Active process model supported collaboration

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ABSTRACT: We discuss the reuse of process knowledge through conceptualized workflow patterns. Knowledge reuse in the life-cycle of projects has been widely studied, but most known solutions focus on communication issues, isolated from the processes themselves. Due to the huge potential benefits from the immediate reuse of communicated information (e.g. architectural, structural solutions, details, technical specifications, etc.) most of the attention has been given to information retrieval techniques and contextualization of the retrieved information. Actual processes, actors and tools that have led to results of work usually remained unrecorded, since this was considered technically impossible. Indeed, in contrast to intuitive ad-hoc reuse of parts of documents that fit into a given context, ad-hoc reuse of parts of actual processes together with meta-descriptors is not so straightforward. In the paper we identify the methods and media in which processes were modeled and executed as the main problem to achieve this goal. Based on analysis of process modeling techniques, we suggest a novel methodological approach and a conceptual solution for a prototype collaboration system supported by active process models.

1 INTRODUCTION

Knowledge reuse in the life-cycle of projects has been widely studied. From the process perspective we can divide knowledge into two main categories: (1) knowledge about processes, and (2) process results as containers of knowledge. Currently, most known solutions address the reuse of knowledge that is communicated through different traditional and digital communication channels – isolated from the processes themselves. Due to the huge potential benefits from the immediate reuse of communicated information (e.g. architectural, structural solutions, details, technical specifications, etc.) most of the attention has been given to information retrieval (IR) techniques and contextualization of the retrieved information. However, reuse of *all available* knowledge is the key to efficient dynamic decision making (DDM) of project teams. Gonzales (2005) aggregates three definitions of DDM: (1) the need to make multiple and interdependent decisions in an environment that changes as a function of the decision maker's actions, in response to environmental events, or in both ways, (2) real-time decision making – time constraints become an important performance determinant, (3) dynamical complexity – time delays and decisions that positively or negatively influence one another in complicated ways overtime. In this paper we focus specifically on the reuse of *process knowledge* by means of conceptualized process patterns.

1.1 *Problem Statement*

In contrast to intuitive ad-hoc reuse of parts of documents that fit into a given context, ad-hoc reuse of parts of actual collaborative processes with meta-descriptors is not so straightforward. We identify the methods and media in which processes were modeled and executed as the main problem and barrier to achieve this goal. In the past different process modeling techniques have been used to describe or prescribe the way processes were, or should be carried out (GANTT, PERT, IDEF0, UML, Process Matrix). On the other hand, actual (instance) processes, actors, and tools that led to real-world results of work – or have been used in communication – usually remained unrecorded. Consequently, support for DDM in ad-hoc AEC teams is yet quite insufficient.

1.2 *Hypothesis*

Web-mediated collaboration provides a new media for collaboration-oriented process models. We call these *active process models* (APM). We argue that processes can be improved through the utilization of *conceptualized workflow patterns,* and supported by a APM enabled, decentralized collaboration platform.

2 RELATED EFFORTS

The study of related efforts is focused on the use of process models in collaborative environments. It is based on taxonomies for qualitative and quantitative classifications of types of collaboration, and process modeling. Identified taxonomic views provide a framework for ontological analysis, and are used for AEC-focused review with emphasis on business intelligence and process mining.

2.1 *Collaboration Taxonomy*

Collaboration in AEC is noticeably different from joint intellectual endeavors in other industries. Kalay (2004) uses the term "multi-organizational teams" and depicts the following exceptionalities of AEC teams: individuals representing often fundamentally different professions, perforce, hold different goals, objectives, and even belief system. Collaboration is by definition not possible without teamwork, and so are views for taxonomies (Table 1).

Table 1: Views for collaboration taxonomies. For detailed taxonomies of tools see (Cerovsek & Turk 2004).

View	Qualitative	Quantitative
Location	Same, Different	Number of Locations
Time	Syn. & Asynchronous	Date & Time, Duration
Group	Type of group	Size (# of Members)
Teamwork	Form, Storm., Norm, Perf.,	Dynamism, # of Teams
Processes	Type of processes	Time, Money, Resources
Information	Type of information/know.	Quantity (# of records, Mb)
C. Channel	Type of media/message	Number of channels
Interaction	Comm., Coordinat., Collab.	Modalitiy, Devices

Collaboration can be characterized by a *Collaboration Circumference*. An example based on the Process Matrix approach (Katranuschkov et al. 2004) is shown on figure 1, where radial directions represent task frequencies for specific roles.

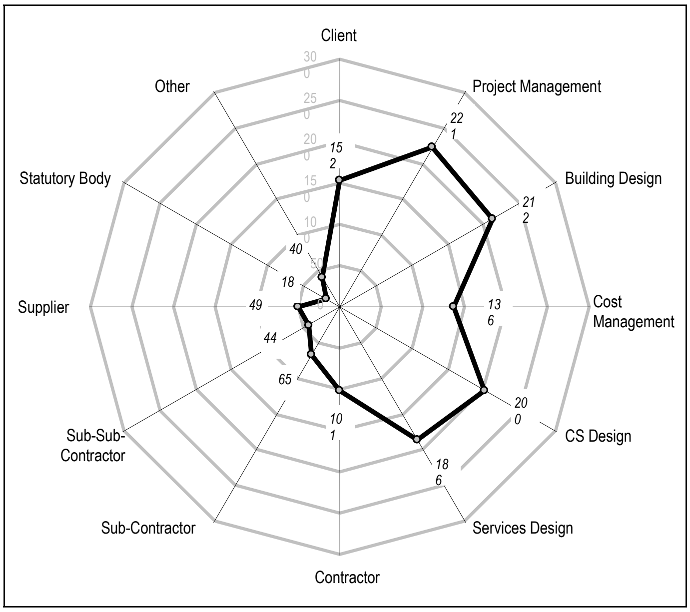

Figure 1: Collaboration circumference: involvement of different roles in communication during project life-cycle.

2.2 *Process Modeling Taxonomy*

A more complete process modeling taxonomy should address several interrelated issues, answering the questions: why, what, who, for whom, where and how? Some of the corresponding views are listed in table 2 below.

Table 2: Views for taxonomies of process models.

View	Qualitative	Quantitative
Purpose	Planning, Education, BPR …	Range of use, and ways
Basic types	Meta, Conceptual, Customized, Workflows	By type of quantities addressed in process model
Media	Active, Passive	Communication channel
Coverage	Ontological concepts	# concepts covered
Used by	Man, Machine	Single, Group, Network
Decision making	Recognition, identification, criteria, proposing, evaluating, making final choice	# of Problem parameters, Resources, Time, Criteria Taxonomy, etc.
Process groups	Initiating, Planning, Executing, Controlling, Closing	Time, Resources, Dependencies, Roles, etc.
Representation	Graph Based: Arrow Diagramming Methods, Conditional diagramming, Swim lanes, Matrix, Text-based	Single, Multiple representation methods, and ability to represent diff. quantities and ontology concepts

Each view is important for a specific perspective, and there is no universal view that corresponds to all possible aspects of process models (Cerovsek, 2003). We address below some *combined views* that are important in the focused context. More detailed explanation of views and corresponding qualitative and quantitative classifications is out of the scope of this paper.

Although several research efforts have been focusing on modeling of processes with the purpose of process reuse, most conceptual process models were modeled on paper, or as digital files, without any dynamic and/or enactment power on actual processes. The strength of such *passive process models* is mainly in their descriptive nature and conceptuality – meta descriptions improving overview, control, understanding and communication about the processes themselves. On the other hand, several *enactment enabled process models* have been studied and prototyped, usually in the form of workflow models. Such models – typically embedded into virtual working environments such as collaboration software or expert systems – operate on concrete tasks, actors and times. These models have two drawbacks: they do not provide conceptual descriptions as well as dynamicity, and they are mainly intended for machine and not for human interpretation.

A suggested taxonomy for the classification of second generation process modeling languages for software engineering divides process modeling languages into five categories (Zamli & Le 2001): (1) Modeling support covering ability to represent concurrency, artifacts roles, tools, communication mechanisms, (2) Enactment support, (3) Evaluation support with "enactment data" (4) Evolution support, and (5) Human dimension support, i.e. understandability. The next section provides more detailed evaluation of the coverage of ontological concepts.

2.3 *Process modeling for AEC collaboration*

Björk (1999) divides processes in general into material and information processes. The focus of this section is on the latter – information processes that are carried out in virtual environments. The main purpose here is to provide process modeling support for collaboration in AEC. To achieve that, we need to study both collaboration activities in AEC, and how to model corresponding processes. As a starting point two developments are used:

1 The *Process Matrix approach* (Katranuschkov et al. 2002, 2004) – used as a foundation for the study of AEC collaboration.

2 *Bunge-Wand-Weber* (BWW) analysis of 12 different process modeling techniques with focus on ontological completeness (Rosenmann et al. 2005) – used for the selection of criteria for the description of process models.

2.3.1 *Process Matrix*

The approach termed 'process matrix' was developed in the frames of the EU ICCI project and further extended in the prodAEC project. It provides for the definition of a multi-dimensional matrix capturing the classification of roles, activities and communication, together with their inter-relationships within building construction. The matrix is designed in accordance with two main objectives: (1) to provide a suitable form for database management as well as web-based presentation and processing for the support of AEC collaboration, and (2) to improve the capabilities for information capture so that various analyses can be easily performed and reported, as and whenever needed.

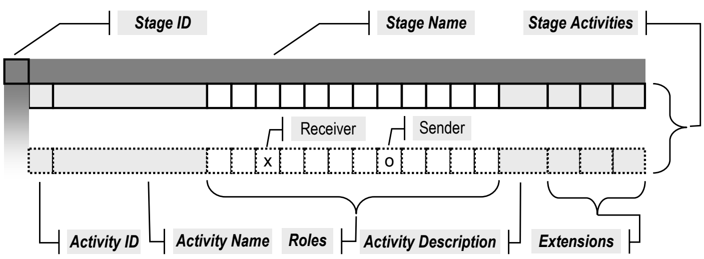

Figure 2: Process Matrix with extensions. For each extension, a separate table is specified and linked to the basic matrix via the Activity and Extension IDs.

From end user viewpoint the Process Matrix appears as a simple table that brings all stored information concerning a reference process together in one line. This approach has been adopted because experience shows that industry end users are not particularly familiar with formal modeling notations. However, they are familiar with, like, understand and respond to the tabular approach of the Process Matrix. To enable adequate capture of the data associated with an AEC process, three extensions of the basic matrix are provided: (1) *Information Requirements Extension* covering data model and data content, (2) *Communication Requirements Extension*, covering the technical aspects of communication described by communication model, communication method and exchange format, and (3) *Standards extension*, covering formal or ad-hoc standards to be applied to a process such as building codes and regulations, use of classification system for construction related information, exchange format, schema, network topology etc.

2.3.2 *Bunge-Wand-Weber*

BWW is a comparative meta ontology for Information Systems and System Analysis and Design. It consists of four elements that can be used to structure a framework for the research: (1) conceptual modeling grammar – a set of constructs and their construction rules, (2) conceptual modeling method – a procedure by which the grammar can be used, (3) conceptual modeling script – the product of the conceptual modeling method, and (4) context – the setting in which the modeling occurs.

Respectively, to assure improvement of process modeling for collaboration the study should include process capturing, modeling language, ad-hoc-ness, and model reuse.

Collaboration process capturing. Several modeling techniques have been used in order to support process capturing, but not activities in real-time. Ontological analysis showed that this is the least supported concept covered in only 8% of all known techniques. Capturing should be enabled by communication channels used in collaboration.

Comprehensiveness of modeling language. The comprehensiveness of a modeling language can be expressed through ontological analysis, since the plethora of process modeling languages (PML) currently in use for different purposes offers very diverse coverage of ontological concepts. The most comprehensive BWW analysis addressing expressiveness of PML was done in (Rosenmann et al. 2005). From ontological perspective ebXML is the most comprehensive process modeling language system.

Ad-hoc-ness support. Several applicable examples exist in the field of scientific collaborative environments – scientific workflows characterized by ad-hoc-ness and incompleteness, partial re-use, abandon/rewind and dynamic modification, tracing of individual processes, specification from case. Several other approaches have been used in practice-oriented Decision Support Systems (DSS). To facilitate teamwork, group-oriented support systems (GSS) have been implemented e.g. for code inspection meetings.

Process model reuse and improvement. A rather basic, but representative example are Network Templates – a well known concept used to expedite preparation of project network diagrams. Another important example are low-fidelity process models which specify nominal order of tasks but leave actors free to carry out their activities as their expertise and the situation dictates. This approach is grounded on three main components: (1) process specification based on low fidelity process models, (2) a distribution process deployment and execution mechanism for enacting low fidelity process models, and (3) a virtual repository of artifacts providing access to distributed physical repositories related to the current work.

Table 3: Overview of process modeling technologies for collaboration.

Feature	Candidate process model
Capturing	ASME diagram, ebXML, DFD, EPC, UML, Process Matrix
Comprehensiveness	ebXML, BPMN, UML, PetriNets
Ad-hoc-ness	ebXML, IDEF0, BPEL4WS, BPMN , DFD, EPC
Reuse and improve	IDEF0/IDL, PetriNets, ebXML, GPP, Process Matrix, Matrix of Change, DSM (Design Structure Matrix)

2.4 *Process centered business intelligence*

Process centered business intelligence (PCBI) refers to the web-mediated tools integrating three inter-related components for effective collaborative problem solving in virtual environments:

(1) business intelligence with data mining,
(2) process mining techniques, and
(3) real-time decision support systems (DSS).

The envisioned features of PCBI are illustrated through definition of components and exemplary applications.

Business intelligence (BI) generally refers to the process of transforming the raw data companies collect from their various operations into usable information (Quinn, 2003). Since data in its raw form is of fairly limited use, companies are increasingly electing to use business intelligence software to realize their data's full potential. BI software comprises specialized computer programs that allow an enterprise to easily aggregate, manipulate, and display data as actionable information, or information that can be acted upon in making informed decisions. BI is a broad category of applications and technologies for gathering, storing, analyzing, and providing access to data to help enterprise users make better business decisions. BI applications include the activities of decision support systems, query and reporting, online analytical processing (OLAP), statistical analysis, forecasting, and data mining (whatis.com). The information – as a candidate for mining processes in the context of construction projects is very diverse: from CAD data to Schedules and technical specifications. Thus, the traditional understanding of BI was limited mostly on knowledge produced as process results and not on processes themselves. Process Centered Business Intelligence (PCBI) extends this traditional approach through process oriented analysis. Additionally, these methods should be supported with analyses of product models.

Process Mining (PM) refers to techniques and algorithms used for mining of raw process data such as workflows and audit trails as well as conceptual models. Typical examples include pattern recognition by Dependency/Frequency Tables (DFT) containing frequencies of different tasks individually in relation with their predecessors, successors and causality (Weijters & Aalst 2001). A DFT table can be successfully applied for semi-automatic generation of process models, but not for conceptualization. Process mining techniques are also used in the field of bioinformatics – for discovery of structured multidisciplinary care plans. Lin et al. (2000) have developed a process mining technique for mining time dependency patterns for discovery of clinical pathways. The solution to these problems can be applied to the problem of providing support for DDM in the context of AEC. The uniqueness of the solution is in the algorithm for analysis of directed acyclic graphs where vertexes represent time and nodes transition between times.

Decision support systems (DSS) are an important part of PCBI. They combine both BI and PM as well as other methods. DSS for individuals are well established, in contrary to group (or intra-organizational) decision support and inter-organizational DSS which are not widespread. An interesting example of inter-organizational DSS is the emergency collaboration platform ENSEMBLE developed at ISPRA (Bianconi et al. 2004). It combines the following three features: (1) simulation through forecasting using different models, (2) spectrum of different scenarios that affect the decision making process, and (3) multi-national and multi-institute collaboration. ENSEMBLE provides an effective, web-based solution of multi-institute collaboration for long-range transport and dispersion forecasts in the event of release of radioactive material. The principles of the developed system could serve to any type of problems that require real-time consultation of large amount of information produced by a number of remote sources and tools, since it provides accessibility to several model results and real-time verifications of the models' quantitative and qualitative predictions.

Recent innovative techniques in civil engineering real-time support systems come from transport management (Zografos et al. 2002, Tavana 2004). In (Hernandez & Serrano 2000), a framework for application to real-time traffic management is suggested – intelligent system based on reflective knowledge model for human-computer-interaction with three classes of questions especially relevant for decision support of effective systems, i.e.: (1) "What is happening?" (2) "What may happen?", and (3) "What should be done?". The core of the system is a reflective architecture where a meta level layer dynamically configures reasoning strategies.

Developed DSS can be measured by effectiveness (output of DSS) and efficiency (best possible use of resources), and can vary in complexity. An evaluation method according to steps of decision making is described in (Phillips-Wren et al. 2004), and a methodology for defining, modeling and measuring complexity is described in (Coskun & Grabowski 2001). The latter addresses Embedded Intelligent Real-Time Systems (EIRTS) which are introduced into safety-critical large scale systems to improve the system's reliability and safety, and to reduce the risk of accidents or mishaps. EIRTS are interesting since they exhibit characteristics of embedded systems, intelligent systems and real-time systems, show how to communicate with larger systems, process data and produce results based on intelligence, and complete their work in real-time. The developed metrics includes: (1) Architectural / Structural Complexity, (2) Data Processing / Reasoning / Functionality Complexity, and (3) User Interface and Decision support / Explanation complexity.

3 FRAMEWORK FOR REAL-TIME PROCESS REUSE

We define joint functioning of tools as integration and joint functioning of people as collaboration. Real time process reuse in virtual environments addresses both at the same time. Figure 3 below schematically illustrates the enabling framework in IDEF0. It contains the following main activities related to the process models: acquisition, mining, conceptualization, use, and usage analysis.

3.1 *Active process modeling*

Active process modeling (APM) is "*the process modeling for real-time collaboration*", since it aims at providing support for real-time enterprise collaboration. Snowdon (1995) was the first to make a distinction between passive models, active models that are passive, and active models. Warboys (1999) further defined an active model as the one constructed in a modeling medium which allows the modeling relationship to be maintained, even though elements of the subject may change. APM is characterized by:

- *Enactment.* The model actively affects the behavior of its subject system.
- *Adaptability.* The model actively changes in response to changes in its subject system.
- *Learn-ability.* The model has the ability to learn from the processes.
- *Predictability.* The model is capable to predict activities based on history of captured processes.
- *Interoperability.* The model and/or its parts are reusable and interoperable (according to Webster: interoperability = ability of a system - as a weapons system - to use the parts or equipment of another system).

These characteristics make from active process models real-time process-centered information management tools that enable real-time capturing, reuse, conceptualization, customization, later reuse, as well as improvement of processes through their process models.

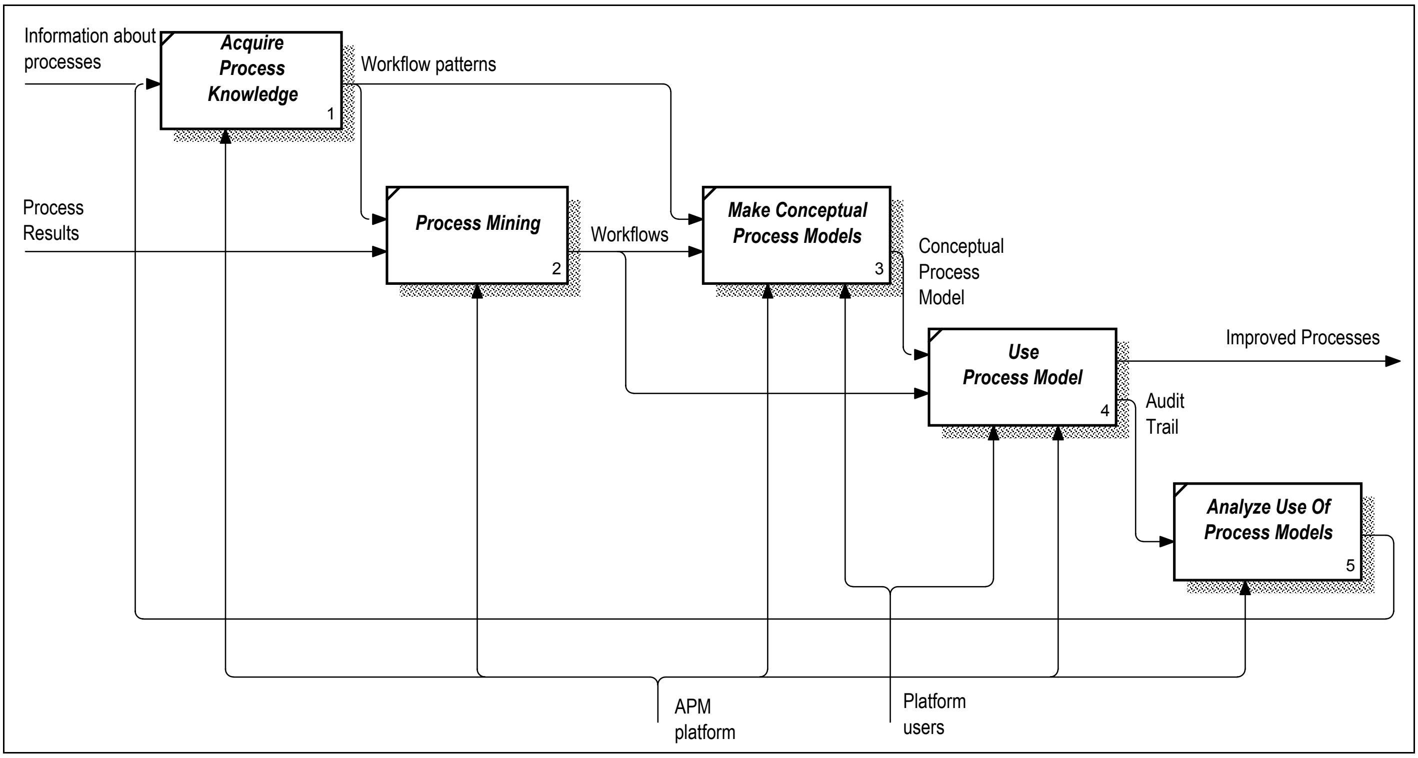

Figure 3: Simplified Framework Process Model for Active Process Model (APM) Supported Collaboration.

Active process models can also provide a bridge between the two types of models using automatic analysis of workflow patterns. This can be enabled by: (1) the media in which processes are modeled, (2) the workspaces in which processes are carried out, and (3) the real-time paradigm of collaboration used. Moreover, active process models offer support in all stages of problem solving, and therefore enable:

- easy recognition of problems,
- identification of objectives,
- establishing criteria,
- gathering data,
- adequate provision of possible workflow patterns,
- enactment of selected processes.

One of the most important aspects of active process model systems is the combination between conceptual models and concrete, enactable process models, i.e. workflows.

3.2 *Conceptualized workflow patterns*

According to the taxonomy outlined in section 2.2, we can use process models at different granularities – from workflow models to conceptual process models. *Conceptualized workflow patterns* provide mapping between different models through simplified views of processes represented for a specific purpose. Conceptualized workflow patterns are therefore defined by history and purpose. Different models can be used interchangeably – workflows, events chains, cause-effect, IDEF diagrams etc. Diversity in representation granularity is among the main advantages of an APM framework, it provides both conceptual and dynamic, run-time modeling support. An example for the individualization of a generic process model is demonstrated in (Scott & Schachter 2005).

4 SUGGESTED APM PLATFORM

In this section a prototype APM platform is suggested on the basis of the above considerations, the anticipated user needs, the goals to be achieved, and technological and technical requirements. Upon that a generalized ICT architecture is outlined and an example based on Groove is given to illustrate the idea on more practical terms.

4.1 *User needs and goals*

With regard to the user needs and goals the platform should provide:

- infrastructure for rapidly establishing interdisciplinary ad hoc teams, aligning different stakeholders and tools to pull required discipline and project knowledge,
- instant team-focused communication infrastructures enabling real-time communication and collaboration,
- easy combination of projects' internal and external roles through collaboration and interoperability among the stakeholders, as well as their enterprise networks,
- pervasive information availability, i.e. team-specific access and retrieval of relevant information from all life-cycle phases and related enterprise networks,
- capabilities for mobile teamwork, particularly considering requirements of safety@work, and life-cycle management tasks such as monitoring, maintenance, re-design, etc,
- capabilities for training and learning of new practitioners,
- simple access to data; efficient Human–Computer interaction is the key for successful implementation of such environments.

4.2 *Technological and technical requirements*

Various technological and technical requirements need to be considered in the development process as follows.

Technological requirements include:

1. Consideration of hybrid decentralized environments: since different collaborative environments require different modality it is essential that different collaboration environments are supported.
2. Balanced use of Push and Pull Technology.
3. Platform independence with open API.
4. Provision of a software infrastructure that:
   - is highly generic and re-usable in any context of one-of-kind industries and services,
   - is ontology-based, to enable the semantic interoperability of the involved business services,
   - can wrap up heterogeneous information sources including external legacy applications,
   - supports the dynamic on-demand creation, management, and control of sustainable teams of different stakeholders,
   - provides for fast, ad hoc creation of workflows focusing on the specific team-oriented tasks on the basis of project-wide knowledge, local context and pre-defined process templates,
   - enables adequate consideration of late client requirements and the subsequent change management.

Technical requirements include:

1. Federated identity management: techniques allowing users to utilize personal(ized) information across systems.
2. Security services: all five basic security services must be enriched, with special attention to confidentiality.

3 Process information retrieval: provision of mechanisms that enable information retrieval techniques to be used in the framework of processes.
4 Traceability of interconnected processes.
5 Information characterization by type of process.
6 Extended presence awareness with activity awareness.

4.3 *Prototype architecture*

The suggested high-level architecture of the system is divided into four main, dynamically linked layers (figure 4):

1 *Knowledge layer* with two sub-layers representing a) knowledge about processes, and b) process results as containers of knowledge.
2 *Tools and services layer*, providing utilization of specific user needs during collaborative activities.
3 *Organizational layer*, containing different intra-organizational schemes matching the project specific organizational scheme.
4 *Project layer*, providing project-related linkage between the other components.

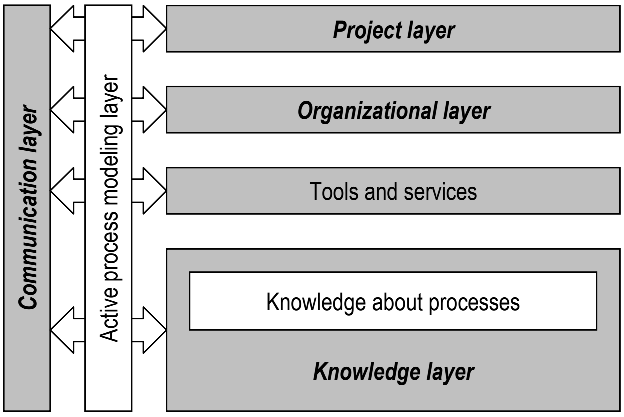

Figure 4: High level APM architecture.

These components are combined through different communication channels and supported by APM features.

For rapid prototyping purposes we have used the *Groove* peer-to-peer collaboration software (www.groovenetworks.com). Groove offers several of the required functionalities: real-time communication with presence indicators, instant messaging, customizable shared space which enables users to select and adjust tools according to the specific needs of the project. Groove also embeds *Groove Web Services* that enable Groove Workspace components to be Web services providers. Another important characteristic of Groove is its decentralized architecture which allows seamless integration of the peer-to-peer and client-server paradigms. The screenshot of the prototype on figure 5 illustrates the use of conceptual process models which are represented in the form of hypertext. These process models could be located anywhere on the Web and could be generated dynamically.

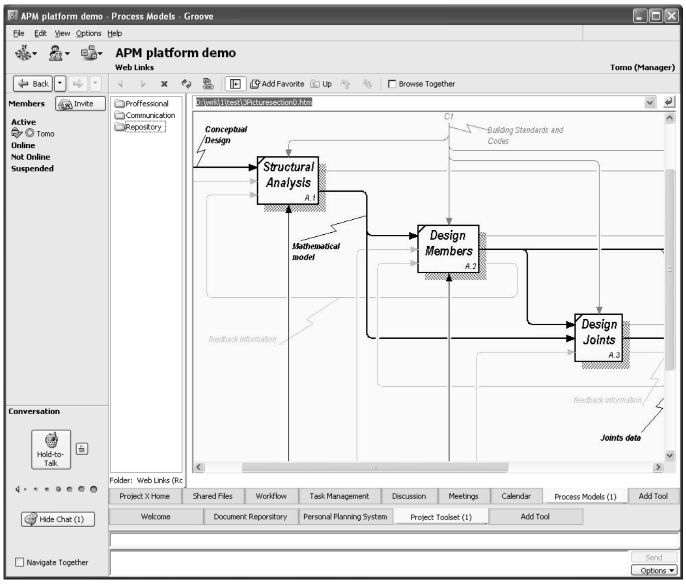

Figure 5: Prototype test bed implementation.

5 CONCLUSIONS

Support for improvement of ad-hoc problem solving in AEC collaborative environments is not yet well established. This could be improved through ad-hoc reuse of parts of processes, i.e. knowledge about prior processes. In the paper we gave an overview of relevant techniques and suggested a framework for further developments. The suggested approach has two major innovative aspects:

1 *Active process model supported platform*.
This can be characterized by:
   – combined use of two paradigms: a) data centered, and b) process centered, that are used in real-time,
   – flexible, variable modeling media in which processes are modeled and in which models are used, thereby leading to a hypermedia active process model,
   – infrastructure supporting real-time paradigm.
2 *Enabled diversity of process models*.
The approach combines several process modeling techniques providing:
   – coexistence of process models of different granularity – from event process chains and workflow models to conceptual process models,
   – coherent use of conceptualized workflow patterns: repeating patterns can be used to generate conceptual process models,
   – customized process models: conceptualized process models can be customized for specific purposes using specific representation formats.

Techniques supporting such kind of platforms need to include different PCBI-related components, such as data mining, process mining, and adequate real-time decision support. However, whilst the first two are highly generic and therefore readily reusable, the latter is tied to the targeted business domain.

Finally, it is important to emphasize two further aspects: (1) Learning and (2) Business Process Re-engineering and controlling capabilities.

5.1 *Learning - APM's facilitating factor*

It is essential to be aware of the potential of APM platforms for improvement of organizational learning. Each recognizable process should be considered as learning process. Two of the most important facilitating factors for adoptions of APM supported collaboration are:

1 *The platform should support organizational learning.* This means that it should evolve towards a knowledge platform providing information on (1) knowing what, (2) knowing why, (3) knowing how, and (4) knowing who. The APM platform could be exceptionally effective in providing information about knowing how – since process models directly address such kind of knowledge.

2 *Conceptual process models facilitate learning.* Generic processes that are either automatically conceptualized workflow patterns or ad-hoc conceptual process models can be considered as very strong teaching tool.

5.2 *Future Work - critical success factors*

The presented research is on-going work that is still in an early stage. Planned future developments can be subdivided into three directions:

1 *Process centered business intelligence*. Provision of business intelligence for product models covering the development of algorithms as well as other relevant technical data using OLAP and other text and data mining techniques. Here especially methods for defining process similarity are of interest. Hence, canonical forms should be more developed.

2 *Human-computer interaction*. Study of suitability of different process modeling techniques and their representation for use in digital media for different purposes.

3 *Study of adoption factors*. Adoptability of new ways of working is another aspect that requires detailed consideration – facilitating factors and critical success factors *need to* be established.

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