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Formalization and reuse of collaboration experiences in industrial processes

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Abstract Collaboration is a key factor for carrying out activities in industrial processes and an efficient collaboration is essential to accomplish an overall improvement of any process. In this article, we introduce a collaborative process-modeling framework, which allows evaluating collaboration throughout all the activities of an industrial process. The proposed framework uses experience management notions towards the creation of a repository of collaboration experiences. This experience base facilitates the reuse of past experiences to support decision making for the organization and execution of future collaborations. The article concludes by discussing the contributions and limitations of the proposed collaboration model.

1 Introduction.

To confront the upcoming challenges of the market, companies must continuously evolve and improve. In order to succeed in this endeavor, an effective collaboration between companies and between people plays a central role to improve or optimize processes.

At the companies level, collaboration can be defined as the cooperative effort between two or more entities striving towards a common goal (Durugbo et al. 2011). In the last decades, the rise of outsourcing has been a strong trend for industrial firms and therefore, collaboration between companies plays a key role in the achievement of successful results in industrial processes.

At the people level, projects and industrial processes are composed by different tasks, and participants with specific characteristics contribute to these tasks. For that, participants must work together based on durable relationships and strong commitments to reach a common goal with the aim of pooling expertise and standardizing tasks (Durugbo et al. 2011).

In order to improve performance in industrial processes, the capitalization and use of past experiences is a key aspect (Skyrme 2007). More specifically, experience

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and knowledge management applied to collaboration processes can create value in inter-organizational activities (Lambert et al. 1999) .

The overall aim of this paper is to propose a conceptual collaboration model that allows capitalizing how individuals collaborate in a process in order to reuse these collaboration experiences in the future.

This article is organized as follows: section 2 describes the related works on collaboration characterization and Knowledge Management Systems applied to collaboration in processes. In Section 3, the collaboration model and capitalization methodology are presented. Finally, section 4 presents the conclusions and discusses some limitations of the proposed model and perspectives for future research.

2 Literature Review.

Collaboration has been analyzed in several studies due to its impact on the enterprise success. This section presents the current research of two key domains in our model: collaboration characterization in industrial processes and Knowledge Management Systems applied to collaboration in processes.

2.1 Collaboration characterization in industrial processes

Collaborative Engineering (CE) emerged in the 1990s as an approach to structure the collective aspects of product and system design (Segonds et al. 2014). CE is defined as a technological approach that supports distributed, multi-disciplinary, and multi-organizational teams during the product development and manufacturing processes (Ma, Chen, and Thimm 2008).

The main characteristic of CE is that the different project stakeholders are requested to work together and interact with each other in order to reach an agreement and make shared decisions (Segonds et al. 2014). To breakdown the wall between functional design and industrial design and to perform the design process with a unique team, (Mas et al. 2013) emphasize the importance of creating a new methodology that needs new procedures and new PLM tools. CE works if the team members' abilities are combined to perform complex tasks in a short time, which individual members will not be able to achieve on their own (Gogan et al. 2014).

On the other hand, Collaborative Business Processes Management - cBPM - intervenes across organizational boundaries involving actors from inside or from outside an organization (Hermann et al. 2017). In addition, (Roa et al. 2015) complement the definition with the inclusion of inter-organizational systems interactions.

Collaboration in organizations can be analyzed as complex networks as shown in **Fig. 1** (Durugbo et al. 2011). They propose a mathematical model that enables to study how individuals in organizations work together to solve a problem or achieve a common goal. The two main objectives of this model are: i) to define topologies for the information structure and ii) to propose quantitative indicators for the information behavior that can be used to characterize collaboration in organizations. This model focuses on information flow but it does not consider other elements of the collaboration context such as contracts, commitments and indicators of quality among others.

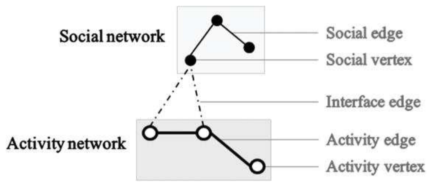

Fig. 1 Collaboration as a graph (Durugbo, 2011).

From Durugbo's mathematical model three indicators of collaboration have been proposed: Team work scale; Decision making scale; Coordination scale. The team work scale measures the ease with which social vertices can pool resources, it is calculated by aggregating two mathematical measures: the clustering coefficient and the centrality degree of the collaboration graph. This indicator allows for assessing the activity of an actor and interconnectedness within a cluster for teamwork. The decision making scale measures the ease with which social vertices can make choices, it is calculated by aggregating the clustering coefficient and the closeness degree. This indicator assesses the ease with which an actor within the intra-organizational network can make decisions based on the interconnectedness and connections for relationships. Finally, coordination scale measures the ease with which social vertices can harmonize interactions; it is calculated by aggregating the closeness and the centrality degree. These indicators permit to characterize the performance of collaboration between actors to perform activities.

2.2 Knowledge Management applied to collaboration in processes

Principles of Knowledge Engineering (KE) have been introduced in cBPM towards a collaboration model based on ontologies and deduction rules in order to build a collaboration information system (Rajsiri et al. 2010). This model is a collaborative process model that describes interactions and information exchanges between business partners. This work proposes a higher abstraction level of a given collaboration. It allows characterizing collaboration from existing knowledge. Therefore, the precision of collaboration characterization strongly relies on the quantity and quality of the knowledge provided by business partners (i.e. the experts). High-level knowledge such as general deduction rules are difficult to implement in specific contexts. Thus, it is necessary to have a detailed level of knowledge modelling consistent with an actual context in order to be able to deduce general knowledge based on actual experiences.

The systematic reuse of experience in industry allows making better use of experiences during an industrial process. Experience Management (EM) supports the capture, storage, search, and retrieval of past experiences (De Mendonça Neto et al. 2001) and its ultimate goal is experience reuse (Bergmann 2002).

Accompanying this logic of experience reuse, Case Based Reasoning (CBR) is an approach that facilitates the resolution of problems by recovering, adapting and reusing previous experiences. This approach requires the characterization of the context in which the experiment took place and the lesson learned in this context for solving a given problem (Kolodner 1993).

In summary, the main purpose of this paper is the use of Experience Management principles in order to establish a model of collaboration experience, capitalize the contributions of each actor throughout the activities of a collaborative process and reuse experiences to improve the future execution of the process or the definition and execution of similar processes.

In the next section we will describe the experience feedback process, the elements of the collaboration model and an illustrative application based on a real process execution.

3 Experience feedback process for collaboration

3.1 Experience feedback process

The main goal of this study is to propose an experience feedback process in order to capitalize experiences of collaboration in industrial processes and to reuse them to define future collaborations. The capitalization of an experience is done for all activities of a process as shown in **Fig. 2** , it is formalized through the elements of the knowledge base in order to standardize the capitalization and facilitate the future reuse of past experiences.

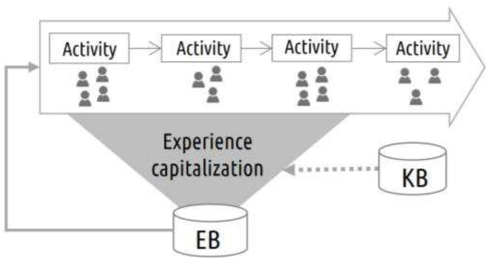

Fig. 2. Overall experience feedback process

In order to facilitate the reuse of experiences, it is necessary to define a collaboration model corresponding to a generic experience frame. This collaboration model is stored in a knowledge base. Every collaboration experience will be an instance of this model. In order to define the characteristics of a collaboration experience without ambiguity, it is necessary to standardize the main concepts and to store them. Therefore, the knowledge base also contains a taxonomy of concepts that are used to characterize the different elements of the experience. Once an experience has been properly defined from the available knowledge, it is stored into the Experience Base (EB). It is important to be able to capitalize the planned collaboration and the actual one within an experience, since this will allow to compute some performance indicators corresponding to the experience. When a process has to be planned for a new execution, the prior experiences stored into the Experience Base, and corresponding to the activities of the process, can be reused.

The collaboration model and the taxonomy are described in the next section.

3.2 Collaboration Model

This section describes the collaboration model that allows standardizing the experience capitalization and which is used by the experience feedback process. The concepts organized in the taxonomy are also presented. An experience is modeled by an oriented graph which is based on the collaboration model as shown in **Fig 3**.

The proposed collaboration model is based on the execution of an industrial process. Different **organizations** can contribute to the execution of several activities of an industrial process in order to reach for defined goals. These goals are represented in our model by **commitments** and they must accomplish one or several **requirements**. In order to formalize the different participation of the organizations, they are governed by **contracts**. The interaction between the organizations to fulfill the commitments of a contract engenders an industrial process. It is a structured, managed and controlled set of **activities** with the purpose of transforming inputs into specified outputs. During the execution of the process activities, **actors** collaborate in order to reach the process commitments. Every actor exerts different roles and contribute to one or several activities throughout the process.

Two or more organizations are **involved** by a contract in order to achieve one or several commitments, and the contract **includes** all the agreed commitments. Furthermore, these commitments must contribute to fulfill one or several requirements. In the model this relation is named **requires**. The commitments are the result of one or several activities of the process, this means that one activity **contributes to** one or several commitments. At this level, there are the interactions between people to execute an activity. Thus, an actor **takes part in** one or several activities and also an actor **interacts with** one or several actors during the execution of the activity. **Fig 3** shows the set of elements of the proposed collaboration model.

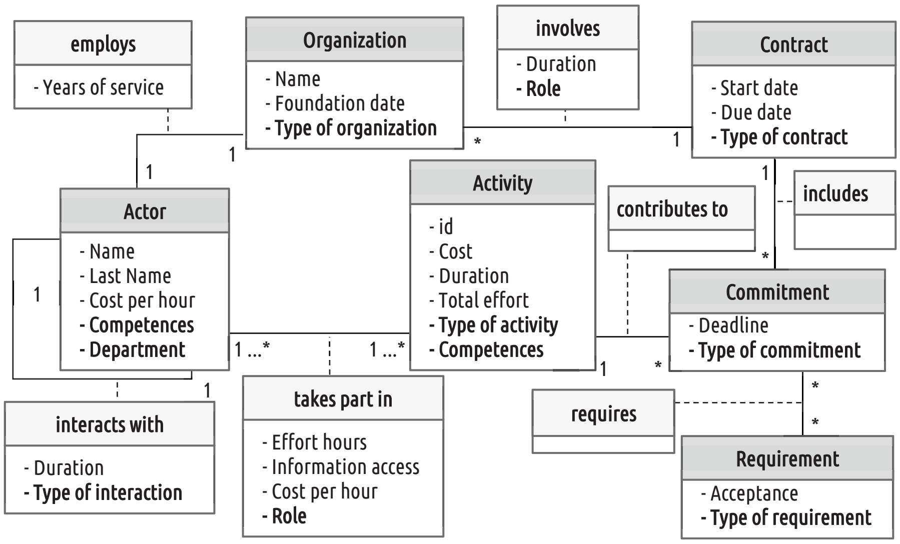

Fig. 3 Collaboration model frame

An organization is a group of people, structured in a specific way to achieve shared commitments. For this element, we must identify the name, the foundation date and the type of organization. A **contract** represents one or several agreements where an organization provides goods or services to another organization, it could be a verbal contract or a written contract. For this element, we must identify the start date, end date and the type of contract. A **commitment** in the proposed collaboration model represents the output of a process activity. It is characterized by a type of commitment classified in: product, report, service and systems for example. A **requirement** is a specific need that the commitments have to meet. For this element, we must identify the type of requirement. An **activity** of an industrial process describes the work which transform one or several inputs in intermediate or final outputs of the process. The following information must be identified for each activity: cost, duration, total effort, and type of activity. The cost attribute includes the cost of all actors who participate in the activity and others costs such as material cost, transportation cost, etc. The duration attribute is the difference between the start date and the due date. The total effort is the sum of all workloads in person-hours needed to carry out the activity. An **actor** a person who participate in one or more activities of an industrial process. They are characterized by: name, cost per hour, department and one or more competences.

For the relations between vertices, the main relations are: **Takes part in, Interacts, Includes, Contributes, Involves, Requires** and **Employs**.

The relation **"Takes part in"** is the relation between an actor and an activity. It is the contribution of the actor for a given activity and it is characterized by the total number of hours required by the actor to execute his/her contribution otherwise the actor's effort. Another characteristic is the information access. We propose to measure this indicator with a number between the 0 and 1. The value 1 indicates that the the information necessary to carry out an activity is easily obtainable. The value 0 means that it is impossible to access to the information. The relation **"Interacts"** is the relation between an actor i and actor j. The relation **"Contributes"** is the relation between an activity and a commitment, it indicates which activity contribute to a commitment. The relation **"Requires"** is the relation between a commitment and a requirement, it represents the requirements that must be met. The relation **"Involves"** represents the relation between an organization and a contract. It is characterized by the duration and the organization's role for a specific contract. The relation **"Includes"** is the link between a contract and a commitment. A contract may have one or several commitments. The relation **"Employs"** represents the link of work between an actor and an organization. An actor cannot have a direct link to two or more organizations.

The attributes of vertices and edges must be standardizing in order to facilitate the future reuse. Then, a taxonomy of concepts allows this standardization and it ensures an accurate capitalization.

3.3 Taxonomy of concepts

Each vertex and some edges must be characterized from a taxonomy of concepts. An example of taxonomy, which can be used for the characterization of collaboration experiences, is represented in **Fig. 4**. A taxonomy is a hierarchical structure described through relations between concepts included in the hierarchy (Van Rees 2003). Taxonomies create a consistent representation of concepts through their structuration into a tree according to their similarity (Jabrouni et al. 2011).

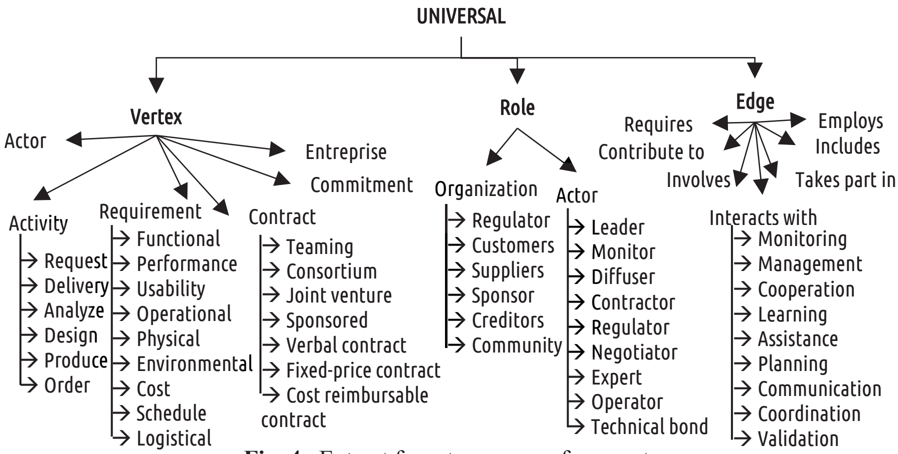

Fig. 4 Extract from taxonomy of concepts

In our work, taxonomies are defined for some attributes in order to characterize the collaboration experiences and facilitate their retrieval into the experience base where all experiences will be stored. This will be develop in section 3.4. An example of taxonomy for collaboration experiences is represented in **Fig. 4**. This taxonomy of concepts is based on existing taxonomies proposed by (System Requirements -

SEBoK, 2015) for requirements, (Boucher et al, 2007) for actor's roles and (Mayer et al. 2012) for contracts.

3.4 Collaboration Experience building

The knowledge base contains the collaboration model frame to structure a collaboration experience, and the taxonomy to characterize, with validated and standard concepts, all the elements of a collaboration experience. The KB is essential in our model because it facilitates the experience formalization and reuse. In addition to the elements and their interactions previously described, it is necessary to distinguish two stages of the collaboration experience: the planned collaboration and the actual collaboration.

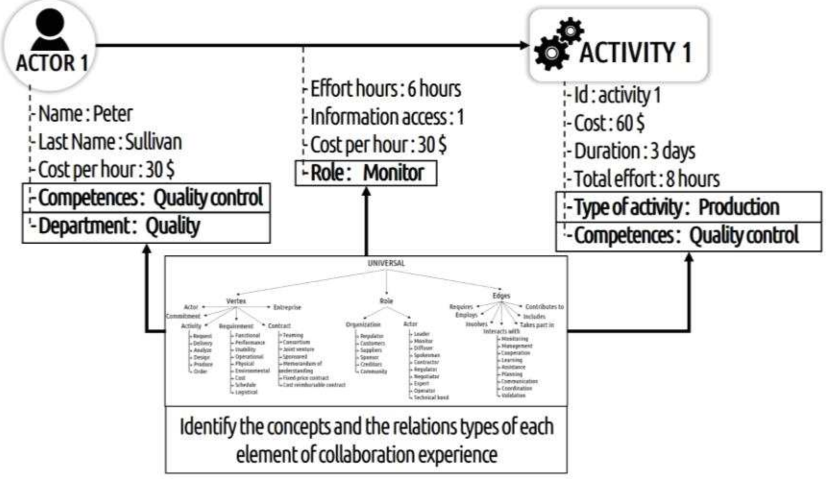

Fig. 5 Example of instantiation and link with taxonomy for two elements

The first stage is the planned collaboration where all the necessary actors, activities, commitments, requirements, contracts and organizations of the process to execute are included. They are planned a priori. **Fig. 5** shows an example of an instantiation for one vertex actor and one vertex activity. For each element, there are certain attributes for which their values will be found in the proposed taxonomy. In **Fig. 5**, for the vertex *activity 1*, the given value for the attribute competence is "*Quality control"* and the given value for the attribute type of activity is "*Production"*. Both values are coming from the taxonomy of concepts.

Fig. 6 represents an example of a planned collaboration instance. It is the instance of a real case of a process in the consulting sector.

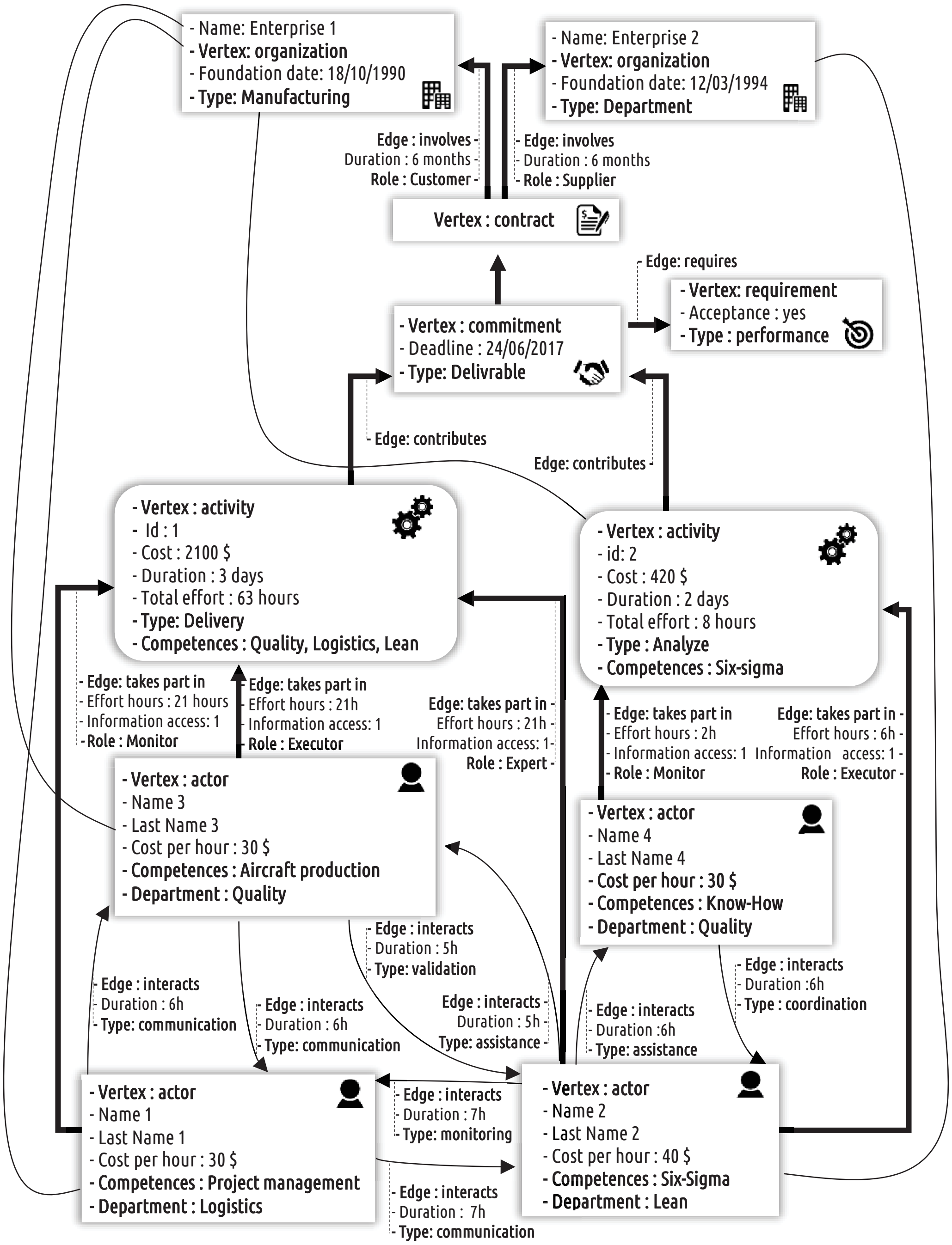

Fig. 6. Example of planned collaboration experience

The second level is the actual collaboration. It means the actual information of the process execution. The **Fig**. **7** represents the changes of the execution of planned collaboration experience, which mainly concerns the activity 2; the other elements have not been represented because they are identical to the planned experience. This allows the calculation of performance indicators in order to identify the gap between the planned collaboration experience and the actual collaboration experience. These performance indicators are commitment acceptance, process delay and respect of the budget among others.

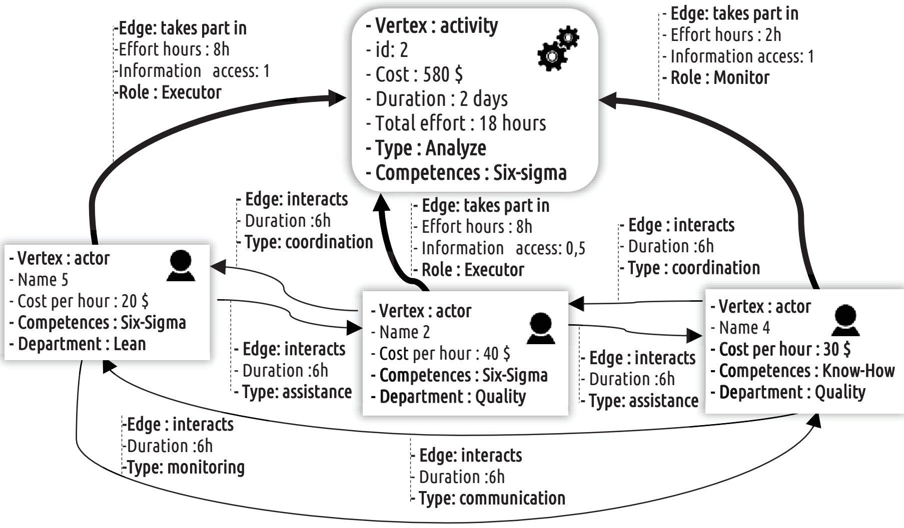

Fig. **7**. Example of an actual collaboration experience (activity 2)

The second step of the proposed approach is the storage in the Experience Base (EB) (after validation) of the planned collaborative experience, the actual collaborative experience and the indicators. When the EB has a significant number of experiences, the information can be reused to facilitate the decision making process of future collaborations. The reuse of experiences is described in the next section.

3.5 Collaboration Experience reuse

The main objective of the Experience Feedback Process is the reuse of past experiences to improve current situations. In order to fall within this reuse logic, we have proposed a characterization of the context of a process by using a labelled graph. In the section 3.2, we defined a collaboration model frame of a process that forms the basis of the search mechanism for similar experiments. This frame allows creating an experience base and to develop a mechanism of research to build on previous experiences. These experiences can then be used to improve the selection of key actors for similar processes. This choice could be done by one of several criteria of the collaboration frame and the characteristics of the actor. For example, given a non-quality situation in an industrial process, the process of problem solving can be improved thanks to the experience base where the actors of the process who have previously participated in the problem solving can be identified and filtered by more specific characteristics such as product type, years of experience or competences.

5 Conclusion

Due to the increasing complexity of industrial processes with outsourcing activities, collaboration has become one of the relevant areas of performance measurement. The analysis of the collected literature indicates that there is a lack of methodologies for collaboration characterization between companies based on the characterization and performance of team collaboration, as well as an absence of a formal inclusion of experience feedback process.

In this article, a collaboration model for experience collaborations characterization has been defined. This model allows characterizing the collaboration experience in two stages: (i) team stage and (ii) company stage. The collaboration model proposed within the formalization of elements such as contracts, commitments and requirements is novel. Also, this article has shown the importance of experiences capitalization and reuse, in order to improve and to facilitate future collaborations in industrial processes.

Despite the model described in this article allows the calculation of performance indicators focused on requirements, activities and actors, it is important to notice that the quality of the collaboration process cannot be evaluated. Therefore, the perspectives of this research are to propose some new indicators which will reflect how good is the collaboration within an experience. This will enable to characterize how two or more organizations are collaborating within the experiences.

From these quality indicators, it will be possible to help to define efficient associations of organizations following the past experiences with regard to collaboration.

Finally, the experience feedback process is still at a preliminary stage and requires further development. The first axis of development is the definition of (i) a method to reuse experiences and (ii) a mechanism to generalize several experiences in knowledge.

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