Reverse-engineering of Individual and Inter-Personal Work Practices: A Context-based Approach

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Abstract. Current enterprise modeling approaches allow representing organization's *design*. This paper describes context-based approach for organizational analysis, to discover and model aspects of the organization's *implementation*. The proposed approach aims at allowing the elaboration of graphical representations of actual work practices within given execution contexts. In particular, it addresses the discovery and analysis of personal and inter-personal contexts from action repositories. The approach is illustrated with sample graphics from case studies. Results on the automatic discovery of personal contexts are also reported.

1 Introduction and Motivation

Enterprise modeling is an overlapping activity of the Information Systems (IS) and Artificial Intelligence (AI) fields. Whereas IS models are commonly referred as Enterprise Architectures, in AI are better known as Enterprise Ontologies. Within both fields, enterprise models aim at; (1) supporting the development of business applications, (2) facilitating shared understandings among organizational members and (3) facilitating interoperability among systems [1]. Since the goal is to facilitate the communication among human and automated agents, they provide languages with syntax and semantics that seek to reduce ambiguities. Enterprise modeling frameworks provide semi-formal and graphical means to represent organization's structures and processes i.e., aspects of the organization's *design*. The hypothesis driving the present research is that enterprise modeling can be valuable tools in facilitating shared understandings of the *actual implementation of organizations*, particularly of the *specific subjects* that fulfill tasks and the *specific ways* of performing these tasks. This kind of information allows uncovering individual and collective *work practices*.

The importance of discovering work practices to improve user support has been acknowledged in [2,3]. From our point of view, analyzing work practices is also important to (1) discover problems not detected by generic tasks models and (2) assessing the alignment between design and execution. These issues entail tracing the actual relationship of workers with organizational tasks, resources and other workers. Thus, a better knowledge of organization's implementation issues is useful not only for IS developers but also for organization analysts and managers. Due to their focus on organization's design, current modeling approaches provide process-centered, role-based models that are not able to capture work practices. Moreover, these approaches regard organizations as static, mechanistic and deterministic systems that not reflect the nature of human behavior. We need a semi-formal modeling framework that captures the *complexity*, *situated* and *dynamic* behavior of people at work.

In this paper, we describe an approach to discover and model individual and interpersonal work practices. The proposed approach is based on a conceptual framework that regards organizations as complex, adaptive systems that result from the interaction among its agents [4]. This framework defines an architecture and ontology of organizations agents consistent with that view. The concept of context is an essential component of this *"architected"* ontology [5]. Drawing on this ontology, we propose an approach to discover and depict context-based representations of work practices from repositories of executed actions. More specifically, we capture subject actions in terms of <subject, verb, object> triples, that identify the human actor, action type and resources used. We use contexts to group together action streams and associated resources of each individual. These groupings are thereafter regarded as "units" to identify individual and interpersonal work patterns. The representations obtained are intended mainly for organizational analysis ends. Hence, rather than supporting an engineering process, we aim at facilitating a "reverse-engineering" of work practices. The remaining of this paper is structured as follows; Sections 2 and 3 summarize related work on enterprise and context modeling. Section 4 summarizes the underlying model of the framework. Section 5 describes the acquisition approach proposed and illustrates it with examples from case studies. Section 6 briefly summarizes results on automatic discovery of personal contexts and Section 7 gives our conclusions and future directions.

2 Enterprise modeling

Enterprise modeling approaches coming from IS/AI fields models are commonly referred as Enterprise Architectures or Enterprise Ontologies. One distinctive feature of Enterprise Architectures is enabling to model organizations from different perspectives or viewpoints and to provide means to assess the alignment between them. Enterprise Architectures are process-driven and regard agents as simple resources of business process. In AI, two well known enterprise ontologies are the Enterprise Ontology (EO) proposed by Uschold [2] and the ontologies developed within the TOVE project [12]. Several Multi-Agent Systems (MAS) development frameworks have proposed meta-models comprising several social and organizational concepts, encompassing single-agent, two-agent, group and organizational level concepts [11]. AI Enterprise ontologies and MAS meta-models provide an organizational perspective with richer sets of agent-related concepts. However these models do not fully reflect the complexity and autonomy of organizational agents.

3 Context notions and modeling approaches

Despite efforts to enlarge a shared understanding of this notion [6], the definition of context remains dependent on its application area. In a pioneer work within the AI field, McCarthy [14] introduces contexts as abstract mathematical entities to allow axioms valid within limited contexts to be expanded to transcend its original limitations. He argues that the formulas *ist(c,p)* (i.e., a proposition p is. true (ist) in a given context c) are always considered as themselves asserted within a context, that produce assertions like *ist(c',ist(c,p))*. Hence, this regress is infinite. In AI and other fields of computer sciences, context is viewed as a collection of things (sentences, propositions, assumptions, properties, procedures, rules, facts, concepts, constraints, sentences, etc) associated to some specific situation (environment, domain, task, agents, interactions, conversations, etc). In problem solving, Pomerol and Brézillon define context as the implicit constrains of each step of a problem and link context to the notion of knowledge [6]. Context surrounds a focus (e.g. a task at hand) [16]. For a given focus, context is the sum of three types of knowledge; external knowledge, contextual knowledge and proceduralized context. External knowledge represents related knowledge not relevant for a particular problem step. Contextual knowledge is the corpus of knowledge directly relevant for a problem step. Proceduralized context is the part of contextual knowledge that is invoked, assembled, organized, structured and situated according the given focus and shared among the actors involved in the decision involved. The authors represent proceduralized contexts through contextual graphs. Contextual graphs are composed by two essential concepts; (1) actions and (2) contextual nodes. Actions are elementary acts composing a task. Contextual nodes are conditions surrounding task execution that may alter the course of actions taken (e.g. location, motivation, user or time-related factors).

In cognitive sciences, B. Kokinov [8] developed a dynamic theory of context that defines it as the set of all entities that influence human (or system's) behavior on a particular occasion. The main principles of the dynamic theory of context are: (1) context is a state of the mind, (2) context has no clear-cut boundaries, (3) context consists of all associatively relevant elements and (4) context is dynamic. Sociological approaches typically regard context as networks of interacting entities (people, actors/agents and artifacts). Whereas some focus on the network elements, others focus on its emergent properties. In the latter case, context is regarded as sets of rules and resources that support and regulate interactions among agents [10]. Activity Theory [9] and Actor-Network Theory [7] have been used in modeling social contexts.

4 Conceptual Framework

The approach described in section 4 is based on a conceptual framework, which regards organizations as complex and adaptive systems that emerge from successive interactions among activity and resource-related agents [4, 5]. The framework combines five essential concepts; activities, resources, agents, roles and contexts. Activities define what organizations do. Activities use resources (inputs) and produce resources (outputs). Resources are the *things, persons* or *information* required for the realization of activities. Activities are composed of tasks, which have associated *procedures* (steps to execute them). Agents are special resources with acting, coordination/management and change/learn capabilities. Roles define the observable behavior of agents within particular interaction contexts. Based on their capabilities, each agent can play a set of activity or resource-related roles. The definition of **activities** and agent **roles** is part of the organization's *design*. **Contexts** emerge from *execution*. At execution time, agents perform actions that change the state of given resources. Action streams create and update action contexts, originating a network of actions and resources. Interactions are pairs of *adjacent, communicative* actions exchanged between two given agents**.** *Interaction* contexts emerge from interactions among agents. Contexts may contain one or more *action streams* and their associated resources. Context boundaries are defined by given topic(s), agent(s) and time-intervals. Since activities are abstractions, the relationship between activities and contexts depend on the activity definition. While a single activity may involve several contexts, a context may be related to one or several activities.

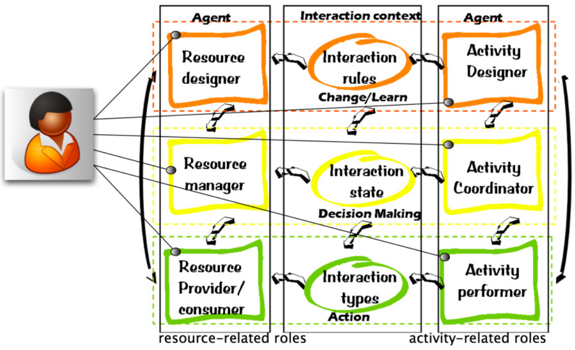

Fig. 1. Architecture and Ontology of Organizational Agents

The framework integrates agent and enterprise architectures. It is divided in three layers; action, decision-making and change/learn. The ***Action Layer*** captures action and interaction patterns between activity performer and resource provider/consumer roles, situated within specific interaction contexts. The ***Decision-making Layer*** captures how resource manager and activity coordinator agents *activate* resource provider/consumer or activity performer roles and their corresponding contexts. This layer offers a state-based view of agents and contexts. The ***Change/Learn Layer*** aims at capturing the (re)design of interaction and activation patterns of resource managers, producer/consumer, as well as activity coordinator and performer roles. In this framework, the nature of context varies according the agent layer. In the action layer, contexts are regarded as networks of agents, actions and resources. At decision-making layer, they are regarded as states of affairs. At the design layer, contexts define the set of unobservable rules governing agent behavior (for details, see [5]).

This research employs the present framework to capture individual and inter-personal behaviors at action and decision-making layers. From the action layer perspective, personal contexts are networks of actions and resources (information items, individual skills, tools and other subjects) created by action threads of an individual. Within their personal contexts, individuals see themselves as activity performers. Other agents are regarded as resource providers or consumers. Figure 2 illustrates an example personal context of an individual of our case study (Alexandre. Figure shows how this personal context, identified as the data collection for mail application context, is related to two formal tasks of Alexandre (data collection and analysis).

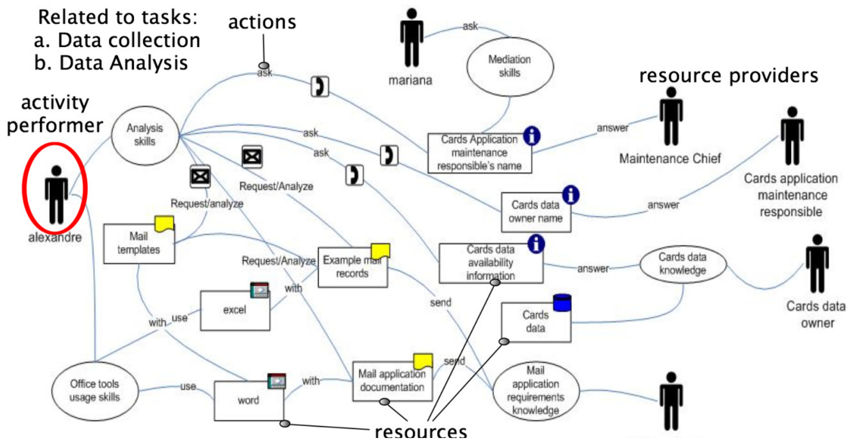

Fig. 2. A example personal context: (data collection for mail application)

Due to their multitasking abilities, people handle several, *unrelated* contexts and switch among them. Furthermore, interactions between two individuals create inter-personal contexts and the same two agents may share several inter-personal contexts. Individual and inter-personal work practices reflect not only action layer behaviors i.e. how individuals perform activities, which resources they use (tools, information or human). They also reflect behaviors of the decision-making layer such as how do they coordinate their own work and the work of others, as well as the dynamics of inter-personal networks created by action and resource flows. These practices can only be discovered analyzing the corresponding execution contexts.

5 Model Acquisition Approach

The conceptual framework described in section 3 suggests first, that agent observable behavior (action/interaction patterns) may be captured from its actions. It also suggests a separate modeling of the different complexity levels of agent behavior Third, agent behavior cannot be dissociated from their contexts of execution. Consequently, we define a bottom-up and context-based approach where we collect actions of a group of subjects, identify and analyze *action-layer* behavior i.e. typical actions and resources of personal and inter-personal contexts and infer *decision-making layer* behavior i.e., find personal and inter-personal context activation patterns. *Design* or *change/learn-layer* behavior is acknowledged suggesting a cyclic or periodic usage of the approach.

Case Studies. This approach is being developed iteratively, refining it successively from lessons learned from case studies in real organizational settings. Presently, it has been tested it in two case studies. The first case involved a software development team of a commercial bank. The main motivation of this case study was to (1) discover multi-tasking behavior of the team members and (2) discover team interaction patterns. The team was integrated by 4 programmers *(Gonçalo, Carla, Catarina, Alexandre*) and the project leader *(Mariana)*. During the observation, the team performed tasks on the following applications; (1) *Suppliers,* (2) *Claims,* (3) *Clients' Mail Correspondence (called Mail application),* (4) *Evictions* and (5) *Marketing Campaigns*. In this case, a three-week observation was conducted, where over 650 actions were collected. A second case study was conducted within a purchasing center team of a furniture retail store. This case was motivated by the need of further improving a set of performance metrics. Five members, all performing similar activities, integrated the team. In this case, a three-week observation period was conducted, where 711 actions were collected.

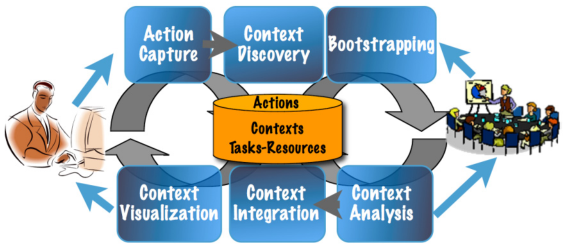

Fig. 3. A Context-Based Approach

Approach Activities. Our approach encompasses six activities; (1) bootstrapping, (2) action capture, (3) context discovery, (4) context visualization (5) context-based analysis and (6) context integration. Figure 3 depicts an overview of the approach activities. In this section we describe and illustrate them it with examples from our first case study.

1. Bootstrapping: Our basic building blocks are agent, action and resource types. Agent types are *individuals or teams*. The following action set is an example set of action types identified in one of our case studies: *accept, analyze, answer, ask assist, calculate, discuss, elaborate, evaluate, find, help, inform, install, modify, print, program, promise, propose, reject, remind, request, research, send, solve, supervise, test, update*. Resource types include *formal information items* such as documents, *informal information items* such as suggestions, ideas, facts, etc. Another type of resource are the tools employed in performing each action, which in the organizational environments we have addressed, are mainly composed of *software tools*. The basic set of action and resource types is defined after a brief observation period. The basic set is discussed and validated by the observed subjects. The collection of actions is started with this basic set, but it can be extended through the acquisition process.

2. Capturing and Structuring Actions: Traditional modeling approaches describe tasks, activities or processes with predicates (e.g. **sell** car, **buy** book, **fill** form). These descriptions lack the subject. We register actions in chronological order, and described through what we have defined as *organizational sentences* [5]. Organizational sentences (depicted in figure 4) are triples subject-**verb**-object, where the subject identifies agents, the verb identifies the action type and the object identifies the resources used or produced by the subject performing the action. *(e.g*. Gonçalo **solve** problem in Suppliers Application). Communicative actions are further structured using speech theory

[13]. Speech acts are composed of a propositional content and the intention of the sender on that proposition. Communicative actions implicate the execution of another action (which can also be a communicative action). In other words, communications actions have always embedded another action. In our approach, communicative actions took the form subject-verb-action. For example, Mariana **request** (Gonçalo **solve** problem in Suppliers Application).

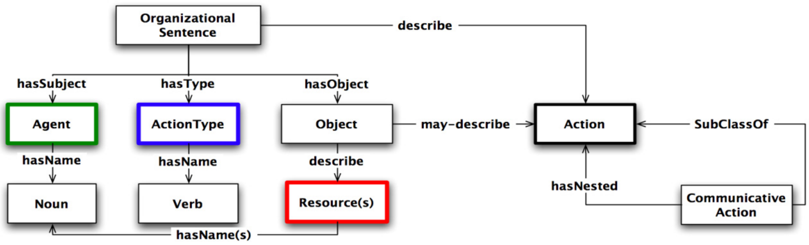

Fig. 4. The structure of Actions

The object of organizational sentences may include several noun(s) (or noun phrases) including not only informational resources but also of auxiliary tools used in performing the action. All the collected actions fitted within the present structure. Most complex actions found where two-level communicative actions, i.e. communicative actions embedding another communicative action e.g. *"Alexandre request Mariana to ask Maintenance Chief who is responsible for the cards application"*, which has the following structure: Alexandre **request** (Mariana **ask** (Maintenance Chief **answer** who is responsible for the cards application).

Table 1. Characteristics of Carla's Common Services Application context

		Object Keywords		
Context	Action	informational resources or implicated tasks	tools	human resources
c1	program	common services application	visual studio dotnet, sqlserver, msdn, google	
c1	discuss	technological issues, common services application		pedro, mariana

3-4. Context Discovery and Visualization. We discover personal contexts accordingly to our definition; grouping together action threads with similar resource sets of single individuals. Each grouping is shown to their owners, who validate and label them. Table 1 depicts the most representative actions and resources of the context c1 of Carla (Common Services Application Programming), as well as its associated set of informational resources, tools and human resources. Subjects validate (and maybe regroup) and label groupings using the information provided in this table. Table 2 depicts some labeled personal contexts of Alexandre, Carla, Mariana and Gonçalo.

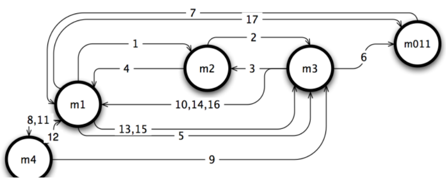

Fig. 5. Context Switches of Mariana during first observation day

5. Context-based Analysis: Identifying, characterizing and labeling contexts allow using them as unit of analysis. The identification of personal contexts allows a variety of context-based depictions Due to space limitations, we here only show a small sample of graphics from both case studies. Figure 5 illustrates the context switches of Mariana, the team leader of our first case study during the first observation day. Each circle represents a personal context of Mariana (see table 2), and numbered arrows represent context switch and its order of occurrence. These graphics were used in measuring daily work fragmentation, and in finding context activation rules.

Table 2. Some Personal Contexts

Person Name	Context ID	Context Name
Alexandre	*a1*	Data Collection for Mail Application
	a2	Mail Application Programming
	a3	Evictions Web Service Problem
	a5	Carla's Support (Web Serv & Mail App)
Carla	*c1*	Common Services Application Programming
	c2	Programming support (Mail & Suppliers App)
	c3	Team Meetings
mariana	*m1*	Project Management
	m011	Cards Information Collection
	m3	Integration Tests
	m4	Claims Application User Support
	m6	Evictions Web Service Problem
	m8	Suppliers Application Programming
goncalo	*g1*	Suppliers Application Programming
	g2	Discussions/Collaboration with Catarina
	g3	Development and User Support

Once owners have labeled their personal contexts, each action can be tagged with its corresponding context. Grouping together tagged interaction threads between two given individuals and personal contexts, allows identifying inter-personal contexts. Figure 8 depicts two inter-personal contexts; the web service problem (a3-m6) and data collection for mail application-cards information collection (a1-m011) shared by two subjects from our case study (Mariana and Alexandre). Since personal contexts reflect a personal view of an interaction context, they do not necessarily have the same label. Linking together several context pairs allows finding inter-personal, context-based networks. Each personal context is related to specific action types and resources. Thus, it is possible to build resource and action flows from these networks. Figure 9 depicts part of the resulting network from linking several context pairs.

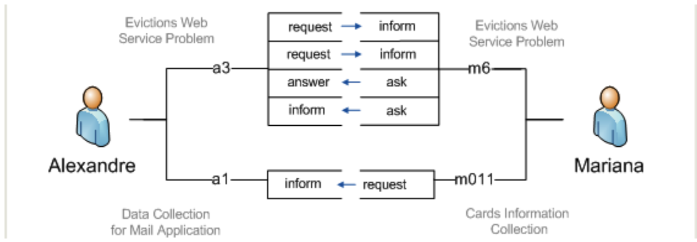

Fig. 6. Inter-personal Contexts

“Decompiling” tasks entails identifying the possible action flows from executed action threads. In this work, tasks are partially decompiled identifying recurrent action-resource sequences. These sequences are found grouping together similar action-resource threads within personal and inter-personal contexts. In our first case study, we identified several (request/inform-publication of software) sequences among developers, the team leader and the publication team. The numbered blue lines depicted in figure 9 illustrate these recurrent sequences and their frequency of occurrence within the action log. These sequences partially revealed the software publication practice implemented by the team. When considering inter-personal interactions as a contextual factor, the potential of flow variability is very high. Hence, we do not seek a complete and deterministic and specification of action flows. Rather, we aim at expressing them probabilistically. We are currently exploring the usage of *sequence clustering* algorithms to this end. Preliminary results are reported in [15].

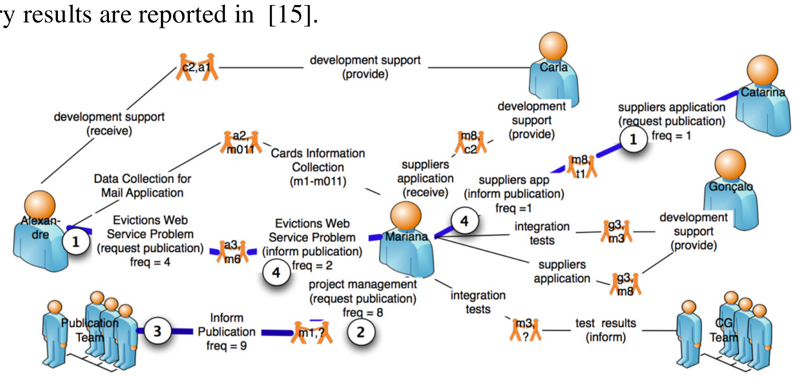

Fig. 7.A Context-based interaction network

6. Context Integration: This activity “decontextualizes” the graphics and representations from the context-based analysis activity. It is a *human* process where context-based representations are discussed and compared with current task models in order to decide their re(design). Figure 10 depicts the final form of the *official* (shared) software publication procedure after it was discussed among the team members.

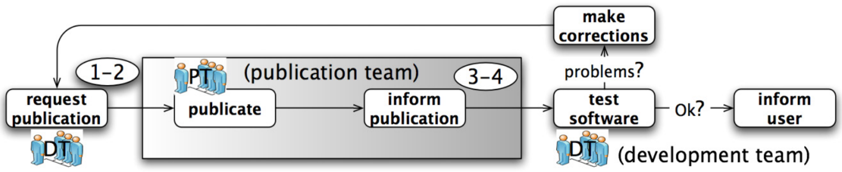

Fig. 8. The *official* publication procedure

5 Automatic Discovery of Personal Contexts

Since we are in the process of validating our approach, we have used relatively small data sets. However, a wider application will require processing of very high data volumes. Hence, it is necessary to devise automated mechanisms to support all its activities. One critical issue is the identification of personal contexts; we are currently researching on its discovery through automated means. This section provides a brief summary of the results obtained from applying a probabilistic clustering algorithm to discover personal action contexts using data coming from our first case study.

Clustering Procedure and Results. We selected a probabilistic clustering approach to discover personal contexts due to (1) the nature of the attributes (textual data) and (2) it allowed overlapping clusters. We used the Microsoft EM **Clustering algorithm** ®. Actions were stored in a MS Sql Server® data-base using the structure described in section 5.2, with their date and sequence of occurrence. Since no pre-defined structured was defined for object descriptions, before applying the algorithm, we used Sql Server text mining services to extract most recurrent noun phrases within action objects. Extracted noun phrases were analyzed and identifying nested actions, informational items, tools or people were selected as keywords. Table 3 depicts some noun phrases and their frequency.

Actions were clustered according to action type and object keywords. Since our goal was to discover personal action contexts, the clustering process was performed separately for each individual.

Table 3.Object Keywords

Keyword Te rm	frequency
suppliers application	192
Claims application	105
Team meeting	58
evictions web service	42
Mail application	31

Cluster Evaluation. We evaluated each cluster qualitative and quantitatively. The qualitative evaluation involved the analysis of the cluster diagrams, as well as cluster characteristics and profile produced by the algorithm. The algorithm discovered three clusters for the subject Carla. Figure 12 illustrates the most important characteristics of cluster 1. As depicted in figure 12, cluster 1 is characterized by the action *program*, the object keyword the *common services application* and the *tool visual studio* .NET. These characteristics suggested correspondence with Carla's personal context c1; the *Common Services Application Programming* (table 2). This procedure was applied for all clusters of all case study individuals.

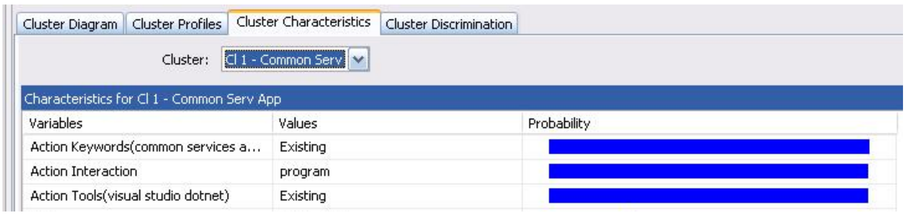

Fig. 9. Main Characteristics of the Cluster 1 of Carla

As a result, a correspondence matrix relating manual and automatic clusters was built. The qualitative evaluation allowed mapping manual and automated clusters but it does not provide a quantitative measure of its accuracy. In order to obtain an accuracy measure, a comparison matrix was built. The matrix rows identified the subjects' manual contexts and columns identified the clusters produced by the algorithm for each subject. The action-cluster distribution of the algorithm was similar to the context-cluster correspondence found by the qualitative analysis (matrices are not shown here due to space reasons). Accuracy was estimated adding the number of correctly grouped actions and dividing them by total number of actions. Accuracy estimates for each cluster, individual and overall accuracy were calculated. At a cluster level of each subject, programming and team meetings contexts exhibit more accuracy. This is consistent with the qualitative evaluation since those contexts were identified most easily than others. At an individual level, accuracy ranged from 0.89 (Carla) to 0.56 (Mariana). The overall accuracy estimate (0.71) indicates that over 70% of the total actions were correctly grouped. Table depicts the values corresponding to the subject Carla.

Table 4. Success rate of clusters found for the subject Carla

Context Description	Cluster 1	Cluster 2	Cluster 3	*Total Context*	**Success Rate**
Common Services Application Programming	***20***	1		*21*	**0.95**
Development Support		***8***	2	*10*	**0.80**
Team Meetings		1	***11***	*12*	**0.92**
Total Cluster	*20*	*10*	*13*	*43*	***0.89***

6 Conclusions and Future Work

In this work, we describe a context-based approach to discover and model personal and inter-personal work practices from action repositories. The present approach facilitates the depiction of a variety of representations to facilitate organizational analysis. The main aspects of our approach were illustrated through examples from two case studies.

In these cases, we gathered empirical evidence of the usefulness of semi-formal, graphical depictions in developing shared understandings of actual work practices. Using contexts in analyzing execution had two main benefits. First, activities are abstract concepts; associating actions to their corresponding activities requires prior knowledge of the activity definition. Our definition of context allows grouping actions without this prior knowledge. Second, it allows a situated modeling approach, appropriate in capturing the behavior specific individuals, the usage of specific resources and time-related circumstances, which is essential in capturing work practices. Moreover, it allows situating interactions among individuals at work. The present approach can be used first, to assess the alignment between tasks models and actual execution and to correct deviations. Second, to discover innovations and update current tasks models. Third, to uncover problems related to how tasks are implemented by people. Presently, the applicability of our approach is restricted to case studies conducted within limited time intervals and organizational settings. A wider and longer application entails the development of automated means to support the approach. In this paper, we briefly discuss some results of the application of clustering techniques in discovering personal action contexts. Results show that clustering produces acceptable groupings. Nonetheless, more testes need to be conducted to further improve current success rate. Another issue that must be addressed is devising ways of minimizing action entry effort. Developing automated means of extracting actions embedded in logs of collaborative tools such as e-mail applications are highly desirable. We are currently researching semantic technologies and text mining techniques to address this issue. Finally, further case studies should be conducted in order to continue refining the proposed approach.

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