for defining dependencies of workflows on situations in their environment.

2.1.1 WF-Modeling Concepts

The first challenge is to provide an integrated, but from a modeling perspective still decoupled, representation of workflows and relevant situations stemming from various heterogeneous sources. The relevant context information can be structured along the taxonomy of Rosemann et al. (2006), which include not only information about the workflow instance itself (e.g., throughput) but also environmental context (e.g., legal regulations).

As representation formalism, we foresee the utilization of *ontologies* since they have proven to be beneficial in the realm of situation awareness by providing a formal and at the same time we can benefit from both, our previous research (Retschitzegger et al., 2010, Baumgartner et al., 2010ab) and from related disciplines such as context awareness in mobile computing (Strang et al., 2004, Baldauf et al., 2007) situation awareness and qualitative reasoning (Kokar et al., 2009) as well as workflow-related ontologies and meta models (Gasevic et al., 2006).

2.1.2 Situation Modeling Concepts

Since a vast amount of contextual information is to be expected, information overload for agents must be reduced by aggregating low-level context information to semantically enriched, high-level

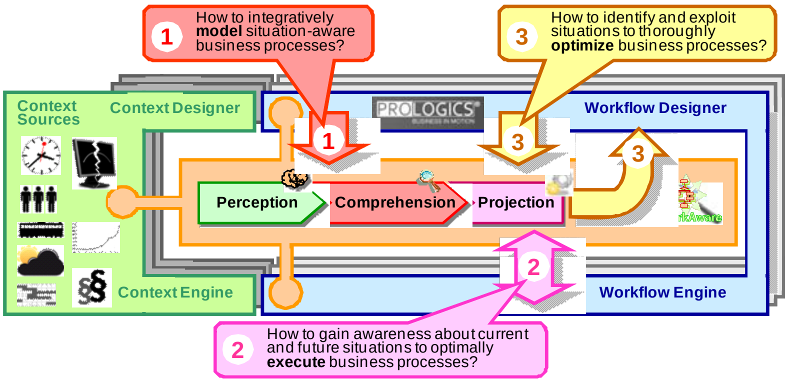

Figure 1: Key research questions of WorkAware.

semantically rich knowledge representation which enables reasoning (Strang et al., 2004). Current workflow modeling languages and standards either provide only limited context information support (Russel et al., 2007), or do not adequately decouple workflow from context modeling (Wieland et al., 2008), often using proprietary languages such as, e.g., uWDL (Shin et al., 2007), CPDL (Li et al., 2006), or pvPDL (Chen et al., 2006). Moreover, workflow instances themselves have not yet been recognized as beneficial context factors, although meta-models and ontologies for describing workflows exist (Haller et al., 2006).

Thus, the challenge will be to develop, on the one hand, a core ontology unifying concepts from different workflow modeling languages with concepts from context and situation awareness, thereby enabling reification of workflows as context information, and to develop, on the other hand, modeling concepts for attaching context and situation queries as well as adaptation mechanisms to workflow models, without the need of changing the models themselves. For realizing this challenge, situations. Relations between context factors are most crucial in human perception for describing such situations. Since workflow management systems completely abstract from application domains, the challenge is to define appropriate domain-independent extension mechanisms allowing the incorporation of diverse relations describing aspects like, e.g., causality, business relationship, market dependencies, or social networks of workers.

For describing relations, their interpretations (i.e., how to derive them from context factors), and their aggregation to situation types, workflow designers need to be supported with intuitive and easy-to-use modeling concepts. Thereby, WorkAware should be configurable with both, deterministic and probabilistic relation and situation definitions. Current approaches focus mainly on deterministic outcomes, providing hardcoded relation interpretations for a particular domain (Kokar et al., 2009). For realizing these challenges, we can base upon related research from the areas of spatial information theory (Kurata et al., 2009) and situation calculi (Mateus et al., 2001). Especially relevant are results from our currently running research project BeAware! (Baumgartner et al., 2010ab) focusing on assessing situations using spatio-temporal relations between traffic objects.

2.2 Situation-Aware WF-Execution

Our second research goal aims at the execution phase during which agents have to be supported with situations, being characterized by *semantically enriched relations between content and context factors* in order to increase their ability to adapt a workflow. Three kinds of adaptations can be performed during a workflow's runtime (Samchat et al., 2008), potentially triggered by situations, comprising *customizing, correcting or optimizing adaptations.* Most approaches to workflow adaptations only *react* on context changes, while only Müller et al. (2004), support predictive workflow adaptation. We aim at filling this gap by not only supporting reactive measures, but allowing agents to proactively act on projected future situations, while maintaining continuous provenance of performed actions and situation evolutions.

2.2.1 Situation Awareness of Agents

Adjusting a workflow model's execution parameters to fit a particular situation relies on increasing an agent's situation awareness (Endsley, 2000). In order to be able to quickly access information for adjusting a workflow's parameters, efficient assessment and retrieval of relevant situations is a major concern. Going beyond current context-aware workflow systems providing only uninterpreted, low-level context, WorkAware's challenge is to provide both deterministic and probabilistic situation assessment algorithms to aggregate low-level context to situations (Wieland et al., 2008). In this realm, special focus has to be laid on the highly creative nature of collaborative and ad-hoc workflows, which makes it impossible to foresee every relevant aspect during the modeling phase. Another challenge therefore is to provide agents with techniques allowing them to browse and extend context information and assessed situations.

2.2.2 Predictive WF-Adaptation

While reactive adaptations can be made by an agent with the help of increased situation awareness as lined out above, WorkAware additionally focuses on adaptations based on *predictions of future situations*. Such predictions enable an agent, e.g., to prevent potentially adverse effects by pro-actively taking corrective adaptations, and to perform optimizing adaptations before workflow execution is actually delayed. Therefore, situation prediction techniques for qualitative spatio-temporal reasoning (Dylla et al., 2007) must be adopted for integrated situation and workflow prediction, allowing agents not only to access and browse predicted situations and workflow states, but also to adjust and vary predictions by incorporating domain knowledge, enabling what-if-analysis. Major emphasize is put on overcoming the limitations of related approaches from areas like qualitative neighborhood-based prediction (Dylla et al., 2007), qualitative simulation (Bhatt et al., 2005) and robot agent control (Netjes et al., 2008), often needing manual modeling on a per domain, or even worse, per prediction basis.

Performing the actual adaptation of a workflow's execution differs between workflow engines, and approaches for architectures of such adaptive systems exist (Reichert et al., 2009). In addition to helping an agent to manually perform adaptations, WorkAware's challenge is to directly interact with workflow engines so that adaptations can be performed automatically. Therefore, different adaptation strategies found in common workflow engines have to be supported, e.g., following an active strategy by dynamically adding or removing tasks at runtime (Adams et al., 2006) or passively by notifying the engine of events (Müller et al., 2004).

2.3 Situation-Aware WF-Improvement

WorkAware's final key research goal closes the workflow lifecycle by supporting workflow designers in improving current models. The first challenge, in this respect, aims at optimization in the form of situation-dependent *evaluation techniques* to detect possible deviations between modeled and actual workflow practice, *feedback measures* to integrate recorded, manual workflow adaptations into the models, and *maintenance techniques* for updating situation awareness with previously unrecognized entities, relations, and situations.

Evaluating and optimizing the performance of enacted workflow models is vital for adapting models to constantly evolving businesses (Netjes et al., 2008). Appropriate performance indicators are needed allowing goal-driven evaluation and clustering measurements by situations. Current indicators are typically structured around the dimensions time, cost, quality, and flexibility, without considering situations under which the indicators were measured (Netjes et al., 2008).

Since not all situations occurring in the course of WorkAware's usage may be foreseen, an additional challenge is the evolution and adaptation of workflow models and the maintenance of situation awareness on the basis of continuous provenance information, such as observed real-world adaptations and situations. For this, recurring adaptations taken by agents in the configuration or enactment phase of workflows need to be matched with observed situations, in order to direct a workflow designer's attention to shortcomings in the workflow model, or to automatically perform workflow optimization.

3 APPROACH

The technical approach followed by WorkAware is discussed in the following along the three key research goals and their associated challenges.

3.1 Situation-Aware WF-Modeling

3.1.1 WF-Modeling Concepts

To provide a uniform representation of workflows including variants and exceptions, their relevant business entities, as well as relevant situations in their context, we will develop an *integrated core situation awareness* and *core workflow ontology*.

Figure 2 depicts an exemplary ontology structured into Core Workflow Ontology (showing a Petri net formalism (Gasevic et al., 2006)), Integration Ontology, Core Situation Awareness Ontology (basing on our previous work Baumgartner et al., 2010ab), Domain Ontology Extensions, and Relation Extensions.

The resulting core ontology must be extensible with *domain-dependent ontologies* (e.g., from our demonstration domain) integrating necessary context data sources. Therefore, we envision using OWL in combination with RDF, since the structure of RDF triples is inherently extensible. The unification of context and workflows under one umbrella, especially, results in enacted workflows being reified as context information themselves, which during workflow execution, enables tracking of both workflow content and context as provenance information at different levels of granularity, ranging from low-level attributes to high-level situations.

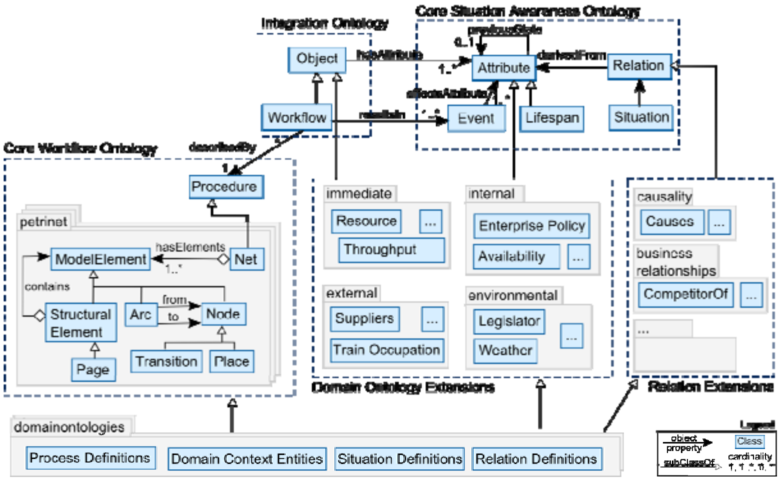

Figure 2: Core workflow ontology integrated with the core situation awareness ontology.

Although beneficial from a system perspective, from a modeling perspective such an integration according to Rosemann et al. (2006) and Adams et al. (2006) leads to "unnecessary model extensions, mixes run-time with build-time decisions, and tends to reduce the acceptance of process models by end users", and results in "complex models, complicating verification and modification of business logic and exception handling, in addition to rendering the process model almost unintelligible". We thus will adopt aspect-oriented techniques (Retschitzegger et al., 2010), introducing dedicated modeling tools for different roles, each focusing on an orthogonal aspect of workflow modeling, e.g, the core business logic, context integration, exception handling, and flexibility measures, thereby facilitating *separation of concerns*. The separated models will be woven into core business logic, resulting in a materialized model.

3.1.2 Situation Modeling Concepts

The definition of relations and their interpretation in a particular domain is of major importance for finding interrelated context factors during workflow execution, in order to highlight the occurrence of modeled, relevant situations. Basing on our experience in the development of domain-specific languages (DSL) for model-driven development (Schwinger et al., 2010), we intend to develop a range of design languages for relations, relation families, and situations, aiming at supporting different user interaction preferences including textual DSLs allowing exact declarative and imperative definitions, as well as graphical DSLs supporting sketchy, intuitive definitions

3.2 Situation-Aware WF-Execution

3.2.1 Situation Awareness of Agents

During workflow execution, agents are to be supported with efficient situation assessment algorithms bringing relevant, high-level situations to their attention, as well as allowing them to easily query context and situation information. The same information, must be machine-interpretable in order to be used by the workflow engine to automatically make decisions on behalf of the agent, which is the pre-requisite for predictive adaptation of workflows.

For this, we will base upon our previous work on situation-awareness, which, however, focuses on deterministic situation assessment only. In the course of WorkAware, concepts on the ontological level, as well as on the algorithmic level, for supporting probabilistic situation assessment are to be developed. In this realm, situation assessment algorithms must be configurable not only with pre-defined situation definitions provided during the modeling phase, but also with additional situation definitions injected by agents at runtime. Especially to support collaborative and ad-hoc workflows, the problem of communicating implicit assumptions between different agents, as well as between a current and potentially future workflow enactments, can be approached with such participant-generated context information and situation definitions during the execution of a workflow. By that, WorkAware is able to pro-actively notify subsequent agents about critical situations, exceptions, and constraints on the basis of a continuously growing knowledge base.

From the context query perspective, we intend to tackle the highly creative nature of collaborative and ad-hoc workflows by supporting agents with extendable reasoning approaches. For example, in order to search only in situations relevant for the current workflow, a reasoner can be provided on the basis of core ontologies with rules. If we know that, e.g., a particular situation contains a relation, and that this relation is derived from a particular attribute, then it follows that the situation is also derived from this attribute.

3.2.2 Predictive WF-Adaptation

For situation and workflow state projection, we will base on our previous work on predictions in qualitative spatio-temporal reasoning on the basis of conceptual neighborhood graphs (CNGs, Baumgartner et al., 2010a). In order to enable integrated projection of future situation and workflow states, we intend to exploit Colored Petri nets (Jensen et al., 2007), being capable of representing the dynamic aspects of systems, and also being used in some workflow engines (Russel et al., 2007). For making them applicable to situation projection, we aim at replacing our current representation of assessed situations in CNGs with such Petri nets. Both, workflow and situation projection nets, must then be integrated in hierarchically composite nets, in order to generate the necessary projected future workflow situations.

For workflow adaptation, two approaches will be provided, respecting the requirements of enterprise policies, as well as the technical capabilities of different workflow systems: Firstly, we will develop a passive situation trigger adaptor, allowing workflow management systems to register for certain trigger situations. Secondly, we will provide an active situation-aware workflow injection adaptor, allowing access to running workflows.

3.3 Situation-Aware WF-Improvement

During workflow execution, a WorkAware-enhanced workflow engine records provenance information in terms of context information and situations, various performance indicators, such as time or resource utilization, as well as adaptations made during a workflow’s runtime, either manually by agents or automatically by a workflow engine. By *aligning* such provenance information (e.g., recorded situations with decisions and adaptations), the findings can be annotated in an optimization and extension point model complementing (i.e., being woven into) the workflow model.

4. CONCLUDING REMARKS

The evaluation of WorkAware will be achieved in two independent steps. The first step will consist of a *case-study based evaluation* of the functional modeling and improvement requirements with domain experts. The second step will be an *experimental evaluation* of situation-aware workflow execution.

We plan to conduct several *case studies* with workflow designers to determine whether the functional modeling and improvement requirements concerning integration of context and situation information in workflow modeling are met. For this, domain experts will define appropriate use cases in a requirements engineering workshop, basing on current workflow models enhanced with possible situations these workflows need to respect. In addition, we intend to address the question how contextualized information on workflow executions together with information on observed situation evolutions can help workflow designers to improve existing workflows, compared to expected outcomes defined by domain experts beforehand.

We intend to evaluate whether our approach to a situation-aware workflow management positively influences workflow execution on the basis of actually running situation-aware workflows concurrently to current systems. In this respect, both a *qualitative evaluation* in the form of questionnaires with workflow agents, as well as *quantitative comparison* of performance indicators, such as task completion time, created workflow costs, are planned. For repeating and automating such tests in our lab environment, we will also base on domain-expert-defined test data sets of sample workflows together with available context and situation information.

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