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# Automated experiential engineering knowledge acquisition through Q&A contextualization and transformation

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ABSTRACT

Experiential knowledge (EK) in the brain of proficient engineers is an important asset for manufacturing enterprises. As a kind of tacit knowledge, EK is hard to describe clearly and often requires a lot of human efforts to be acquired in a computer-operable form. In this paper we propose a context-aware mechanism to acquire EK in an automatic and timely manner. The proposal comprises a formal description of EK using ontology and default logic, a machine learning-based method that discovers Q&A from the context of collaborative engineering tasks, and a semantic mapping step transforming the discovered Q&A into ontological concepts and relations. An application case shows that the EK of a group of engineers collaborating over a finite element analysis task can be automatically captured from their desktop information flow. The effectiveness of the proposed method with respect to other knowledge acquisition approaches is demonstrated through quantitative and qualitative comparison.



## 1. Introduction

In recent years, with the increasing mobility of employees, the loss of skilled workers has become a serious problem for many companies. The phenomenon has led to the need of acquiring skilled workers' experiential knowledge (EK) in computer-operable forms, via which the knowledge can be stored and reused easily after the person leaves the company. However, EK cannot be easily acquired because it resides in human brains and is difficult to be described formally. In the previous research, EK was often acquired through interviewing proficients and then manually tidying the narratives of the interviewees [1–3]. This approach does not only require the intensive intervention of knowledge engineers but also makes the acquired knowledge uncontextualized – the interview is not situated in real time task processing and thus has the risk of rendering the acquired knowledge isolated from necessary application details.

In this paper, we use context awareness to solve the problem of real-time EK acquisition. The real-time acquisition of EK also implies the automated nature of the acquisition method, since manual processing of the large volume of contextual information is not realistic. With computer-based analysis of contextual information of a knowledge worker, the developed EK acquisition tool can tell whether any EK is showing up in the current working environment as well as what problems the emerging EK is meant to solve. So far context awareness has been adopted by several knowledge management systems to realize active knowledge reuse [4–6], but little research has explored context awareness for knowledge acquisition. This study makes use of a special kind of contextual information – Q&A, to realize EK acquisition. Being the most common way of knowledge communication, Q&A signifies both the communicated knowledge and the usage condition of the knowledge, thus becomes a suitable carrier of personal experience. To find out the Q&A containing EK, we employ machine learning techniques to classify sentences into useful Q&A elements and useless information. Then the captured EK is changed into a computer-operable form by mapping the identified Q&A to the semantics defined in a domain ontology called the EK ontology. The semi-automatic construction of the EK ontology will also be discussed in this paper.

The paper is organized as follows. Section 2 introduces some recent studies about experiential knowledge and its acquisition. Section 3 defines the concept of EK in this paper and provides EK's formal representation. Section 4 proposes our context-aware EK acquisition method. Using a real-world application case, Section 5 shows how the proposed method is used. Section 6 concludes the paper and points out some future research directions.

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## 2. Related research

### 2.1. Experience and tacit knowledge

In the knowledge management literature, experience is often mentioned with tacit knowledge [7–10]. Tacit knowledge is a kind of knowledge residing in human brains and being difficult to tell, imitate and disseminate [11]. Experience is often regarded as the source of tacit knowledge or a part of tacit knowledge. For example, Noh et al. think that tacit knowledge is related with people's intuition, insight, faith, and skills, and people's problem-solving experience is stored in their memories as tacit knowledge [8]. Brockmann and Anthony define tacit knowledge as the practical know-how originating from a person's experience of achieving a goal at work [9]. Armaghan and Renaud believe experience is the knowledge people gain after solving a problem [12]. Azadeh et al. define experience as the practical knowledge for dealing with complicated situations where nonlinear, time-varying and fuzzy characteristics are hard to be described by rigorous mathematics [13]. D'Eredita and Barreto investigate the formation of experience and reach the conclusion that experience is a series of associated scenarios encompassing the goal an individual tries to reach, the stimuli the individual receives when achieving the goal, the explanation to the stimuli the individual makes, and how the individual react to the stimuli [14]. Foguem et al. propose that the representation of experience should include the dimensions of *context*, *event*, *analysis* and *solution* [15]. Based on the summarization of previous research, Chen proposes three basic elements of EK, namely *problem*, *cause*, and *solution*. Chen also outlines eight features of EK, deeming EK as being tacit, hierarchical, descriptive, causal, procedural, associative, action-oriented and skill-oriented [16]. Gavrilova and Andreeva think that the EK of employees can be transformed into explicit knowledge through using metaphors, analogies and models in discussions [17]. Some research on case-based reasoning (CBR) also mentions experience, treating cases as the encapsulation of experience [18,19]. Ruiz et al. propose an experience management framework called Experience Feedback (EF) to draw lessons from the positive and negative events in an enterprise's database [20]. Ruiz et al. also distinguish EF from CBR by pointing out that the former is a tacit knowledge externalization mechanism while the latter does not concern tacit knowledge externalization.

From the above literature one can see that experiential knowledge has aroused the interest of many researchers and has been studied from its definition, representation to acquisition methods. However, inheriting the tacit nature from tacit knowledge, experiential knowledge is hard to describe clearly, and currently there is no authoritative definition of EK. While common understanding of experiential knowledge exists (it is *personal*, *contextualized and problem-solving oriented* knowledge), currently there is a gap between the common understanding and the EK some studies assert to get. To better explain this gap, we provide a survey of relevant research in the following subsection.

### 2.2. Knowledge acquisition

Knowledge acquisition is to acquire knowledge from experts or other knowledge sources and express the acquired knowledge in a computer-operable form. Table 1 lists the recent studies focusing on acquisition of "non-explicit" knowledge. The listed works are analyzed from four perspectives – knowledge source, knowledge type, knowledge representation and knowledge acquisition method.

#### 2.2.1. Knowledge source

Knowledge source refers to the data or data-generating mechanism/subject used as the input to a knowledge acquisition method. Typical knowledge sources include database [13,21–23], interview [2,3,24], conversation [25,26], expert [27], MIS (management information system) [20,28], operation [29] and domain text [30]. When using database as the knowledge source, it usually means multiple cases represented as attribute–value pairs in a database are generalized to produce conclusions. The attribute–value representation of cases supports a variety of advanced data mining techniques, but it can only be used when the target problem can be characterized by a few known parameters. Interview and conversation both produce narratives for knowledge acquisition. Composed of natural language, narratives are much more complicated and expressive than attribute–value pairs. The difference between interview and conversation is that the former aims at obtaining knowledge from a single interviewee, while the later involves multiple knowledge contributors expressing opinions alternatively and guidelessly. Experts are an important source of knowledge. Although there is only one paper listed in the "expert" column of Table 1, the interview and conversation are often conducted on/by experts for knowledge acquisition. In [27], experts directly participated in knowledge acquisition as they are asked to assign the cause-effect relation to the decision variables. Featuring explicit business model, data structure and workflow, a management information system can serve as an effective knowledge source due to the clean, structured and categorized data accumulated in the system [20,28]. The operations of experts solving a class of problems can be used to mine operational knowledge. The operational knowledge source consists of a series of sequentially arranged actions to achieve a certain target [29]. Domain text such as failure report can be used as knowledge source [30]. It can be viewed as a mixed case representation containing both attribute values and text.

#### 2.2.2. Knowledge type

Knowledge type refers to how researchers call the knowledge they have acquired. In Table 1, the surveyed literature focus on acquiring knowledge that is experiential, tacit, personal, operational and uncertain. These types of knowledge are different from the "explicit knowledge" which shows itself as textbooks, formulae or computer programs. The meaning of experiential knowledge and tacit knowledge has been discussed in Section 2.1. The personal knowledge literally means all the knowledge that a person owns, but when mentioned with knowledge acquisition, it mainly means the experience and insights possessed by a certain individual and cannot be found in publicly available sources. Operational knowledge is about how to get things done, usually without telling the reason to do so. Uncertain knowledge is the knowledge containing imprecise and incomplete aspects due to the limitation or error of sensors.

#### 2.2.3. Knowledge representation

Knowledge representation determines what kinds of relations are modeled in the knowledge and how these relations connect the elements of the knowledge. Knowledge representation is important as it affects knowledge's expressiveness, readability and machine operability. The if-then rules are the most widely adopted knowledge representation method because it makes a balance between the machine operability and the human readability [13,20–22,28,30]. Concept maps denote the knowledge concepts connected by relations with nodes and edges [2,3,20,27]. Compared with the if-then rules focusing on representing the causal relation, a concept map can represent arbitrary bilateral relations. Text segments, when properly selected and annotated, can represent knowledge in a traditional, easy to understand way. Liu et al. [25] select text segments from expert discussions as experiential tacit knowledge. The wiki techniques used to overcome the knowledge acquisition bottleneck present knowledge as