9-1-2020

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Journal of King Saud University – Computer and Information Sciences 32 (2020) 818–828

Contents lists available at ScienceDirect

Journal of King Saud University – Computer and Information Sciences

journal homepage: www.sciencedirect.com

An approach to the acquisition of tacit knowledge based on an ontological model

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ARTICLE INFO

Article history:
Received 24 May 2018
Revised 23 August 2018
Accepted 11 September 2018
Available online 17 September 2018

Keywords:
Knowledge model
Tacit knowledge
Explicit knowledge
Know-how
Know-that
Ontology

ABSTRACT

Our knowledge includes irreducible tacit elements which are related to the individual's personal nature that go beyond what we can express, which makes it very difficult to formalize, communicate and share. As this tacit knowledge consists of either actions or personal attitudes, we propose an approach to acquisition of tacit knowledge based on an ontological model. The ontology is built top down by changing the actors' cognitive focus from the focal to the subsidiary, or from the aim of an action to its detailed objectives. We also use explicitation interviews and self-confrontation techniques to identify the tacit elements in actors' activities, such as the concepts of situation, know-how and know-that, which constitute our ontology for knowledge acquisition.

1. Introduction

In recent years, companies' intellectual capital has become an essential resource for survival, and the mastery of production tools no longer seems sufficient for companies to differentiate themselves from their competitors. In general, several factors can lead to serious dysfunctions that can affect an entire company, such as retirements, deaths, staff promotions, and mutations and dispersion of team work. Given this context, companies must ensure a durable competitive advantage by knowing how to define and defend their specificity, which distinguishes them from their competitors. The specificity which creates this competitive advantage depends on the company's ability to identify the knowledge held by its staff, to mobilize it quickly and to promote its development, forming the basis for new competitive strategies.

The concept of knowledge is related to the capacity of human beings to reason based on observation, perception, and previously acquired knowledge. Different disciplines approach this subject differently. However, disciplines seem to converge on the view that knowledge does not exist outside of individuals, but is rather strictly a cognitive representation (Ganascia, 1996). According to Prax (2000), knowledge results from information and the actions we take regarding it: it involves both a memory and the process of constructing a representation. Knowledge is associated with a cognitive structure which allows interpreting information which is acquired through experience, learning or introspection in order to engage in a physical or mental activity in a particular situation (Ermine, 2000).

Tacit knowledge is one kind of knowledge, namely, personal knowledge which cannot always be articulated in a coded form. It is implicit and appeals to the experience and know-how of the person who possesses it; it is rooted in that person's actions, procedures, routines, commitments, ideas, values and emotions (Nonaka et al., 2000). It is not tangible, it can be difficult to make explicit, and it is impossible to make it explicit in a form which can be used by another person without using special techniques. Tacit knowledge is a consequence of years of learning and experience acquisition. It is not formulated explicitly in scientific results, but is an essential condition for these results. Thus, all knowledge is either tacit or rooted in tacit knowledge (Kakabadse et al., 2001). Tacit knowledge can only be transmitted if we can convert it into

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Peer review under responsibility of King Saud University.

Production and hosting by Elsevier

https://doi.org/10.1016/j.jksuci.2018.09.012
1319-1578/

words, numbers or pictures which can be understood by others (Kakabadse et al., 2001).

Jha (1998) bases tacit knowledge on a specific relation between the focal and subsidiary consciences made through action. This relation can also be explained in terms of the relationship between a totality (focal attention) and its parts (subsidiary attention). These two consciences cannot be manifested at the same time, as one automatically excludes the other, that is, actors totally invest themselves in the realization of an action and concentrate on a goal to be reached by use of their body and the movements to be performed without being aware of the details of the action's execution, which are in the background (subsidiary conscience).

Polanyi distinguishes between 'subsidiary' and 'focal awareness' and explains how these work together:

When we use a hammer to drive in a nail, we attend to both nail and hammer, but in a different way. We watch the effect of our strokes on the nail and try to wield the hammer so as to hit the nail most effectively. When we bring down the hammer we do not feel that its handle has struck our palm but that its head has struck the nail. Yet in a sense we are certainly alert to the feelings in our palm and the fingers that hold the hammer. They guide us in handling it effectively, and the degree of attention that we give to the nail is given to the same extent but in a different way to these feelings. The difference may be stated by saying that the latter are not, like the nail, objects of our attention, but instruments of it. They are not watched in themselves; we watch something else while keeping intensely aware of them. I have a subsidiary awareness of the feeling in the palm of my hand which is merged into my focal awareness of my driving in the nail (Polanyi, 1958, pp. 55).

According to Akhavan et al. (2018), tacit knowledge includes all of the implicit elements of subsidiary personal knowledge which participate in the focal interpretation of explicit knowledge (theoretical or practical). The acquisition and extraction of tacit knowledge is a very complicated task, because a person's attempts to explain or understand his or her actions or know-how will lead that person to switch from focal attention to subsidiary attention. For this reason, we have chosen to use two techniques in our proposal, explicitation and self-confrontation, in order to prevent disorganization or paralysis in an actor, as these can cause observations or conclusions contradictory to the detailed description of the activity.

Most existing research proposes ontological models for knowledge acquisition. However, most of this research has not proposed ontological models for the acquisition of tacit knowledge. In this paper, we propose a four-step approach whose objective is acquisition of the tacit and explicit knowledge mobilized in an activity. In the first step, tacit and explicit knowledge are made explicit by means of explicitation interviews and self-confrontation. The second step identifies and describes the constituents of the activity (the know-that, the know-how, the situation and a video). The third step exploits these conceptual elements and reconstructs the studied activity. Finally, the fourth step exploits the results of the third step to populate the proposed ontology model.

In this research, we have opted for using an ontology as an operational means for representing and sharing tacit knowledge because ontologies offer several advantages, including interoperability between systems, the ability to share data and the ability to reuse knowledge about a domain. Thus, our proposed ontological model allows for the acquisition of tacit and explicit knowledge about a company's activities, and this knowledge can then be shared and reused in order to reduce the company's loss of skills and memory, that is, future actors will be offered the means to search for a specific activity that has been memorized in the ontology, and this will enable them to exploit this tacit knowledge to realize their activity. Our proposed ontological model also adds value to the tacit knowledge by generating, through inferences, new knowledge which the actors are not aware of. Actors can then exploit this generated tacit knowledge to improve or realize the company's activities.

The remainder of this paper is organized as follows. In Section 2, we present the different typologies of knowledge, and in Section 3, we discuss the relationship between knowledge and actions. Section 4 is devoted to related work on tacit knowledge. In Section 5, we present the basic assumptions and the general principle of our proposed approach. Then, in Section 6, we describe our proposed ontology, our method of developing it, the logic of its structure and the fundamental concepts and semantic relationships. Section 7 discusses the use and evaluation of our ontology. Finally, we conclude the paper in Section 8.

2. Knowledge typology

According to Polanyi (1966), Kano-Kikoski and Kikoski (2004) and Nonaka (1994), there are two types of knowledge, explicit and tacit:

1. **Explicit knowledge**: Arling and Chun (2011) explain that explicit knowledge is codified, that is, it is organized and communicated according to a formalism, a symbol or appropriate natural language. It is therefore easily transmitted and can be recorded in artefacts structured forms such as procedures, reports, strategies, guidelines and so forth.
2. **Tacit knowledge**: The same authors (Arling and Chun, 2011) assert that the tacit knowledge we possess goes beyond what we can express. It is oriented toward an action, an experience and a commitment of actors in a specific context. It is difficult to formalize, communicate and transfer.

The main distinction between tacit and explicit knowledge is that tacit knowledge is acquired through experience, while explicit knowledge is represented in a material manner, such as on paper in a computer program, book or notice, which endures and is therefore easily transmissible and conservable. Together, these form an interactive set in which the two types of knowledge are mutually dependent. The interactive set strengthens the quality of our knowledge and allows us to interpret it (Alavi and Leidner, 2001).

All knowledge has a tacit origin. Thus, explicit knowledge depends on and is rooted in tacit knowledge. Nonaka and Takeuchi (1995) formalized a Knowledge Creation Model by identifying four modes of knowledge creation and transfer. The model assumes different interactions between implicit and explicit knowledge, as depicted in Fig. 1.

This model in (Fig. 1) summarizes the main knowledge conversion process that occurs through social and cognitive processes. There are four modes of knowledge conversion:

- From tacit knowledge to tacit knowledge (socialization): This arises from the interaction between individuals in a group. The learning is done by observation, imitation and sharing experiences.

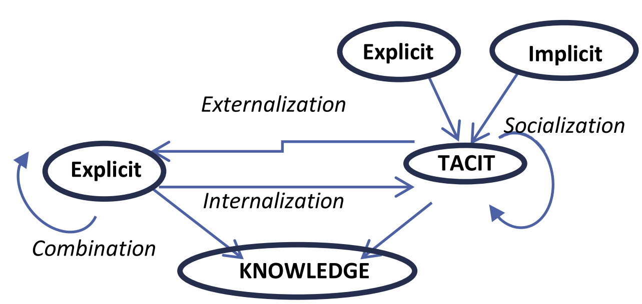

Fig. 1. The Knowledge Creation Model (Nonaka and Takeuchi, 1995).

- From explicit knowledge to explicit knowledge (combination): This allows the creation of explicit knowledge by deduction or induction from a restructured set of items of explicit knowledge that have already been acquired.
- From explicit knowledge to tacit knowledge (internalization): This is a conversion from explicit knowledge to tacit knowledge by a learning process of the type 'learning by doing'.
- From tacit knowledge to explicit knowledge (externalization): This is the explanation of practices and beliefs. Externalization is a process of articulating tacit knowledge into explicit concepts such as analogies, concepts, hypotheses or models.

Knowledge can be considered as immaterial elements carrying wealth. Indeed, knowledge is perceived as intellectual capital which differentiates a company from its competitors (Ermine, 2000). Companies must therefore create a favourable context for the conversion of tacit human capital into explicit structural capital, and they must take into consideration that this capital must be obtained from each competent staff member of the organization. With the departure of a key employee, tacit knowledge is literally lost for the organization. To address this, we propose an approach in which the tacit human capital of an organization's experts can be expressed through explicitation interviews and the self-confrontation technique—this is an externalization phase in which tacit knowledge is externalized as explicit knowledge—and then the knowledge can be modelled in an ontological model in order to preserve it. Afterwards, the tacit and explicit knowledge in the ontology provide a referential knowledge base of know-how which can be used to measure an individual's potential to assume a given task, and other knowledge can be generated through inferences—this is the combination phase.

2.1. The concept of tacit knowledge

Through our literature search, we have identified several concepts regarding tacit knowledge. The first researcher to address tacit knowledge was Polanyi (1966), who said that we can know more than we can tell. According to Polanyi, all scientific knowledge is in fact based on personal experience, which is closer to practical than to theoretical knowledge. He offered the example of riding a bicycle as involving tacit knowledge (today called incarnate knowledge). This knowledge is acquired by calling on our biological capacities.

Wagner and Sternberg (1985) consider tacit knowledge to be an aspect of practical intelligence. It is knowledge that reflects our practical ability to learn by experience and apply this learning to reach personally valued goals. Since tacit knowledge is an aspect of practical intelligence, the concept of tacit knowledge offers a unique perspective on an important factor that underlies the successful execution of real-world tasks.

Tacit knowledge includes, on the one hand, a cognitive component—namely, the mental models (Johnson-Laird, 1993) which humans form about the world (schemas, paradigms, beliefs and viewpoints which provide perspectives that help humans collect and define their visions about the world), and on the other hand, technical components—namely, the know-how and skills which are applied in specific contexts (Dieng et al., 2000).

2.2. Tacit knowledge forms

Tacit knowledge involves know-how and not know-that. According to Anderson (1983), these two types of knowledge are, respectively, procedural and declarative knowledge. Thus, knowing how is a completely different activity from knowing that; it involves knowing how to do things and knowing the means and methods for doing these things. More specifically, procedural knowledge is knowledge represented in such a way that it enables us to do a job or a particular set of jobs. Procedural knowledge is the knowledge which usually orients behavior, without being directly accessible to conscious introspection. People may not know that they possess such knowledge and may have difficulty articulating it.

Ryle (1946) considers "knowledge that" to be the factual knowledge which is expressed in propositions and which can be "true" when expressed as a fact. However, it can be judged either in accordance or not in accordance with the criteria of truth. "Knowledge that" is the mode of theoretical knowledge.

Depending on the nature of the tacit knowledge and its amenability to codification, we can distinguish between three main forms of tacit knowledge: *somatic*, *contingent* and *collective* tacit knowledge (Ribeiro, 2013). These three main forms of tacit knowledge can be further divided into subtypes. Thus, Dinur (2011) has proposed nine subtypes of tacit knowledge, which are skill, cause–effect, cognitive, composite, cultural, unlearning, taboo, human and emotional tacit knowledge.

3. Relationship between knowledge and action

In actions, tacit knowledge brings together the know-how and know-how-to-be knowledge of each individual (Cook and Brown, 1999), as well as the synergies of groups (Polanyi, 1966). Know-how is the knowledge related to performance of an action, which can be an intellectual operation or related to a practical activity.

Pastré (2011) considers action to be autonomous knowledge (know-how), i.e. knowledge which is always associated with an action. Indeed, the knowledge is active: it reveals a capacity to act and to take into consideration the context in which this action occurs.

Piaget (1975) and Vergnaud (2007) have analyzed human activity through the concepts of a scheme and operating invariants, the latter being theorems-in-act and concepts-in-act. The theorems-in-act and concepts-in-act are considered to be tools for supporting the action. These tools are our tacit and explicit knowledge. The concepts-in-act and theorems-in-act represent an evolutionary cognitive organization that allows adapted behavioral answers according to the characteristics of a situation, where the scheme is composed of a set of operating invariants which structure the activity. The main function of the operating invariants is to collect and select pertinent information and to infer useful consequences for the action and controlling and extracting subsequent information.

In the present paper, know-that represents both theorems-in-act and concepts-in-act. A theorem-in-act is any proposition which is held true—whether rightly or wrongly—by a person in a specific situation, and the concepts-in-act are what is considered pertinent by a person (what must be taken into account to succeed), depending on the activity being engaged in a specific situation (Vergnaud, 2007).

4. Related work

Knowledge modeling consists of identifying and structuring knowledge in a schematic representation in order to make it visible, manipulable, comprehensible and communicable (Paquette, 2002). In this section, we present the main work related to our domain.

In reviewing the literature, we found that the majority of the studies that deal with tacit knowledge use either the ontological or the UML formalism, and even multi-agent systems. Thus, for a group work context, Al-Mutawah et al. (2009) proposed a framework which utilizes multi-agent system techniques with a corresponding tacit knowledge sharing mechanism dedicated to manufacturing supply chains (MSCs). The agents in the MSC model perform actions which are guided by their own tacit knowledge beliefs. Al-Mutawah et al. used a multi-agent simulation model based on Dempster–Shafer theory to investigate the importance of developing a shared level of tacit knowledge amongst MSC agents.

Noh et al. (2000) stated that the knowledge circulating in an organization can be explicit or tacit, and that it is very difficult to formalize and reuse the tacit knowledge. To this end, they proposed the use of (1) a cognitive map as a main vehicle for formalizing tacit knowledge and (2) case-based reasoning as a tool for storing the cognitive-map-driven tacit knowledge in the form of frame-typed cases, from which they could retrieve appropriate tacit knowledge for a new problem.

Chen (2010) focused on the empirical knowledge which is encompassed by tacit knowledge. The goal of Chen's work was to facilitate tacit knowledge storage, management and sharing in order to provide those who request it with accurate and comprehensive empirical knowledge for solving problems and supporting decisions. To this end, he developed a method of ontology-based empirical knowledge representation and reasoning which uses the Web Ontology Language to represent empirical knowledge in a structural manner to help those who request empirical knowledge clearly understand it. Chen then adopted an ontology reasoning method to deduce empirical knowledge in order to effectively share and reuse relevant empirical knowledge.

Since the tacit knowledge of health-care experts is an important source of experiential know-how for various operational and technical purposes, Abidi et al. (2005) developed the Tacit Knowledge Acquisition Info-structure (TKAI). This provides tools for explicating and acquiring health-care experts' non-articulated tacit knowledge. It then represents the acquired tacit knowledge in a computational formalism which structures the knowledge in terms of clinical scenarios and finally crystallizes the acquired tacit knowledge so that it can be amalgamated with existing knowledge info-structures that are used by front-end health-care decision-support and medical education systems.

Mezghani et al. (2016) proposed a tacit knowledge model for a scientific research group. This model consists of two phases: knowledge organization and knowledge acquisition. The authors presented a basic ontological model called the Core Reference Ontology, which corresponds to conceptualization, and then specialized this ontological model to reflect domain experts' knowledge through their collaboration on an ontology called the Domain Specific Ontology.

Pépiot et al. (2007) proposed a unified language devoted to the area of competence-based enterprise modeling. This formalism presents skill-based enterprise knowledge in terms of classes of resources, skills, processes, activities, and other company entities. These classes are connected to each other by relations in order to formalize the Unified Enterprise Competence Modelling Language.

The research framework proposed by Liu et al. (2017) consists of three major parts: the remote sensing domain experts, the Grid workflow platform and the knowledge system. The latter includes knowledge acquisition, representation, transformation and inference. The acquisition process for domain tacit knowledge should support the transformation of tacit knowledge into explicit knowledge. Liu et al.'s process has two main steps: (1) Domain Tacit Knowledge Extraction and (2) Domain Tacit Knowledge Classification. Finally, the collected information, concepts and rules are encoded into a machine-readable ontology in the OWL language, which constitutes the domain knowledge base. Liu et al.'s proposed method for tacit knowledge acquisition and representation is based on the specific type of tacit knowledge and its concrete application, since the tacit knowledge is often associated with a special field or specific staff and is quite different for each individual.

Di Iorio and Rossi (2018) tackle the problem of how to elicit and diffuse the implicit knowledge through social software such as wikis, blogs and micro blogs. They note that this kind of knowledge is dispersed and unstructured and it is difficult to establish ways to create value from it. To address this problem, they propose KnowBest, which allows representing this knowledge in structured ways to better communicate and reason with it, preserve it and make it available. KnowBest extends the role which social software already has in allowing implicit knowledge to emerge by leveraging semantic web technologies to accomplish its goals.

Śliwa and Patalas-Maliszewska (2015) have proposed a model for converting tacit knowledge into explicit knowledge. The proposed model is dedicated to the research and development (R&D) department in a manufacturing company and is composed of five steps. In the first step, the sources of tacit knowledge in this department are defined, and in the second step, the methods of collecting tacit knowledge are defined. Then, in the third step, a Bayesian algorithm is used to classify the collected tacit knowledge, and in the fourth step, the acquired tacit knowledge is converted to a formal representation such as procedures, operating instructions, scripts, brochures, training materials, databases, libraries (paper, electronic) and multimedia presentations. Finally, in the fifth step, the conversion of tacit knowledge into explicit knowledge for this enterprise is evaluated in order to verify the usefulness of the acquired explicit knowledge for working on similar tasks.

Regarding the above work, we note that Abidi et al. (2005), Pépiot et al. (2007), Al-Mutawah et al. (2009), Mezghani et al. (2016) and Di Iorio and Rossi (2018) do not take into account the situation concept in their studies—unlike our approach, in which we consider the situation concept as a state of knowledge which includes all information describing the actor, the actor's environment and the activity in which the actor is involved. Furthermore, Abidi et al. (2005), Liu et al. (2017) and Mezghani et al. (2016) do not model the actor concept (a person or a group of people), Noh et al. (2000) and Liu et al. (2017) do not provide details for the know-how concept, and none of the previous literature addresses the concept-in-act and theorem-in-act.

Our goal in this paper is to model the tacit knowledge of an individual actor in a workplace. Our proposed formalism is an ontology which allows the cognitive form of knowledge acquisition based on the research of Vergnaud (2007) and Pastré (2011) as well as activity theory. The ontology concepts allow the representation of the tacit knowledge of an actor (**know-how,** which is mobilized in action as a process, an activity and tasks) by describing the elements of the actor's general environment (the **situation**) and the operational invariants (**know-that**: the **theorems-in-act** and **concepts-in-act**). The concepts of **actor**, **know-how, situation and know-that** represent the core of our model for changing cognitive activity from focal to subsidiary. Table 1 compares related works with our proposal.

As explained above, we decided to use an ontology for several advantageous. An ontology describe all information in a consensual way, which allows conceptualization of a broad range of application domains, unlike a conceptual model, which prescribes the information that must be represented in a database for a specific application. An ontology uses axioms represented in a logical language such as description logic or first-order logic to add semantics to models; however, such axioms are nonexistent in databases. Ontological inference engines which are based on fundamental rules allow new knowledge to be obtained. In databases, however, only stored facts/data is used to obtain new information.

Table 1
Summary and comparison with related work.

Reference	Know-how	Actor	Situation	Concept-in-act	Theorem-in-act
Noh et al. (2000)	No	Yes	Yes	No	No
Abidi et al. (2005)	Yes	No	No		
Pépiot et al. (2007)	Yes	Yes	No		
Al-Mutawah et al. (2009)	Yes	No	No		
Chen (2010)	Yes	No	Yes		
Mezghani et al. (2016)	Yes	No	No		
Liu et al. (2017)	No	No	Yes		
Di Iorio and Rossi (2018)	Yes	Yes	No		
Our approach	Yes	Yes	Yes	Yes	Yes

5. An overview of the proposed approach

Based on the different notions discussed above, we conclude that there is an integrated relationship between the realization of an activity and the situation and, following Tardif (2006), that it is not possible to separate the activity from the situation. The tacit knowledge concepts **know-that**, **know-how** and **situation** allow us to propose a model for acquiring tacit knowledge from the activities that are actually performed in a work situation. Our proposed approach is structured in four steps, as summarized in Fig. 2.

The four steps are as follows:

Step 1: When an individual is asked to express what is involved in his or her activity, it is necessary to make explicit all or some of its constitutive elements. An effective explicitation tool will allow the company to capitalize on all explicitable parts of an individual's activity. Two conventional techniques can be used for this purpose:

a. An explicitation interview (Vermersch, 1994), which is a technique to aid posterior verbalization of a task and is oriented toward the details of the activity.
b. Simple self-confrontation (Theureau, 2010), which allows an actor to provide the essential elements for understanding the production of his or her activity in relationship to the reality of the practice, and enables accessing the actor's own perspective in a specific situation. The self-confrontation involves a procedure during which the actor is confronted with an audio-visual recording of his or her activity and is invited to explain, demonstrate and provide a commentary on its significative elements.

In this step, the actor is filmed while he or she is working. Then the actor is asked to explain the experience of his or her actions through an explicitation interview, in order to schematize a pattern for each performed action. During this interview, we extract the process, the activities and the goals and their tasks, as well as the situation. Then the video of the realized action is used as a complementary means to help the actor express the subsidiaries of his or her action, to obtain a detailed description of the procedural aspects of the realized action.

Step 2*:* Once the significative elements of the activity have been made explicit, we determine which elements are true (theorems-in-act) and which are pertinent (concepts-in-act), as well as the instances of the pertinent contextual information about the situation and the tools used in the realization of the activity.

Step 3*:* We then reconstruct the significative elements of the activity that have been made explicit: the situation, theorems-in-act, concepts-in-act, process, activity, task, goal, tools and a video made during the self-confrontation phase.

Step 4*:* Finally, we populate the ontology with the explicit activity elements.

The aggregation of actors' individual activities (the tacit knowledge model) represents the company's operational memory (knowledge, know-how, know-that) or a set of activities in the different situations. This tacit knowledge can be enriched for similar situations, and new tacit knowledge can be created if it does not already exist.

6. The proposed ontology

6.1. The Méta-model of tacit knowledge

Knowledge is rooted in action, and by knowing the organization of a given activity we can reconstitute the activity through the three concepts **know-that**, **know-how** and **situation**. The know-that represents the operating invariants which structure the activity. As mentioned above, these invariants are related to a number of indicators that allow us to evaluate their value in a given situation. The indicators can be true (theorems-in-act) or pertinent

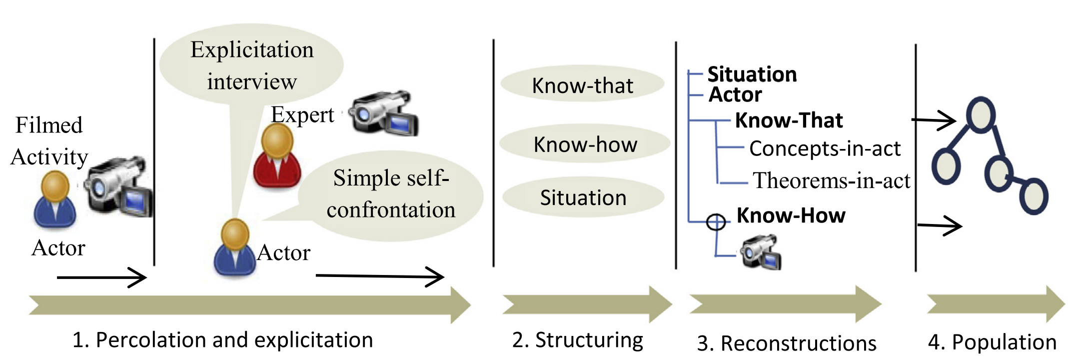

Fig. 2. The tacit knowledge acquisition model.

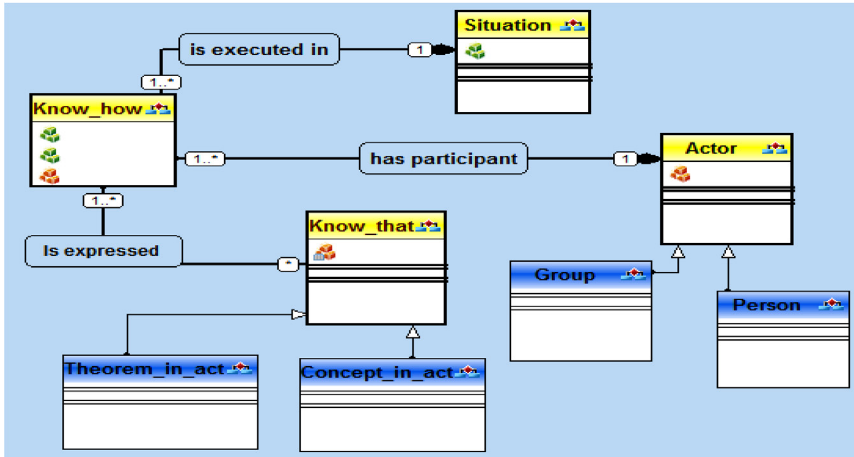

Fig. 3. Tacit Knowledge Meta-model.

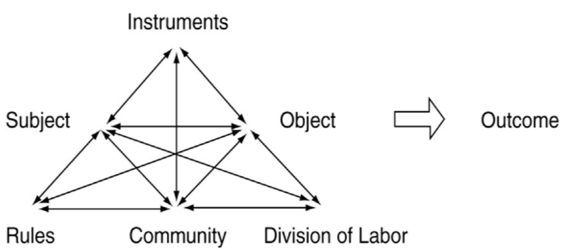

Fig. 4. The structure of a human activity system (Engeström, 1987).

(concepts-in-act). The three concepts are modelled in the tacit knowledge meta-model using the UML class diagram in Fig. 3.

Know-how is the knowledge of how to do things, i.e. it is knowledge about the means and methods for accomplishing tasks. According to Engeström's (1987) activity theory, know-how involves a representation of the activity. Engeström proposed an activity model called "the Engeström triangle" (Fig. 4), a model structure that makes explicit the mutual relations between the three basic concepts of subject, object and community. The relationship between the subject and the object (or the subject and the community, the community and the object) is mediated by tools (explicit or implicit rules, work division, etc.). The activity analysis has two parts. The first part is observable and operative in terms of the activity sequence, tasks and tools. The second part links with the subsidiaries of the activity such as the goals, conditions, events, theorems-in-act, concepts-in-act and a description of the activity situation.

The Engeström triangle (Fig. 4) and the previously mentioned concepts can be used to obtain our generic tacit knowledge meta-model, as shown in Fig. 5.

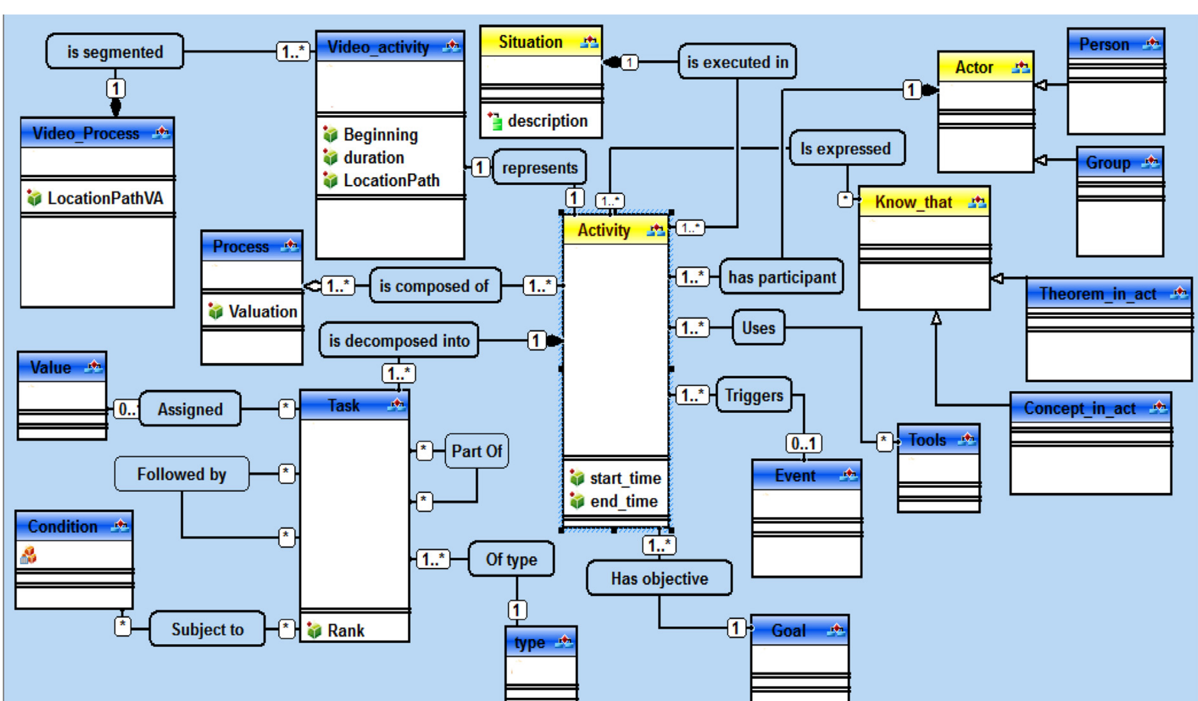

Fig. 5. A generic Tacit Knowledge Meta-model.

6.2. The ontological tacit knowledge model

Based the generic tacit knowledge meta-model, we propose an ontological model for tacit knowledge acquisition. This model is represented in Fig. 6.

The classes, object properties and data properties of our ontology are as follows:

- **Actor***:* The actor class is used to represent an agent or an autonomous actor who performs the activity. The actor class can also be replaced by its subclasses, such as **Group** or **Person**. This class allows specifying the participant type involved in the activity (individual or collective). The **has_participant** property represents the involvement of an **Actor** in an activity.
- **Goal***:* The **Activity** stands in a strong relationship with a **Goal**. These can lead to a multiplicity of actions. An **Activity** is a form of doing which is directed toward an object, and we can distinguish between activities according to their objects. Following Kuutti (1996), the **has-objective** property represents the **Objective** of an **Activity**.
- **Activity**, **Task**, and **Process**: The **Activity** is a set of **Task**s, with each **Task** belonging to a specific **Activity**. The **Activity** is a "set of correlated tasks constituting a transformation step of a process", and the **Process** is "a set of correlated or interactive activities which transforms the input elements into the output elements" (AFNOR, 2005, pp. 7–8).
- The **Valuation** property is used to determine the weight of a **Process** relative to other **Process**es.
- The properties **start_time** and **end_time** are used to specify the execution time of an **Activity**.
- The property **Rank** is used to determine the chronological order of **Task**s.
- The property **is_composed_of** is used to describe the **Process** composition of one or more **Activities**.
- The property **is_decomposed_into** is used to describe how the **Activity** is composed of a set of **Task**s.
- The **Task** concept represents the acts intentionally realized in the **Activity**. It is the smallest element of an **Activity** decomposition. When a **Task** is attached to an **Activity**, it has no autonomy. It may, however, be subject to a condition specified by the **Subject_to** property. The **Task** is executed only when this condition is satisfied. It therefore includes a prior filter for its execution, which must verify that the reality is as expressed. The sequence of the **Task**s in the **Activity** representation is provided by the property **followed_by** as well as the aggregation of several tasks by the property **part_of**.
- The **Type_task** concept represents the tacit knowledge types, and the property **of_type** designates the tacit knowledge type exploited in the **Task**.
- The **Value** concept is used to quantify the quality of the **Task** through the following values: 1 = *very poor*, 2–3 = *more or less bad*, 4–5 = *neither bad nor good*, 6–7 = *more or less good* and 8 = *very well*, and the **Assigned** property designates this value.
- The **Video_Activity** concept represents the path on the hard disk for the audio and video records for an activity. The properties **LocationPath**, **duration** and **beginning** represent, respectively, the path to locate the video on the hard drive, the duration of the video and the startup time of the video recorded for this **Activity**, since the video of a process is composed of a set of **Activity** videos.
- The property **represent** is used to assign each **Activity** concept to its corresponding **Video_Activity** concept.
- The **Video_Process** concept represents the path to locate the audio and video records for a process. The property **is_segmented** is used to assign each **Video_Activity** concept to its corresponding **Video_Process** concept, and the property **LocationPathVA** indicates the local path for the **Video_Process**.
- An **Event** is a stimulus that causes a reaction in an **Activity**; it does not involve the **Actor** of the **Activity** and does not consume its resources. An **Event** is always associated with at least one **Activity** on which it acts. The same **Event** can act on several **Activities**, thus allowing specification of **Activities** which may

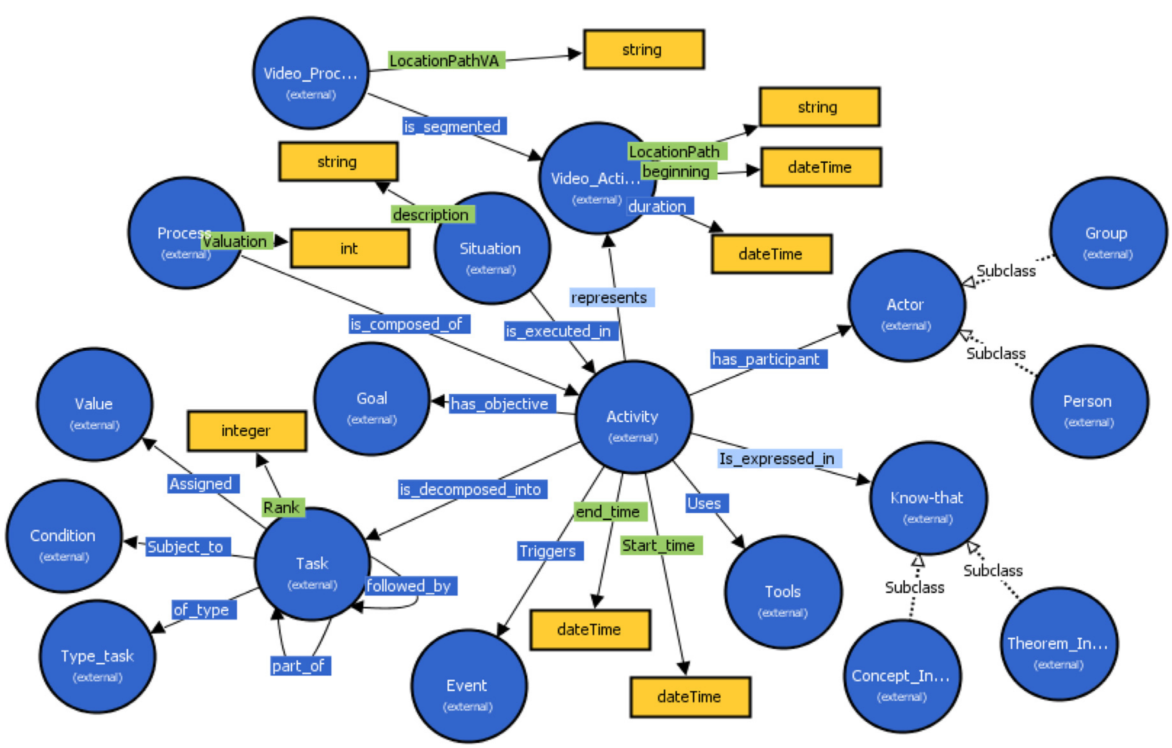

Fig. 6. The ontological Tacit Knowledge Model.

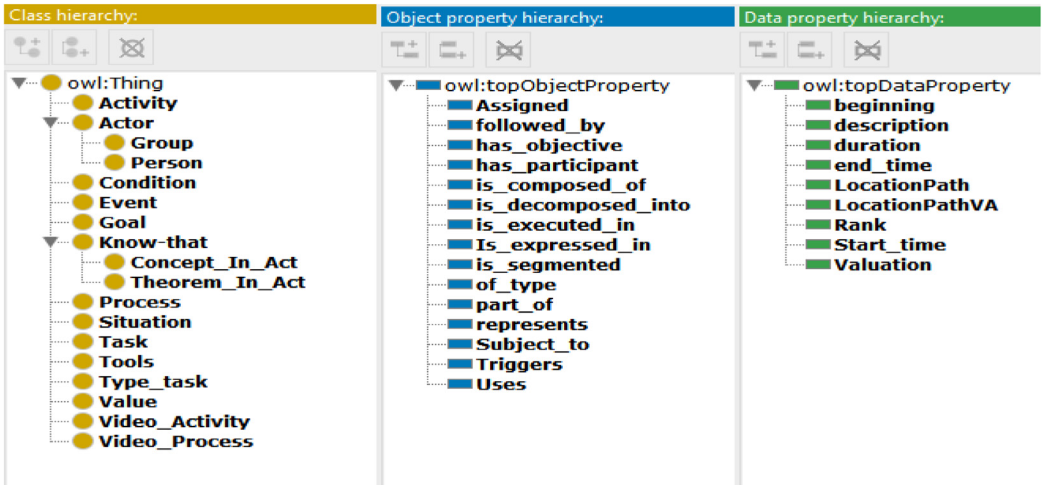

Fig. 7. Class hierarchy, objects and data properties in the Tacit Knowledge Ontology.

be performed in a parallel manner, and the **Triggers** property designates this **Event**.

- **Tools** are elements used for the execution of an **Activity**. The **Uses** property is used to indicate the **Tools** that are used in the **Activity**.
- The **Situation** concept represents the instances of pertinent contextual information at a given moment. The **Situation** is knowledge that includes all the information that describes the **Actor**, his or her **Environment** and the **Activity** in which he or she is involved, given by the property **description**.
- The property **is_executed_in** is used to describe the **Situation** where the **Activity** is performed.
- The **Know-that** concept represents the factual knowledge which is expressed in the **Theorem_In_Act** and/or **Concept_In_Act**.
- The property **Is_expressed_in** is used to describe which element of **Know-that** is used by the **Actor** to realize his or her **Activity**.

7. Implementation and evaluation

7.1. Implementation

The implementation of the ontological model is the precedes the ontology population. This implementation uses the Protégé[1] software, which is an open-source ontology editor and knowledge acquisition system. The ontology is serialized in OWL[2] form, which can be used for common ontology management software such as Jena API. Fig. 7 shows the main classes, objects and data properties of our ontological model, using Protégé.

The ontology population is a very important step. For this step, we have developed an interface using the Java language. This interface enables the ontology population and respects the semantics presented in Section 6 by adding the instances with the relations and the declared properties as shown in Fig. 8. This interface is structured according to the fields of the activity reconstruction phase, as discussed in Section 5, with the option of segmenting the recorded video into several subvideos in order to assign each subvideo to its specific activity.

To further show how the instances are populated, an example population of instances with their relations is given in Fig. 9. This figure illustrates the populated instances through the input interface by using PROTÉGÉ.

The ontology population allows the acquisition of different instantiations for the same situation realized by different actors, since in the same situation, the activity can be achieved by different actors. This enables the acquisition and representation of all tacit knowledge mobilized in the activity.

7.2. Validation and evaluation

Several aspects of an ontology can be evaluated: (1) the syntax, with respect to the standard or the recommendation which is used, (2) the consistency of the ontology and (3) the real aptitudes of the ontology. Concerning the syntax and the adherence to recommendations, we have used RDFvalidator[3] to correct the syntax to conform with conception practices. Regarding the ontology's consistency, we must validate it by checking the consistency between the concepts' relations to allow the inference engine deducing the implicit relations. For this purpose, we decided to use RacerPro (Haarslev et al., 2012). RacerPro works well with large ontologies, and it supports reading an OWL file and converting into a DL knowledge base. Using RacerPro, we validated our ontological model to include:

- Concept consistency and satisfiability testing: checking whether a concept can have instances;
- Subsumption checking: checking whether a concept subsumes a given concept;
- Instantiation checking: checking whether an individual i belongs to a class C.

The evaluation of the capabilities of the proposed ontology is based on the application of reasoning operations by either searching for an activity which is represented in the ontology in the form of tacit and explicit knowledge or by inferring new knowledge. These two points will be discussed in the following subsections.

7.3. Querying with SPARQL

Our model provides the option of listing all of the populated instances relative to the activities that have been made explicit, which allows finding the desired process and visualizing its details:

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[1] http://protege.stanford.edu/.

[2] http://www.w3.org/TR/owl-features/.

[3] https://www.w3.org/RDF/Validator/.

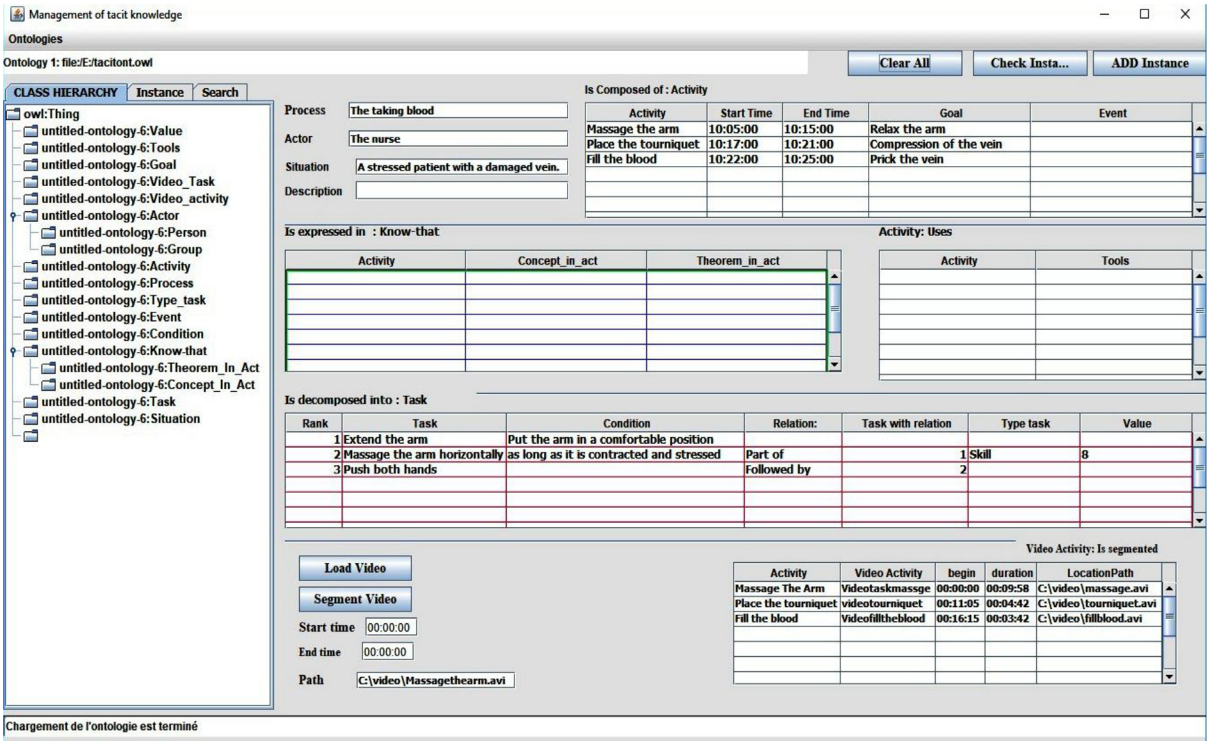

Fig. 8. Tacit Knowledge Management interface.

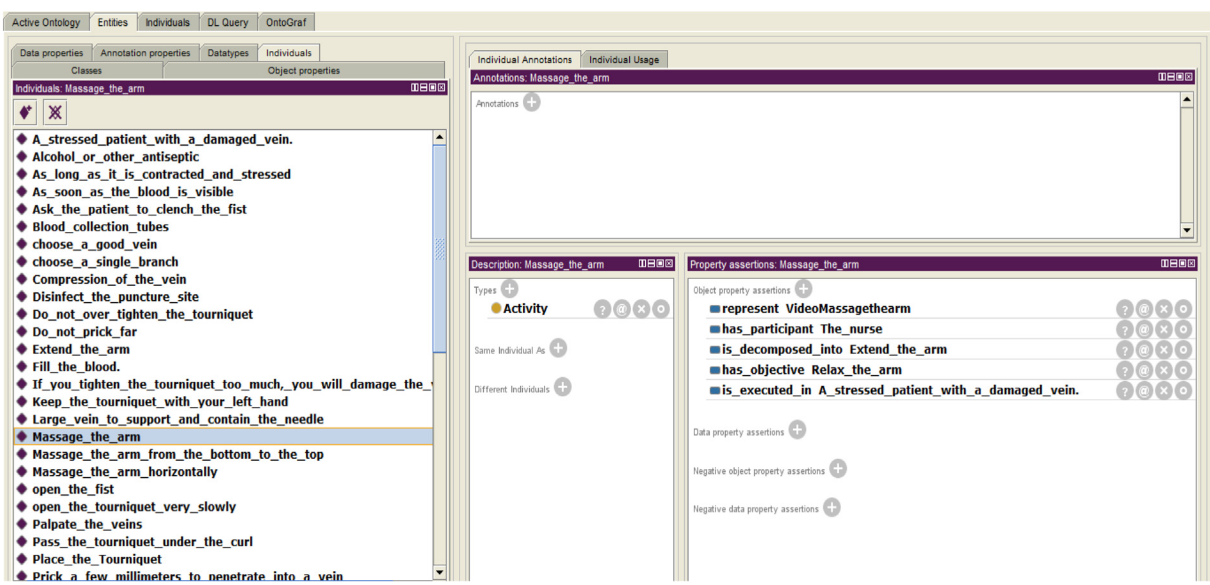

Fig. 9. Population of instances.

the situation, actor, know-how and know-how. Fig. 10 shows a SPARQL query which lists all of the existing processes in our proposed ontology.

To improve the relevance of the search, we use the process valorization property. The value of a process is equal to the sum of the values of its tasks' valorizations. Thus, the user can select the most valorized process (compared to other processes involving the same activity performed by different actors). Thus, the search result for a process will be sorted according the process's valorization property value.

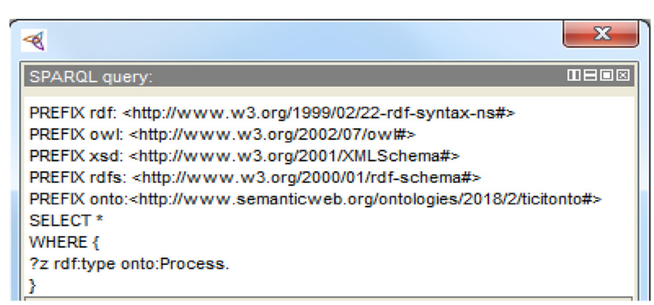

Fig. 10. Query all existing processes.

7.4. Knowledge reasoning

Know-that knowledge is considered to be a set of tools supporting the action. These tools constitute the tacit and explicit knowledge that are mobilized in a given situation in order to accomplish the action. Rule-based reasoning is used to identify this knowledge and provide further explicitation with the following rules:

Rule 1: If, in the same situation, a process is performed by several actors, then all the theorems-in-act and concepts-in-act expressed by these actors represent the basis for the conceptual field of the activity. From this basis, we can extract the tasks which are of a tacit type.

Rule 2: The existence of either theorems-in-act or concepts-in-act for a given situation which appears in our ontology can give approximate or indirect answers about similar existing activities.

For example, if Concept-in-act1 of Actor1 is the same as Concept-in-act2 of Actor5, then the activities realized with this concept are approximately similar or identical. In this case, it is important to find the similar activities related to the theorems-in-act and/or the concepts-in-act realized in the same situations in order to simulate other possible activity solutions.

8. Conclusion

Tacit knowledge is inseparable from the people who hold it. It is personal knowledge that cannot always be articulated in a coded form. The knowledge is implicit and appeals to the experience and know-how of the person who owns it. To capitalize on this kind of knowledge, we have proposed an approach based on an ontological model because of several advantages. The ontological approach allows us to (1) make explicit tacit and explicit knowledge by using two techniques, explicitation and self-confrontation; (2) identify and describe the constituent elements of the activity (actor, know-that, know-how, situation and a video); (3) reconstruct the studied activity; and (4) populate the proposed ontology model. Once the tacit knowledge is acquired, it can be reused and shared in order to reduce a company's loss of skills and the company's memory by offering future actors the means to search for a specific activity that has been memorized in the ontology. This will enable future actors to exploit this tacit knowledge and realize their activity. Our approach also offers the possibility of adding value to the tacit knowledge through inferring new knowledge which the actors themselves are not aware of.

In future work, we aim to (1) propose an approach that allows semi-automation of the first phase of our approach by aligning the content of the recorded video with the explicitation interview, and the role of the expert in this case will be to validate the obtained results, and (2) develop an inference algorithm to propose new processes from the instances in our ontology in order to improve the tacit-knowledge-type activities.

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