Intelligent Information Systems for Knowledge Work(ers)

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Abstract. Our society needs and expects more high-value services. Such "knowledge-intensive" services can only be delivered if the necessary organizational and technical requirements are fulfilled. In addition, the cost-benefit analysis from the service provider point of view needs to be positive. Continuous improvement and goal-directed (partial) automation of such services is therefore of crucial importance. As a contribution to this we describe our current research vision for (partially) automated support of knowledge work(ers) based on intelligent information systems focusing on the use of experience. For the implementation of such a vision we base on the integration of approaches from artificial intelligence and software engineering. A "deep" integration of case-based reasoning and experience factory is a first successful step in this direction [Tau00,Nic05]. We envision the further integration of software product-lines and multi-agent systems as the next one.

1 Introduction and Motivation

The shift of relative importance from more traditional product factors to the new, increasingly important product factor "knowledge" characterizes the developing new economical structure [Kie03]. The use of external knowledge is achieving strategic importance for companies in order to adapt to the current structural change (decentralization, more flexibility). Specialized, up-to-date knowledge is required not only for the intended innovations but also for organization-internal changes as well as the production and sales of products. However, such knowledge often cannot be provided organization-internally.

Knowledge-intensive services and especially knowledge work [BI03,BM00] represent a quickly increasing part of the service sector. "Knowledge-intensive work" includes activities that require an intensive education and experience on a specific subject that has been accumulated over many years [Wil98,Her03b]. "Knowledge-intensive services" need the resource knowledge as their most important input factor for delivering the respective service [Cra03]. "Knowledge work" denotes activities that not only base their problem solving process on knowledge acquired once, but also necessarily have to revise, improve and update their knowledge [Wil98,Her03b]. Experience represents the success-critical knowledge for knowledge-intensive services and knowledge work [BU03].

Within this paper we describe our research vision of how to develop intelligent information systems for supporting knowledge work and knowledge-intensive services with a specific focus on the use of experience [DA04,Alt05]. Our vision especially includes computer-based, fully and/or partially automated knowledge work. Besides the known application possibilities within service economics (for a lot of success stories see [Ber03]) our research also contributes to achieve ambitious goals as being formulated by the European Union (e.g., the so-called ambient intelligence scenarios [Duc01] or the scenarios described in the report on "converging technologies" [Bib04]; also [RA04]). Fully or partially automating knowledge work has the additional advantage that the provided knowledge is not only knowledge for the user, but - to an increasing degree - also knowledge for the computer on which it is used. This enables automated processing of knowledge and offers a unique added-value if compared with more traditional approaches.

Many requirements have to be fulfilled while developing intelligent information systems. In addition, the service expectation of our society is increasing and this is not going to change in the near future. Future information systems users expect to be easily supported, information systems to behave "intelligently" and learn from experience, and to improve their behavior by this. As a consequence, such intelligent information systems should be flexible, modular, and easily to adapt and maintain. These systems should contain a lot of valuable knowledge understandable for both the user and the computer. That is why such systems are also called "knowledge-based".

Implementing such intelligent information systems involves numerous problems, a lot of which have already been solved in principle or exemplary for selected tasks. However, the corresponding solutions are mostly developed by different research communities that only have a restricted exchange/communication with one another. Nevertheless, past experience has proven that achieving major progress for fields like the implementation of intelligent information systems requires integrating methods and techniques from different (sub-)disciplines. We present a research vision that has been developed while the authors were working in the computer science sub-disciplines software engineering (SE), artificial intelligence (AI), and business information systems. As a consequence, our vision is basing on an integration of approaches from these fields.

This includes the SE approaches experience factory and software product-lines as well as case-based reasoning, intelligent agents, and machine learning form

AI. In addition, there are a lot of relationships to knowledge management and business processes, which may be viewed as part of business information systems.

2 Integration of Agent Technology, Case-Based-Reasoning, Experience-Factory, and Sofware Product-Lines

Experience factory (EF) is a logical and/or physical infrastructure for continuous learning from experience (Fig. 1). It includes an experience base for knowledge storage and knowledge reuse. The experience factory concept was introduced in the mid 1980s to support the central process of SE, the software development process [Bas85,BR88]. Basili and Rombach consider software development running in projects separate from the learning organization experience factory because these two sub-organizations have different goals. Projects have to achieve their project goals, that is, developing software according to the given requirements. Experience factory, however, supports learning across projects. From a projects perspective this can be viewed as additional effort and might lead to a goal conflict. Such a separation of learning and project organization is a characteristic feature of an experience factory [Bas94a] and has been validated in practice.

Experience factory bases on the so-called quality improvement paradigm, a goal-oriented learning cycle for the experience based improvement of project planning, project execution, and project learning. Goal-oriented measurement and evaluation is used as a systematic procedure for evaluation [Bas94b]. Figure 1 shows the separation between learning and project organization, the main interfaces between projects and experience factory as well as various roles within the experience factory. While the experience factory manager has the overall responsibility, the experience manager has associated the task of deciding about content development and structuring. The experience engineer is responsible for packaging and analyzing the experience base.

While the librarian cares about the technical and administrative tasks, the project supporter finally is the main contact to the respective projects.

Already before the invention of the experience factory approach, and until the mid 1990s also independent from it, case-based reasoning was introduced in the area of cognitive science and artificial intelligence in the late 1970s and the beginning 1980s. It was introduced as a model for human problem solving and learning [Sch82,Kol93]. Experiences are stored in the form of solved problems (case-specific knowledge, cases) in a so-called case base. A new problem is then solved by transferring the already known solution of a similar case from the case base to the new problem and adapting the solution if necessary (see Fig. 2).

Within AI, case-based reasoning effected a focusing of knowledge-based systems on experience [Bar87,Alt89,Aha99,Alt01] in the late 1980s and the 1990s. Incorporating the the dynamic-memory-idea of Schank ensured a situation-based approach, which often led to a good user acceptance. Accordingly a number of

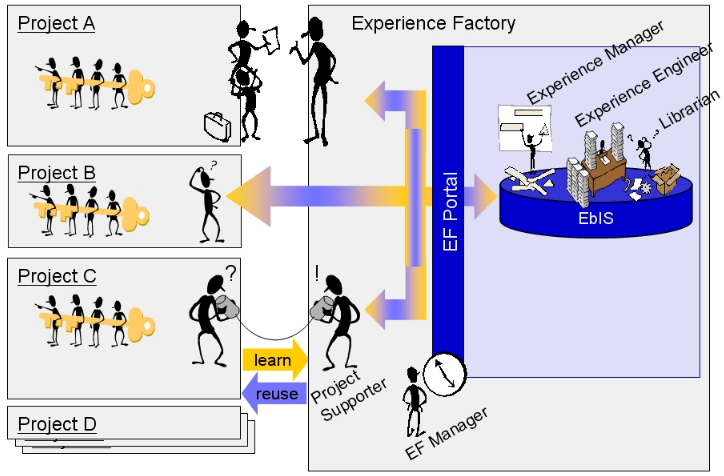

Fig. 1. Experience Factory

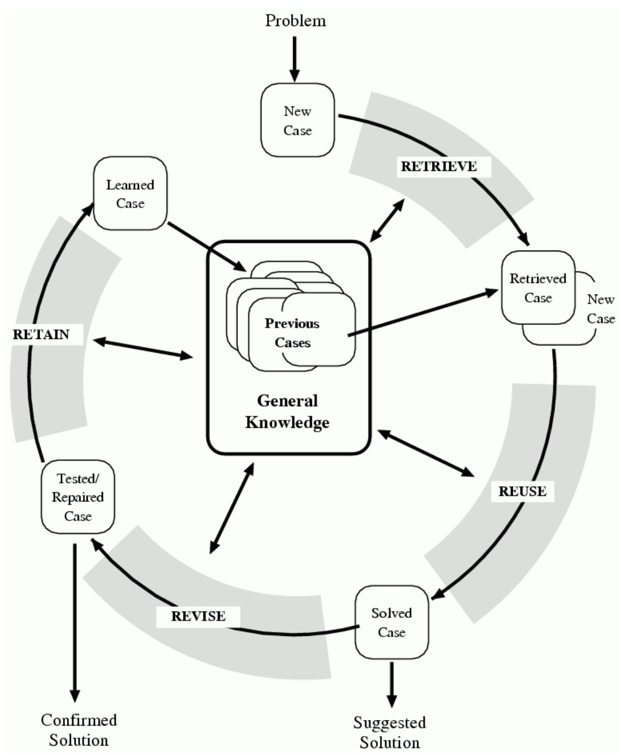

Fig. 2. Case-based reasoning process model [AP94]

commercial tools and many real-life applications were developed (e.g., [Alt95] and [Ber03,Wat03]). Important problems in the mid 1990s were how to systematically develop a CBR system, how to operate it, how to integrate it into an industrial environment as well as how to evaluate it.

From an experience factory perspective in the mid 1990s the basic approach was already introduced by Basili, Rombach et al. With NASA SEL a very successful and established application was available. In addition, there were also some other positive examples. Important problems in the mid 1990s were how to implement an experience base, how the necessary processes for developing an experience factory/base should look like in detail, as well as how experiments about implementation issues could be carried out.

The following integration of the experience factory and the case-based reasoning concepts [Tau00] led to numerous advantages. Case-based reasoning provided an appropriate technology for implementing the experience base. In addition, a lot of detailed knowledge about the case-based reasoning processes was already available in the corresponding community and could be used as a very good starting point for describing experience factory processes. The experience factory approach provided knowledge about organizationally embedding case-based reasoning systems in commercial organizations. In addition, it contributed an approach that could be easily applied for evaluating case-based reasoning systems: goal-oriented measurement and evaluation [AN06].

Enhancing the integration of experience factory and case-based reasoning also led to the integration of systematic reuse into the software development process. As a consequence, the implementation of the experience/case base was based on the software product-line approach [Nic05,Sch04,Mut05] and introduced as so-called "experience based information systems" (EbIS). Thus, an experience/case base was no more realized as single system but as a whole system family. The underlying system architecture is shown in Figure 3. As several of the presented components have different implementations, the architecture describes a family of systems, which definition is based on a number of responsibly designed, common features [Sch02].

3 Vision

The extraordinary significance of knowledge as a production factor of increasing importance was already pointed out in the beginning of this contribution. We emphasized as well our vision to develop intelligent information systems for supporting knowledge work and knowledge-intensive services, focusing on creating added-value through increasingly automated use of available knowledge. This resulted in the idea of a "knowledge product-line" (or short "knowledge-line"). A knowledge-line denotes the systematic application of the software product-line approach to the knowledge included in intelligent information systems.

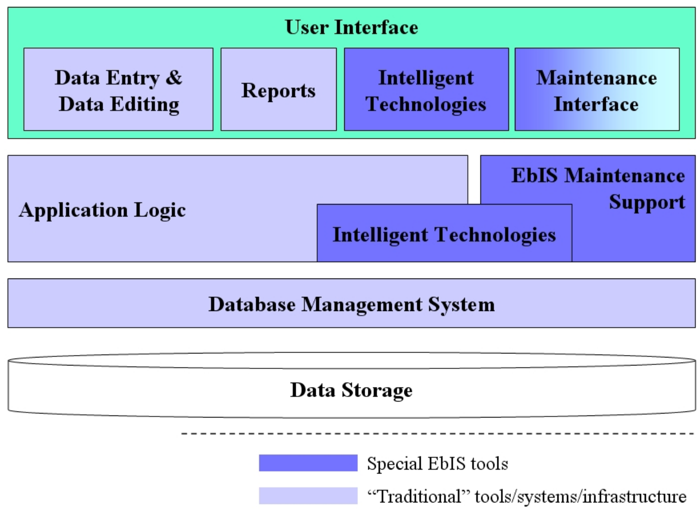

Fig. 3. Product-line architecture for EF/CBR systems [Nic05]

Knowledge-lines enable the necessary "knowledge level modularization" for building potential variants in the sense of software product-lines. This is achieved through the use of multi-agent systems [Bur03,Wei99] as a basic approach for intelligent information systems. An intelligent agent is implemented as a case-based reasoning system, which besides experience can also include other kinds of knowledge. Each case-based reasoning system agent is embedded in an experience factory that is responsible for all necessary knowledge processes like knowledge inflow, knowledge outflow as well as knowledge analysis. Such an experience factory is potentially fully automated, because software agents are available for each role within the experience factory, and perform these roles in an increasingly automated way. For example, machine learning techniques are used for analyzing, evaluating, and maintaining the case base. As part of the vision both the case-based reasoning system agents as well as experience factory agents can learn from experience. As a consequence, the vision considers distributed learning systems as a model for future (intelligent) software systems.

Figure 4 presents a potential implementation of the vision. The left part of Figure 4 shows the case-based-reasoning-enabled operation of an experience factory for different subject areas. The right part of Figure 4 describes the systematic development of a case-based reasoning/experience factory system in the sense of a knowledge-line.

For each role within an experience factory there is at least one software agent. However, each software agent has an associated human coach who is responsible for the role that is jointly taken over by the software agent and its human coach (see Fig. 5). The human role owner "introduces the agent to

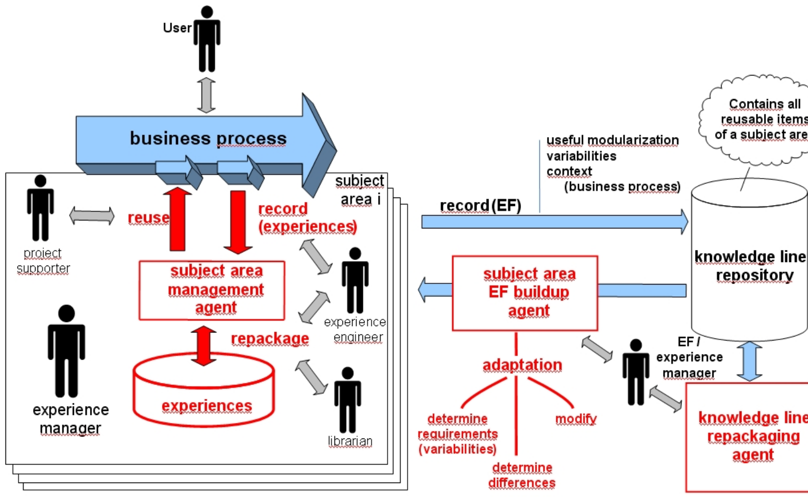

Fig. 4. Knowledge-line for developing intelligent information systems

his job" by taking over difficult decisions and providing his experience. Based on the case-based reasoning/experience factory approach and machine learning techniques the respective software agent should learn while interacting with its human coach and autonomously take over more and more tasks. This enables a gradual transition from purely human based processes to processes where routine tasks are increasingly taken over by software agents, and humans can spend more time on creative tasks.

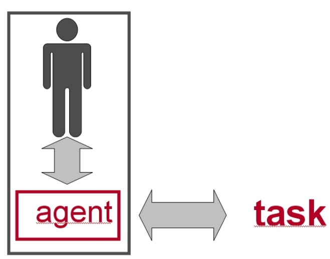

Fig. 5. Experience factory role owner as a coach for the respectively associated software agent

Using the software product-line approach enables a modularization already on the knowledge level. The modules have associated the variabilities and requirements that they satisfy. As a consequence, such knowledge-line modules can be selected using a catalogue of requirements. By this, the development of further experience factories is simplified and speeded up. Nick [Nic05] has identified an efficiency improvement by a factor > 4 for developing the design of an experience based information system. Further efficiency improvement for the build-up of experience factories is expected from increasing automation of an experience factory build-up agent.

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