Journal of Universal Knowledge Management, vol. 0, no. 2 (2005), 77-100
submitted: 2005-10-14, accepted: 2005-11-14, appeared: 2005-11-28 © J.UKM

Challenges for Business Process and Task Management

Uwe V. Riss, Alan Rickayzen
(SAP AG, Walldorf , Germany
{uwe.riss|alan.rickayzen}@sap.com)

Heiko Maus
(German Research Center for Artificial Intelligence (DFKI GmbH), Kaiserslautern, Germany
Heiko.Maus@dfki.de)

Wil M. P. van der Aalst
(Department of Technology Management, Eindhoven University of Technology, Eindhoven,
The Netherlands
w.m.p.v.d.aalst@tm.tue.nl)

Abstract: Requirements resulting from knowledge intensive work go beyond what is provided by classical workflow management regarding process flexibility and integration into the personal task management. This is demonstrated considering the example of Engineering Change Requests (ECR), handled by an integrated workflow as provided by SAP's Product Lifecycle Management (PLM) with its specific problems. Only a Process-Aware Information System (PAIS) based on a completely new paradigm seems to be able to cope with these problems. Such a new paradigm is introduced and discussed in this paper on the basis of the additional requirements that occur in the described ECR process. Starting point for the approach is a bottom-up scheme that builds process and task related information of case handling as provided through personal task management. It is compared to previous approaches as provided by projects at the DFKI and others. Central components such as personal task management and pattern mining are discussed in more detail. The approach makes more extensive use of knowledge management methods like retrieval and semantic technologies. Advantages for small and medium-sized enterprises (SME) are considered.

Keywords: Knowledge Work, Process-Aware Information Systems, Task Management
Categories: H.1, H.4.1, H.5.3, I.2.6

1 Introduction

Over the last decade there has been a shift from "data-aware" information systems to "process-aware" information systems (PAIS) such as Workflow Management Systems (WfMS). Although it is generally accepted that PAIS have made a significant contribution to increase the productivity of employees, it is also known that their rigidity restricts their applicability. This is especially true for knowledge intensive and agile processes [Schwarz et al. 01] (also referred to as knowledge work) such as consulting and design processes. Contemporary PAIS provide excellent support for routing and distributing work using a top-down approach from process engineering to execution. Unfortunately, these systems - but also the models considered in literature - do not incorporate a user-centric view, i.e., they do not try to learn from the way that people really execute their work. This particularly affects knowledge work with its complexity and need for extensive expertise on the side of the process executers with their inherent demands for flexibility, negotiation, and collaboration. Such knowledge intensive processes are extremely difficult to be modelled within traditional PAIS. On the other hand knowledge workers often concentrate on their tasks, forgetting the organizational needs of streamlining processes, and therefore evade the usage of PAIS whenever possible. This clearly illustrates the different needs and perspectives of the individual knowledge worker and the knowledge intensive organization: While the knowledge worker strives for as much flexibility and autonomy as possible, the organization aims at standardization and control.

Similar conditions can be found within networks of small and medium-sized enterprises (SME) and cooperating business units of large corporations. In a network of SME each SME collaborates with various partners and has closely entwined processes with these. On the one hand the SME needs to preserve enough room for flexible execution of the individual tasks assigned; on the other hand the execution needs to be coordinated within inter-organizational business processes (value chains). In a network of business units the business unites need to preserve flexibility while the overall corporation is interested in standardizing interfaces between the units.

The organizational perspective has manifested itself in the field of PAIS. These have fostered productivity by promoting standardization and transparency, enabling traceability of past process executions, allowing effective controlling and monitoring mechanisms, and permitting easier synchronization and coordination of networked and interdependent activities. Here the process is in focus and dictates the way of execution down to details. Consequently PAIS do not allow for much flexibility and can even hamper process execution when the execution context does not fit the underlying process model. Meanwhile several attempts to improve the flexibility have lead to various adaptive workflow research projects that extended the structured automated workflow by different ad hoc capabilities [Aalst et al. 00]. However, these more flexible model-based workflows require explicit model adaptations causing considerable costs. The individual perspective on the other hand is mainly represented by the field of Computer-Supported Cooperative Work (CSCW). CSCW supports knowledge workers in coordinating and negotiating work tasks, in the exchange of information within a specific work context, and collaboratively coming up with solutions to common problems. This approach focuses on tasks (the unit of work a knowledge worker is concerned with at one time) but is mainly unstructured concerning processes. Thus CSCW approaches are characterised by lacking process transparency, traceability, standardization and control.

The goal of the present paper is to propose an approach that resolves this dilemma by supporting the bottom-up development and evolution of flexible process support and services on the basis of existing cases without relinquishing the needed organizational control. This approach turns to innovative applications of knowledge management (KM) methods and technologies such as business knowledge discovery, semantic systems, and knowledge flow analysis to replace classical workflow. Doing so, we expect to cope with the particular demands of knowledge work, regarding its growing importance and its particular complexity, which leads to larger requirements concerning expertise and swiftness [Wiig 04].

Beside process flexibility, process conformance has become an important issue. Reasons are multifaceted, e.g., new rules and regulations such as the Sarbanes-Oxley

Act (SOX) in the USA and the Contra-G law in Germany force companies to ensure that their business processes are standardised, transparent, traceable, and well controlled. In order to comply (and to prove compliance!) to these regulations organisations have to limit the autonomy of their knowledge workers significantly by imposing standardised work processes on them and by enforcing those by the application of PAIS. What makes the situation even worse is that it has become apparent that classical PAIS are too restrictive for agile processes that characterise knowledge intensive work [Schwarz et al. 01]. Although there seems to be a trade-off between the degree of support and control on the one hand and flexibility on the other, there may be ways to resolve this. The concept of case handling [Aalst et al. 04] attempts to address this issue by distinguishing between what can be done and what should be done. Moreover, regulations such as SOX do not need to lead to more restrictions at run-time. Using process mining techniques [Aalst et al. 04], it is possible to analyse compliance afterwards rather than restrict people a priori.

The paper is organized as follows. In [Section 2] we outline the theoretical frame for a task management supporting knowledge intensive work that goes beyond the known restrictions. Such an approach reverts to KM methods supplemented by PAIS technologies. In [Section 3] the example of Engineering Chance Requests (ECR) is presented and their present handling by means of SAP NetWeaver™ Business Process Management (BPM) [Rickayzen 04]. This solution combines business workflow and ad hoc workflow and serves as a starting point for further considerations. On the basis of this example, the problematic aspects will be discussed and related to the points discussed in [Section 2]. In [Section 4] we describe the general challenges that we have to cope with, based on the insights resulting from the example. [Section 5] compiles a number of existing approaches and discusses their efficacy regarding the fundamental requirements of knowledge work. [Section 6] presents an alternative approach that consequently relies on bottom-up information flow concerning task and process knowledge. In this section we present the general structure of such a PAIS. Moreover, we regard details of the central constituents of Personal Task Management and Pattern Mining. The last issues considered in this section deal with the organizational aspects and their handling in this approach as well as a general discussion of the approach. [Section 7] concludes with a summary of the article and a discussion of the proposed task-oriented process management and its relevance for today's business.

2 Theoretical Approach

Core of a task management is to enable actions of individuals in organisations as well as joint organisational actions. These actions are controlled by knowledge of which the individuals or the organisation dispose. They are driven by goals, for the achievement of which several different ways are usually possible. Which of these ways is to be taken decisively depends on the circumstances under which the action has to take place. Therefore the underlying knowledge is not a static resource but a dynamically adapting basis of action [Riss 05]. Consequently the usage of static models as applied in classical WfMS can only work if the action context remains identical and the alternative ways of execution are clearly predictable.

For almost all kinds of knowledge intensive work these preconditions are not fulfilled. They are either characterised by a high degree of context variability or a high action complexity that prevent complete planning [Riss and Wagland 05]. [Table 1] describes the different cases that are to be considered. In the case of high context variability it might be possible to describe coarse process structures or fragments but no task details. On the other hand, high action complexity prevents a complete process depiction but might allow the description of task details. Only if context variability and action complexity are low, traditional model-based process management can be applied.

	Low Context Variability	**High Context Variability**
Low Action Complexity	Realm of Model-based Process Management	Process Pattern Management
High Action Complexity	Task Information Management	Minimal Planning Opportunities

Table 1: Complexity and Context Variability

Traditional WfMS only work with complete processes on the basis of process models. Therefore they fail to support a large class of knowledge intensive business processes, e.g., search processes, in which a global process structure does not exist. Search processes are an example for processes of high action complexity. However, even search processes can be supported, e.g., offering most frequently accessed information. Very individual kinds of work belong to the second kind of processes that cannot be handled by traditional WfMS, e.g., adapting computer systems to the particular conditions at the customer site. Here best practices and descriptions of general process steps are available but not in a way that allows direct execution.

To realise an efficient process pattern and task information management, which also covers high action complexity and context variability, it is necessary to handle process knowledge in a more modularised and open way than this is done by traditional methodologies. We need PAIS that can deal with independent instances of information to support the execution of tasks that only show partial regularity according to [Table 1]. Consequently the approach requires the separation of work knowledge into independent *Task Information Units* (TIUs). TIUs can describe data aspects, e.g., concrete customer data, but also process aspects, e.g., steps required to file a patent. The former is related to specifics of the object whereas the latter describes examples to be followed. Both can be used to support users in executing knowledge intensive tasks. However, existing systems mainly focus on one of these aspects, i.e., they are mainly data or process centric.

Another important dimension of a PAIS is its learning capability. [Figure 1] shows the PAIS spectrum to illustrate this. One dimension shows whether the functionality of the system is data centric (emphasis on information/data) or process centric (driven by process models). The other dimension shows the degree of structuredness. Note that structuredness is closely related to the memory lifetime, i.e., systems supporting unstructured activities have no memory used to support future activities, while systems supporting structured activities typically have a long-lasting memory in the form of standards and procedures. So far there are mainly systems, which either only support current activities, i.e., they are without any memory, or systems with rather long-lasting memory, which is mainly updated on the basis external initiative. However, possessing learning capabilities requires regular and situation-aware memory updates. Both types of systems show only a minimal learning attitude.

To make the PAIS fully adaptive it is necessary that the system learns from actual execution of tasks, i.e., from cases, comprising both task related data and task related processes. Here the underlying idea is that knowledge executers are the first who recognize changes in the business environment that affect processes. Consequently these changes influence the way in which tasks are executed, leading to adapted cases. From these the information directly enters the PAIS built in a bottom-up way.

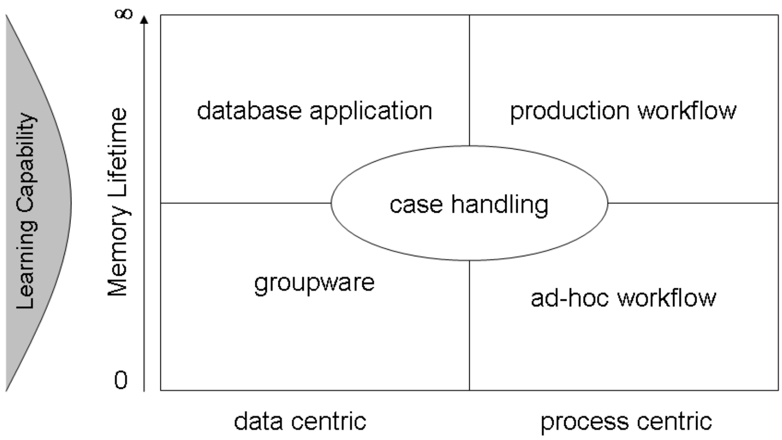

Figure 1: PAIS Spectrum

Finally, we have to consider the aspect that influences organisational KM. It concerns the balance of individual and organisational interests. This problem concerns the motivation for knowledge sharing as the basis for a PAIS built on individual work experience. [Allee 03] states several factors that influence this aspect:

- People must not be too busy and overloaded in order to find the time to take part in knowledge sharing activities. Knowledge sharing always consumes time;
- If people have time for knowledge sharing, they require certain capability of communication to make this knowledge comprehensible for others;
- Finally people need an appropriate infrastructure that allows them to share what they know. Many people mainly exchange experience only within their immediate work groups but for globally active organisation this is not sufficient (social distance [Ruggles 97]).

Fundamental precondition for a successful approach is that these intrinsic barriers are removed. That means, (1) the time consumption caused by the PAIS must be reduced as much as possible, e.g., by context evaluations that rid knowledge workers from providing already available information (2) knowledge workers must directly benefit in their everyday work by using the PAIS, e.g., by proactively providing relevant information based on the current context. (3) User must be supported by templates and other forms wherever feasible to ensure that their process knowledge is provided in a form that can be efficiently exploited by the system and other users resp. sophisticated information mining must be applied to exploit semi- or unstructured information. (4) Work experience must be made globally available under consideration of the individual privacy needs, i.e., it must be beneficial for knowledge workers to use the PAIS both in contributing to KM-activities in the organization as well as by using this work experience in their everyday work. Summing up, we can observe that motivation of knowledge workers is a crucial point for a case based PAIS. We will come back to these issues regarding personal task management.

From a psychological point of view the situation of the user can be described as a social dilemma [Cress 04]. Entering information into the PAIS requires time and effort. To be useful for other users and manageable by automatic analysis this information must be worked out elaborately. However, individually, a user has no direct benefit from providing information. Only if all users contribute to the system a payback can be expected. Therefore it is important to provide users with information that lets them reasonably expect a sufficient amount of benefits for their input. Experimental results show that the measures mentioned above might not be sufficient. For example, Cress and Hesse investigated different strategies to influence the user behaviour in favour of knowledge sharing [Cress and Hesse 04]:

- Providing metaknowledge about the importance of shared information;
- Providing rewards for contributing;
- Reducing the costs of contribution;
- Establishing organisational rules to support information sharing;
- Providing feedback about the other users' sharing behaviour.

Their conclusion from the experimental results is that the possibilities to influence the user behaviour by structural factors (reduction of cost or provision of benefits) is more limited than by social factors. This means that the measures described above must be accompanied by others that concern the latter factors. Feedback about the degree of other users' contributions can be one approach, introductory trainings of the knowledge workers another. Moreover, a strong commitment from the management also appears as an important factor.

In the next section we will demonstrate the relevance of the sketched aspects on the basis of an example from industrial engineering.

3 Use Case – Engineering Chance Request (ECR)

Today's production processes are characterised by the fact that about 25% of the working time consists in waiting for decisions and searching for information [Goltz 00]. This holds especially if multiple partners are involved and a high amount of coordination is required. Changes are all along part of today's business in modern manufacturing enterprises. They result from changing markets, customer requirements, technical innovations, or legal issues. The management of change requests involves various specific activities. The process is initiated by creating a change notification that is routed by workflow to the responsible agents. These check the issue and decide on appropriate follow-up activities. If a decision is made that an engineering change is necessary, an ECR is created on the basis of the change notification.

The management of ECRs is also part of SAP's PLM solution that includes an engineering workflow for ECRs. As SAP's central integrative technology platform SAP NetWeaver™ [Karch and Heilig 05] provides one unified user interface towards all applications that includes a model-based structured Business Workflow as well as ad-hoc unstructured activities (collaborative tasks) to allow for process flexibility. From a user's point of view both are offered as tasks in the Universal Worklist (UWL) that is part of the SAP Enterprise Portal. The model-based tasks concern standard processes, e.g. initial checks or classification of changes, whereas parts that are not standard, e.g. the soliciting of particular expertise, are treated by collaborative tasks. The different nature of both types of tasks is concealed from the user who only sees items in the UWL as her central inbox for task request.

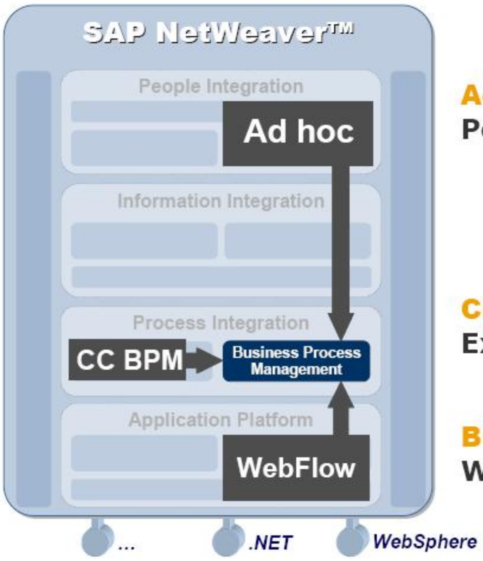

Figure 2: Business Process Management in SAP NetWeaver ™

An example for difficulties that can appear during the handling of ECRs is the treatment of scrapping costs, e.g., for spare parts or remaining stock that is no longer needed resulting from the change of the engineering process. Since these costs can be extremely high today, the decision whether an ECR is accepted can decisively depend on this detail. As long as standard parts are involved the treatment can be processed in a structured way. In this case estimates for the scrapping costs can easily be calculated. The corresponding process can be defined in the Business Workflow framework without any problems. It offers the opportunity of direct access to relevant

SAP applications, e.g., to Materials Management or Production Planning. If, however, precarious chemicals are involved, which require special disposal procedures, the procedure can become rather complicated and it can be necessary to consult various experts who must work closely together. These activities are supported by the Ad Hoc Workflow that is part of the SAP Enterprise Portal.

We see in this case that action complexity is limited but there can appear situations in which the process cannot be handled any longer in a complete structured way. Tasks can occur that require an individual treatment, e.g., the treatment of specific scrapping materials. However, some of these materials might reappear in other ECRs and it would be advantageous to get an opportunity to revert to this knowledge, respectively. Cross-Component BPM enables the execution and monitoring of processes across organisational boundaries using stateful interaction. Thus it is possible to incorporate external services, e.g., regarding the administrative operation related to the scrapping of special materials. The general embedding of these components in SAP NetWeaver™ is depicted in [Figure 2]. Both components, however, do not yet offer full support for reuse of such process parts.

We see that action complexity is partially high since unpredictable consulting activities might appear. However, in these cases some information can be reused, e.g., the expertise concerning the scrapping procedures of specific materials. Such TIUs can be used by other knowledge workers. Although the process in its entirety cannot be completely described, there are large standard parts that reappear in the processing of all or almost all ECRs. Therefore we find various process patterns that can be used to handle ECRs.

The integration of structured and unstructured tasks in the UWL already brings about several advantages. First, compared to expert consultation by email or phone, the transparency of the process is increased since it is clear who is in charge to deal a certain problem due to the corresponding task in the UWL. This also holds for the accountability which is clearly assigned as well. If a problem is assigned to several experts and one of them solves it, the work item disappears from the UWLs of the other experts. Thus the process remains up-to-date and double work is avoided. If questions are assigned to experts via collaborative tasks, it can happen that the same chemicals appear in different components, which are processed by different employees. These might then ask the same expert the identical question or, even worse, they ask different experts and get different answers. Obviously this leads to additional coordination costs. This example also shows the limits of transparency, accountability, and actuality of the current solution. Transparency is only given for task owners not for general users. Examples for the need of process transparency are indeed manifold.

A task management based on a central work list tool like the UWL centralizes the process activities in an analogous way as the email client does this for the mail processing. This is a first step to a user adapted simplification of the personal task management. However, a mere bundling of tasks in a unique tool is not sufficient to support the personal task management. Here we find a broad spectrum of possible improvements that make the task handling easier and thus motivate users to use it.

If the treatment of a specific class of chemical becomes routine, it would be very useful to make the corresponding task pattern generally available. If such a chemical is mostly treated by the same expert who has proven her expertise in previous cases, this information should be made available to all users who have to deal with similar cases. The same holds for resources since there is no model as a basis for a resource planning. Let us assume that there is only one expert for the disposal of a certain chemical but that by a legal change the procedure has become decisively more complex than before. Whereas previously one person was sufficient now the demand has multiplied. The problem must be made apparent to all affected employees as soon as possible. At best the system would even propose alternative experts or report the lack of appropriate experts. However, this information can only be determined by analysis of already executed cases that are identified as similar.

This example proves the demand for an automatically adapting system. Some changes in the business environment have an immediate effect on the process of the required proceedings. Model updates are rather slow and therefore mostly not adequate to provide the required velocity of change. A case-based PAIS brings a clear advantage in this respect.

4 Challenges

Considering this use case in the light of our observations from the preceding sections, we can state five challenges for business process and task management which pose research questions to be answered.

4.1 Process-Aware Information Support

One of the main obstacles found in knowledge intensive processes is the lack of adequate information for the current situation of knowledge workers. To support exactly these knowledge workers and settle their information needs is our first challenge. Here, the involvement of knowledge workers in a process will help in inferring their information need from the process step or task to fulfil. For instance, in the ECR use case this would be the specific chemical in an expert request which could be used to query a database or a case repository for similar requests. Approaches in the area of business process-oriented KM use the availability of processes regarding workflows to realise new methods and services for KM (cf. [Abecker et al. 02]).

4.2 Acquisition and Reuse of Process Know-How

In order to realise effective PAIS that support knowledge workers in their decision making, it is essential to consider processes not only as locations where knowledge is needed but also as locations where knowledge is produced. In the ECR case this would be the identified disposal procedure and costs for the spare parts respectively chemicals by the expert. Having the ability to acquire knowledge with relation to the processes they occur, helps in realising an adequate information support and allowing to build best practice as well as provide it where it is needed. Therefore, the second challenge is to realise the acquisition and reuse of process know-how in PAIS.

4.3 Flexibility of Process Execution

As can be observed from the ECR case, knowledge work reveals characteristics such as spontaneity and communication-orientation, low predictability, and evolvement during execution time. These characteristics pose serious problems for the support by classical PAIS such as workflow systems (cf. [Schwarz et al. 01]). However, knowledge work has a high business value and if a support by a PAIS is desired, knowledge workers need flexibility in the support system "to stay" in the environment which is essential to acquire knowledge by the PAIS. Referring to the ECR case, it would be ideal to provide an expert with the possibilities to solve a complex disposal problem within the PAIS by allowing to manage all tasks needed such as consulting other experts, querying databases, or computations within the system and record the results and rationales as information objects of the tasks. Therefore, the next challenge is to develop PAIS which allow upmost flexibility in process and task execution while still serving as sources for knowledge acquisition.

4.4 Identify and Apply Process Patterns

If the previous challenge of flexibility of process execution is realised by a PAIS to support knowledge work, we face various problems, e.g., no predefined process model can be followed throughout the execution as presented in the ECR case. Instead, we find completely new process steps with respect to tasks, variations of process models as well as various deviations and modifications to adapt the process instance to the situation. Although this provides an overwhelming amount of audit data, it is definitely difficult to exploit this valuable basis for process know-how reuse. Here, methods of process mining will allow identifying process patterns which can be provided for further process executions by knowledge workers. This allows them to iteratively identify and apply best practice in process execution while preserving the flexibility to choose the most appropriate pattern for the current task. Therefore, our fourth challenge is to apply process mining in the area of flexible and knowledge intensive process executions to identify and apply process patterns.

4.5 Make It as Simple and Beneficial as Possible for Knowledge Workers

We formulated four challenges which in the end will allow an organisation to profit from the expertise of their knowledge workers. However, this sounds just as one more promise from the KM community which will burden their users with additional work for the approach to succeed. Many knowledge management projects suffer from the underlying assumption that knowledge workers are willing to spend effort in KM activities without having a direct benefit (see [Section 2]). Discussions about incentive programs in knowledge management show the need for countermeasures. Therefore, our final challenge is to realise systems which primarily let the knowledge worker directly benefit from its usage and require minimal additional effort. We think that in the area of PAIS an integration of processes and a knowledge worker's personal task management is a key to realise such systems.

In the next section we will present some approaches which contribute towards reaching these challenges.

5 Existing Approaches

Support for knowledge workers by the workflow paradigm has been in the centre of interest for quite a time. Therefore the present approach can revert to a variety of existing approaches to the support of knowledge intensive work processes. Ever since the advent of workflow management, the deficiency of available workflow solutions regarding knowledge work has been a hot topic. Researchers used methodologies such as speech act theory, activity theory, and constraints, applied a simplified user-oriented process language or enabled collaborative process modelling (for a recent overview see, e.g., [Jørgensen 04]). The main approaches are compiled in [Table 2] with their specifics and will be discussed in the following. Many valuable features of these approaches can be adopted.

Approach	Characteristics	Reference
KnowMore	Predefined information needs for tasks; context-specific information support during runtime	[Abecker et al. 00]
PRIME	Repository with information needs & support and characterisation when applicable; information support during runtime based on user and task characteristics	[Holz 03]
CBRFlow	Context-specific selection and application of process steps from a case base via conversational CBR	[Weber and Wild 05]
Adept	Workflow system supporting both ad-hoc changes and evolutionary/structural changes.	[Rinderle at al. 04]
FRODO	Agile knowledge workflows for knowledge work; context dependent change suggestions and provision of information and similar tasks / workflows	[Elst et al. 03]
FLOWer	Case handling system supporting a mixture of structured and unstructured processes and data	[Aalst et al. 05]

Table 2: Approaches to knowledge intensive work processes

The KnowMore approach is applicable for well structured processes where knowledge intensive tasks and their contents are known in advance, thus, allow for modelling information needs during build-time within a workflow activity. However, as mentioned, knowledge work bears characteristics that make classical workflows inappropriate here. The PRIME-system is similar to the previous approach but more flexible due to the separation of tasks and information needs which allow defining an information need and relevant information for a broader range of tasks and respective situations. Therefore, such an approach is also applicable if users are already able to adapt workflows to their needs. Given that flexibility, the question arises how to support users in determining appropriate changes.

CBRFlow introduces the additional feature that a user can enter a dialogue and state facts about the current situation. On this basis similar cases are retrieved from the associated case base. The dialogue is continued until the user finds an appropriate process step which she can introduce in the existing workflow. The system learns new cases (situation/process step combinations) by explicit annotation when the user adapts an existing or creates a new process step. To cope with problems of actual running workflow modifications, Rinderle et al. propose in [Rinderle et al. 05] an integration of CBRFlow and ADEPT - an adaptive workflow system which supports consistency preserving (ad-hoc) changes to workflow models and the subsequent migration of already running workflow instances [Rinderele et al. 04] - to memorize changes to workflows and their reuse in similar situations while preserving consistency of the modified workflows.

In FRODO, workflow changes are retained and offered to users in similar situations based on the current workflow context. The system is first of all designed for a knowledge worker accomplishing her personal work who is, however, still embedded in a team's workflow. Thus, a workflow could start from scratch as a personal ToDo-list, be refined and attached with information such as memos or documents. It can also be extended to colleagues using task delegation and in the end it represents the work accomplished and the knowledge items used and produced. In this way the workflow integrates previously hidden process know-how. Since the workflows are embedded in an organisational memory, various services can be provided such as proactive and context-specific information support, support in planning work by providing appropriate task instances from colleagues or task templates from a model repository, capture and disseminate process know-how, and finally allow for process-oriented knowledge organisation. For a detailed discussion of this approach from an information assistance point of view see [Holz et al. 2005].

FLOWer of Pallas Athena belongs to the small number of PAIS that follow a case based approach that can simultaneously deal with data and processes. Case handling is a new paradigm for supporting flexible and knowledge intensive business processes. It is strongly based on data as the typical product of these processes. Unlike workflow management, which uses predefined process control structures to determine what *should* be done during a workflow process, case handling focuses on what *can* be done to achieve a business goal. In case handling, the knowledge worker in charge of a particular case actively decides on how the goal of that case is reached, and the role of a case handling system is assisting rather than guiding her in doing so. The core features of case handling are: (1) avoid context tunnelling by providing all information available (i.e., present the case as a whole rather than showing just bits and pieces), (2) decide which activities are enabled on the basis of the information available rather than the activities already executed, (3) separate work distribution from authorization and allow for additional types of roles, not just the execute role, (4) allow workers to view and add/modify data before or after the corresponding activities have been executed (e.g., information can be registered the moment it becomes available). These features have been implemented in FLOWer [Aalst at al. 05].

6 Proposed Approach

Classical WfMS are too restrictive for weakly-structured processes that characterise knowledge intensive work, although the workflow paradigm is very attractive in terms of provided functionalities such as modelling and coordinating processes (in teams), supporting environments for executing activities, monitoring the current state of affairs, and providing rich workflow context [Maus 01], as well as logging mechanisms providing a process history for later access. However, a tool that is to meet the needs of knowledge work must support structured and unstructured process parts in a uniform way. Precondition for an appropriate solution is the recognition of task patterns based on detailed task descriptions.

From this bottom-up approach we also obtain another requirement. This concerns the motivation of users to record and share their task knowledge [Davenport et al. 98]. This is not a trivial requirement and necessitates careful investigations on personal knowledge management (PKM) [Wright 05]. PKM must establish links between the users' individual knowledge and task handling and the organisational knowledge management (OKM).

The described approach is to be realised on the basis of a PAIS which can be only partially built on existing BPM technology due to the bottom-up approach instead of the usual top-down proceeding.

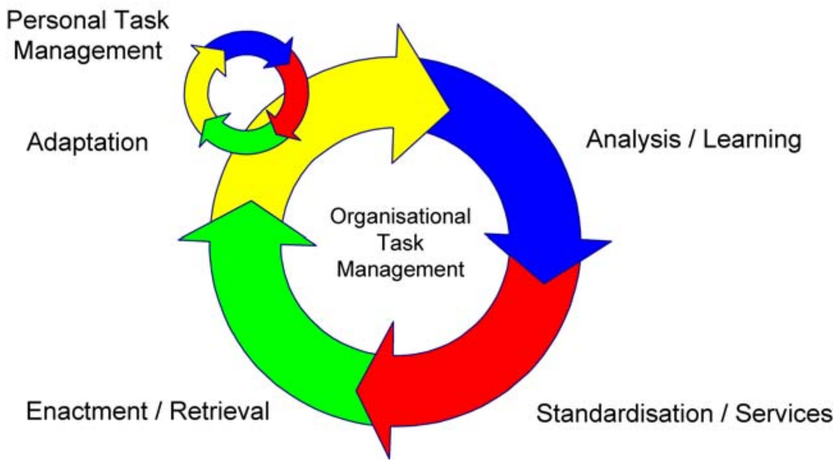

Figure 3: Task and Process Lifecycle

Bottom-up approach means that the information originates from the task executers instead of special process engineers. The general procedure is described in [Figure 3]. The smaller circle describes the personal task management in which users provide the information on which the entire task and process support is built. Knowledge workers define their tasks by specification of a task related process and assignment of appropriate information for later use. In the course of task execution this process can be adapted and new information can be included. This personal task information is managed in a decentralised way for every user in personal case repositories.

The bigger circle describes the phases of the task support in organisational context. In the analysis phase, the adapted processes, as provided by the users, are analyzed regarding reusable patterns and other kinds of information, partially by comparison to original patterns. Task structures and components will be defined in a way that allows disintegration into independently usable information units. The information is consolidated and transferred to a central repository.

In the standardisation phase, the repository allows process and service engineers to monitor the existing processes. Processes can be standardised by the definition of business rules that are applied to all individual processes. New processes can be designed and offered to the users. Business rules can even enforce such processes as standards. This phase also opens the opportunity to service engineers to specify services that are offered within a network of cooperating partners.

In the retrieval phase, appropriate process patterns and task information are identified on the basis of user specification and context and offered to the requesting users who are thus enabled to design their individual task description from the offered components. The identification of appropriate patterns is not only based on the users' input but also on information about their contexts. In this way the retrieval will be made much easier for the users.

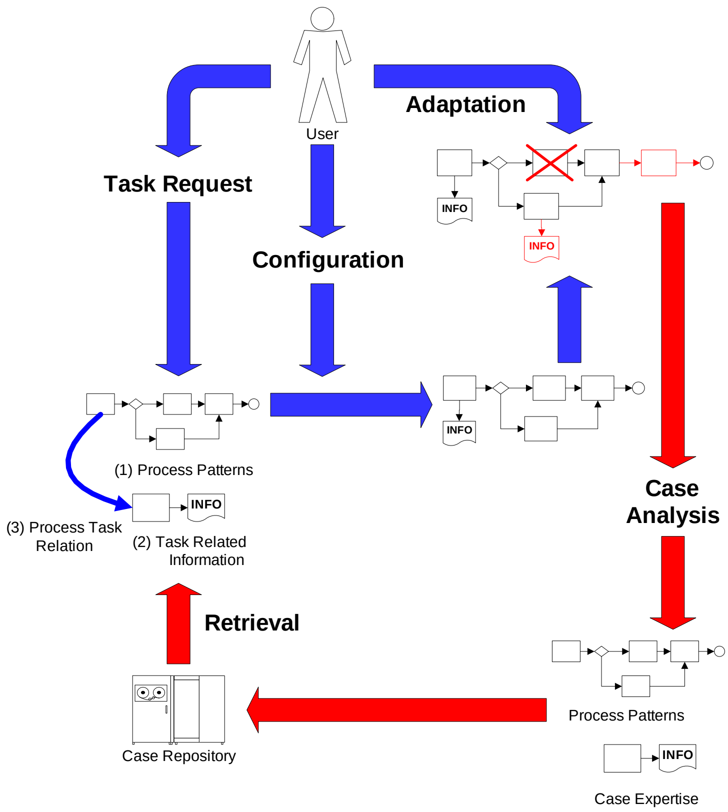

Figure 4: Users Handling Tasks and Processes

[Figure 4] shows the way how users deal with task patterns and task related information. The access to this information is realised via a retrieval process. Users provide information that characterises the task they want to accomplish. On the basis of this information the PAIS provides different kinds of TIUs: (1) Process Patterns that can be used to structure the task into suitable sub-tasks; (2) Task Related Information, which support the execution of task, e.g., regarding experts who can be consulted or external services on which the user can draw; and finally (3) relations between these information units and the task or specific sub-tasks of a chosen process pattern. These relations are not necessarily related to fixed process steps since they are more closely bound to domain aspects than process patterns, e.g., a report writing pattern can be more generally used than certain information concerning a possible state-of-the-art step in the report writing process. The users individually compose the different TIUs that they get and build their own task support structure on this basis. These structures are not fixed but can always be adapted to changing conditions or new experience regarding the process. In particular they can add very specific information to the task structure that only concerns their case. This might also include mistakes and predefined process structures that are not suitable for the current case.

After the case is completed the user can review it and decide which parts of it might be generally relevant. The tolerance regarding such a decision depends on the organisational policy and the users' role within the organisation. Those parts that are released will undergo a pattern and information analysis as described in the next subsection. The aim of this analysis is a disintegration of the different TIUs that are entangled in the case description. Due to this entanglement the mere separation of the case is not sufficient. It is rather necessary to enrich the resulting raw TIU in order to compensate the omission of context knowledge that is required for an individual reuse of these TIUs that are then made available to task retrieval.

6.1 Personal Task Management

As mentioned in [Section 4], a central challenge we have to face is to attract knowledge workers to do their work "within" the system, i.e., we have to provide an environment that allows knowledge workers to easily organize and accomplish their work. In case of acceptance, the envisioned PAIS will provide assistance based on process know-how from knowledge workers as well as use this information for analysis purposes.

We see two main areas to accomplish this attraction for knowledge workers: First, supporting the "personal" knowledge management as well as the personal task management. To focus on the user's "personal" knowledge management – i.e., searching and identifying, classifying and storing, retrieving and applying as well as distributing information resp. knowledge in a user's *personal knowledge space* (PKS) – is motivated by users' avoidance of additional work for KM-initiatives without immediate benefit. The topic has been recently addressed in the project EPOS[1] that provides such a PKS which is fed by the user's native structures found, e.g., in file directories, bookmarks, email folders as well as task structures (ToDo-lists or work lists from WfMS) together with attached documents, respectively. These structures reflect the user's subjective view, e.g., the meaning of a user's mail folder is expressed by the set of contained emails. Furthermore, the user also takes part in the organisation which is reflected by the used organisational structure, project

[1] Evolving Personal to Organizational Knowledge Spaces; `http://www.dfki.de/epos`.

workspaces, processes, and domain ontologies which also influence the user's view and work behaviour. Using this environment, EPOS-services are able to support knowledge workers in their activities considering their own subjective views. For instance, an assistant bar provides relevant structures, information (documents, emails, notes), colleagues, and workflow tasks to support the assumed user goal which is derived from user observation within the PKS [Schwarz and Roth-Berghofer 03, Schwarz 05]. The more users elaborate their personal knowledge space, the more they contribute to an organisational knowledge space which is leveraged from the collection of individual knowledge spaces [Elst and Kiesel 04], thus providing a bottom-up approach to organisational memories.

In that way, EPOS enables a transition between the personal knowledge management and a user's task management, i.e., the EPOS approach consequently allows learning more about a single (workflow) task fulfilment. This will support users to explicitly structure their work. So far a main drawback of agile workflow approaches, such as the weakly-structured workflows in [Elst et al. 03], is the demand of modelling efforts of users during their work. Capturing domain and process know-how does not only aim at immediate user support but also at later reuse in similar cases. Undue efforts only inhibit users from modelling their work in detail. Thus, there is a trade-off between the necessary effort for organizing the work and providing as much details as possible for an effective assistance later on. For instance, in our ECR use case, it should be explained in detail why the decision was taken instead of simply telling the result and going on with the next tasks as soon as possible. The approach taken in EPOS is to additionally observe the user's desktop activities, interaction with applications (email, browser, text editor, document repository), as well as information items, to build and leverage a user's context and try to figure out the generic task the user is executing. Such a generic task or *task pattern* is part of an ontology of task patterns containing part-of and is-a hierarchies, and relations to task and workflow models as well as current instances realising one or more generic tasks [Schwarz 03]. In contrast to the top-down approach of weakly-structured workflows – from the abstract task definition to a refined task – this describes a bottom-up approach by observing user activities. A similar approach is reported in [Fenstermacher 05] to realise a process-oriented support for knowledge workers in agile processes. Once having identified such task patterns, this can be used for supporting users without requiring detailed workflows. However, it will also semi-automatically enrich workflows with observed task patterns in order to refine workflow tasks without (much) user interaction.

The integration aspect in the PKS becomes especially important since a task management has to compete with email as today's most favourite structuring tool for collaborative tasks (see [Bellotti et al. 05]). Compared to phone calls, email brings the advantage of asynchronous communication, i.e., questions can be issued when they occur, replies can play the role of reminders, and questions and answers persist and can be accessed also later. However, if we look at the disadvantages of emails (cf. [Whittaker and Snider 96]) we observe that they are too unstructured. For example, they can get lost, stay (unawarely) unanswered, or the relation between different emails and their topic can get lost. Another problem is that email is inappropriate to structure personal work since it is designed as communication tool and if it is mixed up with task management it definitely looses its lightweight character. A successful task management that shall compete with email must decisively reduce effort and complexity of task handling to convince users. Simplicity is one of the major causes for the success of email.

In this regard, research on personal task management is an important complement to task pattern management. It helps to understand how knowledge workers manage their personal work (see, e.g., [Bellotti et al. 04]) in order to realise a convenient user environment keeping users in their personal knowledge (work-) space as the basis for the acquisition of process knowledge, instead of using, e.g., paper notes to manage their tasks that are out of the reach of automatic analysis.

More details on the realisation of a task-oriented view on a user's PKS is given in [Holz et al. 05] in this issue.

6.2 Process Mining

A case-base PAIS essentially relies on the analysis of stored cases in order to extract reusable TIUs. On the one hand, these TIUs must be simple enough to be manageable by all knowledge workers to organize their personal tasks in a convenient and integrated way and, on the other hand, they must be rich in content to be actually helpful. Therefore an efficient process mining, i.e., discovering process knowledge from existing process data, must be a central part of the PAIS.

case identifier	activity identifier	performer
case 1	activity A	John
case 2	activity A	John
case 3	activity A	Sue
case 3	activity B	Carol
case 1	activity B	Mike
case 1	activity C	John
case 2	activity C	Mike
case 4	activity A	Sue
case 2	activity B	John
case 2	activity D	Pete
case 5	activity A	Sue
case 4	activity C	Carol
case 1	activity D	Pete
case 3	activity C	Sue
case 3	activity D	Pete
case 4	activity B	Sue
case 5	activity E	Clare
case 5	activity D	Clare
case 4	activity D	Pete

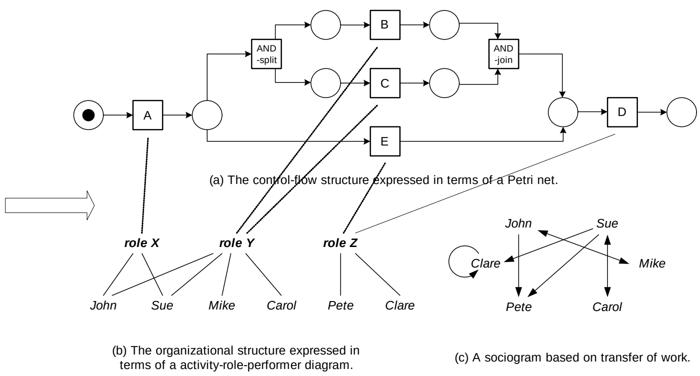

Figure 5: Process mining example: Based on some event log a process model (a), an organisational model (b) and a social network (c) are discovered

[Figure 5] shows the basic idea of process mining as it has been implemented in tools such as ProM (cf. www.processmining.org). Based on an event log (e.g., an audit trail or a transaction log) models are derived using a variety of techniques. For example, using the alpha algorithm [Aalst et al. 04] it is possible to construct a process model in terms of a Petri net (or an EPC, or similar notation). This is not limited to the process (control-flow) perspective as shown in the figure.

The central idea of process mining is not new. For example attempts have been carried out to analyze event logs. The idea of applying process mining in the context of workflow management was first introduced in [Agrawal et al. 98]. Further approaches addressing this problem can be found in [Cook and Wolf 98]. They describe three approaches one based on neural networks, a purely algorithmic one, and one Markovian approach. [Schimm 00] describes a mining tool that allows the discovery of hierarchical workflow processes. Herbst and Karagiannis applied an inductive approach to the problem [Herbst and Karagiannis 98, Herbst 00]. They introduced the ADONIS modelling language and used stochastic task graphs as intermediate representation. [Aalst et al. 2004] concentrated on workflow processes with concurrent behaviour. To address the problem of noise and incompleteness more heuristic approaches [Weijters and Aalst 02, Weijters and Aalst 03] have been developed later. The latter approaches are based on the alpha algorithm.

As mentioned before process mining is not restricted to a mere process perspective (also referred to as control-flow, describing the causal order of activities) but also includes organisational and data aspects [Aalst and Song 04]. The organisational perspective deals with the organisational structure and the people who are part of this structure. Here the focus is the discovery of social networks in this structure. For example, there are people who are used to work together informally because they deal with similar problems. This information can be used to build communities of practice [Lave and Wenger 91, Wenger et al. 02].

Starting from approaches that are based on the evaluation of event logs the situation for process mining is rather complicated since the available information is of extremely fine granularity. To come from this information to process descriptions is a complicated and error-prone. Starting from a situation as described in [Figure 3] appears as more promising due to the richness of the available information derived from direct case recordings. Although the focus of the approach is on task management rather than process management, emphasis must be placed on events inside tasks and between tasks. One can think of tasks as mini-workflows and therefore it makes sense to also search for patterns at the level of events (i.e., the execution of operations inside task and the exchange of messages/triggers with the environment). To reach this goal process mining techniques must be extended and modified to suit this purpose.

6.3 Organisational Aspects

Focussing on the individual task executers' needs also involves some risks. The most important one is that organisational requirements like standardization and process alignment are not sufficiently regarded. In the traditional workflow paradigm organisational aspects are intrinsically considered. In the case based approach they must be externally introduced. This must be done in a form that preserves the fundamental achievements gained by the user centricity. Therefore the organisational demands can only be introduced as certain constraints on the free composition of tasks. We will call these constraints business rules.

Business rules were originally introduced to make business applications more flexible and adaptable [Halle 01]. In a case based approach the focus of business rules is to be restricted to process structures as basis of an organisational policy. A similar situation regarding business rules for PAIS frameworks also appears in the context of mobile agent infrastructures [Meng et al. 05]. The approach is based on web services and resembles the suggested approach in terms of bottom-up proceeding. However, their business rules are not mainly applied to determine the task succession and not to achieve organisational goals.

Business rules have to interfere at different stages of the information lifecycle. First, it must be ensured that the extracted patterns are compliant with them. Second, the users have the opportunity to adapt processes to their needs, but also here every change must be compliant with the rules. Nonetheless business rules must not be considered as static. Business can be rather complex since they do not only have to control the process but might only be applicable to certain parts of the organisation. Thus business rules are based on much broader information than plain process structures.

6.4 Discussion

Although the approaches presented in [Section 5] try to support knowledge work by increasing flexibility they are still based on static models that have to be adapted manually if the standard behaviour is to be changed. Generally, the development of models is expensive and models developed from the scratch are often far from reality when applied. Often companies develop core processes by activating information that is available from their Enterprise Resource Planning systems. However, it seems to be more promising to acquire relevant process information on the basis of execution experience.

Therefore, a pattern based approach built on executed cases is preferable. It allows for a continuous adaptation of processes to external changes and offers more variability for individual needs. Even if we have to face the problem that the offered process templates might become fluctuant due to the developing case base this should not be problematic if we turn to really individual task handling. Task patterns require repositories containing descriptions of cases, which have been executed, including all relevant task constituents. Context, goal, and planning information must be stored and can be used to identify appropriate task patterns. Repeated successful execution of related tasks allows identifying expertise in specific domains. Therefore, the assignment of agents can be seen as source for expert identification.

A case repository, however, can also suit other purposes than pattern and expert recognition. Case repositories provide the opportunity to precisely monitor the execution of task. The state of every task, even if it is separated into a full hierarchy of subtasks, becomes transparent. They also allow for the identification of negative patterns, i.e., patterns that did not lead to the planned goal. Therefore, representations of cases must provide enough information to support other users in planning, coordinating, and executing processes. Moreover, a task recording is the ideal basis for archiving cases by tracking the complete executions. This includes ex post documentation of failures, which is often neglected otherwise. Thus, problems, which results from decisions in previous tasks, can be identified to avoid further failures.

Some of these features might be known from project management. This particularly concerns the planning of tasks and their dependencies. However, the focus of project management is the planning of a process in its individual complexity, while the present approach concentrates on repetitive aspects of processes. The tracking of process experience is not an additional external but an internal aspect. This makes motivation of users, who have to record tasks, a crucial issue. Central motivation is the offering of direct benefits. One benefit is that processes become fully transparent. However, this only works if the users do not feel harassed by task recording, i.e., recording must not become too complex. Here we need a seamless integration of tasks in the personal task management as developed in the EPOS approach. This is a fundamental precondition for treating this kind of knowledge intensive and weakly-structured processes. Only a task management based on consequential user centricity will be successful. Consequently, KM technology has to play a predominant part in such a system reflecting the close relation between knowledge and user action [Wiig 04]. For example, case knowledge must be represented and made available to users, existing cases must be analysed for process knowledge, processes include collaboration and expert identification, and efficient pattern mining is mandatory.

7 Conclusions

In this article we presented a bottom-up approach for evolving a company's business process management based on the execution experience of their knowledge workers while ensuring the required flexibility as well as providing assistance for knowledge workers to stay productive, creative, and motivated.

We showed in a use case of Engineering Chance Requests the complexity of today's knowledge work, how it is supported by recent SAP software solutions, and which problems still occur. In the light of requirements for knowledge work we stated four challenges for business process and task management which can be summarized as follows:

- Process-aware information support, to realise an intelligent assistance for knowledge workers;
- Acquisition and reuse of process know-how, to exploit knowledge worker's process experience for KM-services;
- Flexibility of process execution, to take account of knowledge work's characteristics and ensure the required flexibility;
- Identify and apply process patterns, to evolve organisational processes and support knowledge workers in applying best practices;
- Make it as simple and beneficial as possible for knowledge workers, to motivate knowledge workers to "stay" in the system and to use it to accomplish their everyday work.

The envisioned PAIS which faces these challenges combines state-of-the-art research, namely, personal and business process-oriented knowledge management, task management and workflow support for weakly-structured processes, process mining and pattern management, and finally business rules for compliance.

Looking at the general relevance of the proposed approach we can go back to Peter Drucker who already proclaimed in 1993 the increase of knowledge worker productivity (in a magnitude similar to the increase of the manual worker productivity achieved within the last century) to be the biggest challenge of this century [Drucker 93]. He identified six factors which foremost determine knowledge worker productivity, two of them directly relating to the realm of our presented approach:

- It demands that we impose the responsibility for their productivity on the individual knowledge workers themselves. Knowledge workers have to manage themselves. They have to have autonomy.
- Continuing innovation has to be part of the work, the task and the responsibility of knowledge workers.

Contrary to Drucker's call for knowledge worker autonomy, new rules and regulations such as the Sarbanes-Oxley Act in the UK and the Contra-G law in

Germany force companies to ensure that their business processes are standardised, transparent, traceable, and well controlled. In order to comply (and to prove compliance!) to these regulations organisations have to limit the autonomy of their knowledge workers significantly by imposing standardised work processes on them and by enforcing those by the application of PAIS. What makes the situation even worse is that it has become apparent that classical PAIS are too restrictive for agile processes that characterise knowledge intensive work [Schwarz et al. 01].

In addition to limiting the autonomy of the knowledge workers in an individual instance, these standard processes and PAIS also prevent knowledge workers from improving their work processes on the fly, adapting to new situations and new requirements when needed. This leads to outdated PAIS (and underlying process models) which obstruct work more than they support it. Considering the immense amounts which are spent on process modelling, process reengineering, PAIS creation and the like, the described dilemma is far out of the realm of a theoretical discussion but affects revenues significantly.

The presented approach will resolve this dilemma by allowing for

- Highly autonomous and flexible knowledge work environments supporting grass-roots development of standardised business tasks, processes, and services out of everyday work practice while leaving the knowledge worker in the centre of attention;
- Consolidation and reuse of process knowledge by deriving process patterns from individual cases; and
- Integrated compliance checks with business rules.

Moreover, the presented approach is particularly interesting for SME since these do not apply standardised processes to such a degree as large companies. Therefore the standard BPM methods are mostly not applicable to them. However, even SME demand for knowledge reuse as various Knowledge Management initiatives in SME show. In particular, SME rely on sharing resources within co-operating networks in order to realise innovation, widen product portfolios, and establish new supplier relationships [Levy et al. 03]. Joint processes play a decisive role in these co-operations. Here we see a substantial potential for improvement.

That the presented ideas are not only of theoretical interests can be seen from the fact that the middle and long term strategy of SAP BPM will aim at a full integration of structured core processes and unstructured collaborative tasks, closely related to the presented approach. The primary target is a consistent handling of both task types and the avoidance of errant processes. A consistent workflow environment (UWL) will allow users to survey the entire process related to a workflow item, in which they are involved. Transitions from ad hoc processes to core processes must be smooth. Process mining will become mandatory. The most challenging step will be the implementation of a fully pattern based workflow, which will be the focus of our future research.

Acknowledgements

The authors would like to thank Stefanie Lindstaedt, Marielba Zacarias, Artur Caetano, Felix Nyffenegger, Wolfgang Theilmann and Stefan Scheidl for the collaboration on the topic of case-based task management that helped to bring forward this project.

References

[Aalst et al. 00] Aalst, W.M.P. v. d.; Basten, T.; Verbeek, H. M. W.; Verkoulen, P. A. C.; Verhoeve, M.: "Adaptive Workflow. On the Interplay between flexibility and support"; J. Filipe, editor, Enterprise Information Systems, Kluwer, Norwell (2000), 63-70.

[Aalst et al. 04] Aalst, W.M.P. v. d.; Weijters A.J.M.M.; Maruster, L.: "Workflow Mining: Discovering Process Models from Event Logs"; IEEE Transactions on Knowledge and Data Engineering 16, 9 (2004), 1128-1142.

[Aalst et al. 05] Aalst, W.M.P. v. d.; Weske, M; Grünbauer, D.: Case Handling: "A New Paradigm for Business Process Support"; Data and Knowledge Engineering, 53 (2005), 129-162.

[Aalst and Song 04] Aalst, W.M.P. v. d.; Song M.: Mining Social Networks: "Uncovering Interaction Patterns in Business Processes"; J. Desel, B. Pernici, and M. Weske, (eds.), International Conference on Business Process Management (BPM 2004), Lecture Notes in Computer Science, vol. 3080 (2004), 244-260.

[Abecker et al. 00] Abecker, A.; Bernardi, A.; Hinkelmann, K.; Kühn, O.; Sintek, M.: "Context-Aware, Proactive Delivery of Task-Specific Knowledge: The KnowMore Project"; Int. Journal on Information Systems Frontiers (ISF), Special Issue on Knowledge Management and Organizational Memory, Kluwer (2000).

[Abecker et al. 02] Abecker, A.; Hinkelmann, K.; Maus, H.; Müller, H. (eds.) : „Geschäftsprozessorientiertes Wissensmanagement – Effektive Wissensnutzung bei der Planung und Umsetzung von Geschäftsprozessen"; Springer xpert.press, Berlin (2002).

[Agrawal et al. 98] Agrawal, R.; Gunopulos, D.; Leymann, F.: "Mining Process Models from Workflow Logs"; Sixth International Conference on Extending Database Technology (1998), 469-483.

[Allee 03] Allee, V.: "The Future of Knowledge"; Elsevier, Burlington, MA (2003).

[Bellotti et al. 04] Bellotti, V.; Dalal, B.; Good, N.; Bobrow, D. G.; Ducheneaut, N.: "What a to-do: Studies of task management towards the design of a personal task list manager"; ACM Conference on Human Factors in Computing Systems (CHI04), Vienna, Austria. (2004), 735-742.

[Bellotti et al. 05] Bellotti, V.; Ducheneaut, N.; Howard, M., Smith, I., Grinter, R. E.: "Quality versus quantity: E-mail-centric task management and its relation with overload"; Human-Computer Interaction. Lawrence Erlbaum Associates 20(1-2) (2005), 89-138.

[Cook and Wolf 98] Cook, J.E.; Wolf, A.L.: "Discovering Models of Software Processes from Event-Based Data"; ACM Transactions on Software Engineering and Methodology 7, 3 (1998), 215-249.

[Cress 04] Cress, U.: "Strategic, metacognitive, and social aspects in resource-oriented knowledge exchange"; R. Alterman; D. Kirsch (Eds.): Proceedings of the 25th Annual Conference of the Cognitive Science Society, Lawrence Erlbaum, Mahwah, NJ (2004).

[Cress and Hesse 04] Cress, U.; Hesse, F.W.: "Knowledge sharing in groups: Experimental findings of how to overcome a social dilemma"; Y. Kafai, W. Sandoval, Enydey, N., A.S. Nixon & F. Herrera: Proceedings of the Sixth International Conference of the Learning Sciences, Mahwah, NJ, Lawrence Erlbaum (2004), 150 -157.

[Davenport et al. 98] Davenport, T. H.; De Long, D. W.; Beers, M. C.: "Successful Knowledge Management Projects"; Sloan Management Review (1998), 43-57.

[Drucker 93] Drucker, P.F: „Post-Capitalist Society“; Butterworth Heinemann, Oxford (1993).

[Elst et al. 03] Elst, L. v.; Aschoff, F.-R.; Bernardi, Maus, H.; Schwarz, S.: “Weakly-structured Workflows for Knowledge-intensive Tasks: An Experimental Evaluation”; Knowledge Management for Distributed Agile Processes (KMDAP) at IKNOW’03 (2003).

[Elst and Kiesel 04] Elst, L. v.; Kiesel, M.: “Generating and integrating evidence for ontology mappings”; Engineering Knowledge in the Age of the Semantic Web: Proc. EKAW04, Springer, Berlin (2004).

[Fenstermacher 05] Fenstermacher, K. D.: “Revealed Processes in Knowledge Management”; Proc. KMDAP 05 at the WM 05, Kaiserslautern, Germany (2005).

[Goltz 00] Goltz, M.: “Collaborative Product Development in a Distributed Engineering Environment”; IMW – Institutsmitteilungen Nr. 25 (2000), 43 -50.

[Halle 01] Halle, B. v.: “Business Rules Applied”; Wiley, New York, NY (2001).

[Herbst 00] Herbst, J.: “A Machine Learning Approach to Workflow Management”; Proceedings 11th European Conference on Machine Learning, vol. 1810 of Lecture Notes in Computer Science, Springer, Berlin (2000), 183-194.

[Herbst and Karagiannis 98] Herbst, J.; Karagiannis, D.: “Integrating machine learning and workflow management to support acquisition and adaptation of workflow models”; Proceedings of the Ninth International Workshop on Database and Expert Systems Applications, IEEE (1998), 745–752.

[Holz 03] Holz, H.: “Process-Based Knowledge Management Support for Software Engineering”; PhD-Thesis, TU Kaiserslautern, dissertation.de Verlag (2003).

[Holz et al. 05] Holz, H., Maus, H., Bernardi, A., Rostanin O.: “A Lightweight Approach for Proactive, Task-Specific Information Delivery”; J.UKM (2005), Vol. 0, Issue 2, pp.101-127, http://www.jukm.org/jukm_0_2/from_lightweight_proactive_information.

[Jørgensen 04] Jørgensen, H. D: ”Interactive Process Models. Norwegian University of Science and Technology”; Trondheim, Norway, Dissertation (2004).

[Karch and Heilig 05] Karch, S.; Heilig, L.: “SAP NetWeaver Roadmap”; SAP Press, Bonn (2005).

[Lave and Wenger 91] Lave, J.; Wenger, E.: “Situated Learning: Legitimate Peripheral Participation”; Cambridge University Press, Cambridge (1991).

[Levy 03] Levy, M.; Loebbecke, C.; Powell, P.: “SMEs, co-opetition and knowledge sharing: the role of information systems”; European Journal of Information Systems, 1 (2003) 1-15.

[Maus 01] Maus, H.: “Workflow Context as a Means for Intelligent Information Support.”; Modeling and Using Context. CONTEXT'01, Dundee, UK, vol. 2116 of Lecture Notes in Artificial Intelligence, Springer , Berlin (2001).

[Meng et al. 05] Meng, J.; Su, Y. W.; Lam, H.; Helal, A.; Xian, J.; Liu, X.; Yang, S.: “DynaFlow: A Dynamic Inter-Organizational Workflow Management System”; Int. Journal of Business Process Integration and Management (IJBPIM) 1, 2 (2005) *to appear*.

[Rickayzen 04] Rickayzen, A.: “A Primer on Business Process Management in SAP NetWeaver”; SAPinsider, Wellesley Information Systems, (July – September 2004).

[Rinderle at al. 04] Rinderle, S.; Reichert, M.; Dadam, P.: “Correctness Criteria for Dynamic Changes in Workflow Systems - A Survey. Data and Knowledge Engineering”, Special Issue on Advances in Business Process Management 50, 1 (2004), 9-34.

[Rinderle et al. 05] Rinderle, S.; Weber, B.; Reichert, M.; Wild, W.: „Integrating Process Learning and Process Evolution: A Semantics Based Approach"; W. M. P. van der Aalst, B. Benatallah, F. Casati, F. Curbera (eds.), Business Process Management: 3rd International Conference, BPM 2005, Lecture Notes in Computer Science, vol. 3649 (2005), 252 – 267.

[Riss 05] Riss, U. V.: "Knowledge, Action, and Context: Impact on Knowledge Management"; Lecture Notes in Artificial Intelligence, vol. 3782 (2005), 598-608.

[Riss and Wagland 05] Riss, U. V.; Wagland, C.: "Opportunities and Challenges for Collaborative Task Management Based on Enterprise Services Architecture"; Proc. ECKM 2005, University of Limerick, Ireland (2005), 485-493.

[Ruggles 97] Ruggles, R.: "Knowledge tools: using technology to manage knowledge better"; working paper, Ernst & Young Center for Business Innovation (1997), also appeared as electronic version http://www.cs.toronto.edu/~mkolp/lis2103/kmtools.pdf.

[Schimm 00] Schimm, G.: "Generic Linear Business Process Modeling"; S. W. Liddle, H.C. Mayr, and B. Thalheim (eds.), Proceedings of ER 2000 Workshop on Conceptual Approaches for E-Business and The World Wide Web and Conceptual Modeling, vol. 1921 of Lecture Notes in Computer Science, Springer, Berlin (2000), 31-39.

[Schwarz et al. 01] Schwarz, S.; Abecker, A.; Maus, H.; Sintek, M.: „Anforderungen an die Workflow-Unterstützung für wissensintensive Geschäftsprozesse"; Proc. WM 01. Baden-Baden, Germany (2001).

[Schwarz 03] Schwarz, S.: „Task-Konzepte: Struktur und Semantik für Workflows"; Proc. WM 03, Luzern, Switzerland, GI LNI 28 (2003).

[Schwarz 05] Schwarz, S.: "A Context Model for Personal Knowledge Management"; Proc. of the IJCAII'05 Workshop on Modeling and Retrieval of Context, Edinburgh, Scotland. Springer (2005) *to appear.*

[Schwarz and Roth-Berghofer 03] Schwarz, S.; Roth-Berghofer, T.: "Towards Goal Elicitation by User Observation"; Workshop on Knowledge and Experience Management at GI FGWM 03, Karlsruhe, Germany (2003).

[Weber and Wild 05] Weber, B.; Wild, W.: "Towards the Agile Management of Business Processes"; Proc. KMDAP 05 at the WM 05, Kaiserslautern, Germany (2005), 375-382.

[Weijters and Aalst 02] Weijters, A.J.M.M.; Aalst, W. v. d.: "Workflow Mining: Discovering Workflow Models from Event-Based Data"; C. Dousson, F. Höppner, and R. Quiniou, (eds.), Proc. of the ECAI Workshop on Knowledge Discovery and Spatial Data (2002), 78-84.

[Weijters and Aalst 03] Weijters, A.J.M.M.; Aalst, W. v. d.: "Rediscovering Workflow Models from Event-Based Data using Little Thumb"; Integrated Computer-Aided Engineering, 10, 2 (2003), 151-162.

[Wenger et al. 02] Wenger, E.; McDermott, R.; Snyder, W.M.: "Cultivating Communities of Practices: A Guide to Managing Knowledge"; Harvard Business School Press (2002).

[Whittaker and Snider 96] Whittaker, S.; Sidner, C.: "Email Overload: Exploring Personal Information Management of Email"; Conf. on Human Factors in Computing Systems, CHI 96, Vancouver, Canada (1996).

[Wiig 04] Wiig, K.: "People-Focused Knowledge-Management"; Elsevier Butterworth-Heinemann, Burlington, MA (2004).

[Wright 05] Wright, K.: "Personal knowledge management: supporting individual knowledge worker performance"; Knowledge Management Research & Practice 3 (2005), 156-165.