The Future of Learning Software Organizations: Semantics – Collaboration – Aggregation

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1 Introduction

The reuse of existing knowledge and experience is one of the fundamental principles in many sciences. Engineers often use existing components and apply established processes to construct complex systems. Without the reuse of well-proven experience and knowledge, e.g., in the form of guidelines or software patterns, we would have to rebuild and relearn it again and again.

During the past thirty years, this idea of reusing previously made experiences, products, processes, and best practices has fueled the fields software reuse, experience management (EM), knowledge management (KM), and Learning Software Organizations (LSOs) [48]. Traditionally, LSO approaches are based on concepts such as the Experience Factory [9] [7], Case-Based Reasoning [1], and Knowledge Management [30] [3] [18] in order a) to support *individuals* (i.e., software engineers and managers) in decision making [49] [50], expert identification, short-term problem solving, and long term competence development [38], as well as b) to support *organizations* (e.g., departments or projects) in software process improvement [19], competence management [51], knowledge preservation, and knowledge sharing.

Today, most of the well-known experience factories (EF) (SEL [8], Hughes Aircraft [24], Motorola [11]) focus on *quantitative experiences* gathered through systematic and goal-oriented measurement. Others (IESE [25], Raytheon [23], VSEK [21], ESERNET [26], DOD [16], Daimler-Benz [52]) also include *qualitative experiences* gathered using free content platforms, project retrospectives, or interviews. In order to enable and support the basic functionality, they use technologies such as content or knowledge management systems, web portals, forums / bulletin boards, databases, case-based reasoning, expert systems, etc.

2 New Technologies for Learning Software Organizations

Beside these traditional technologies used for LSOs, progress in other areas has opened new ways of managing experiences made in LSOs. The current developments have moved from heavyweight systems with complex databases and retrieval mechanisms towards lightweight systems for quickly capturing, structuring, retrieving, presenting, aggregating, or using experiences. This has also led to more user-centered experience management technologies (e.g., those that support personal knowledge management).

Web 2.0 technologies facilitate distributed collaboration, foster the free reuse of information, experience, or media/products, and support knowledge workers in coping with the immense information overload by simplifying the organization, integration, and reuse of information scattered across diverse content sources. Major Web 2.0 technologies usable for LSOs are:

- **Wikis:** Wikis enable the simple distributed collaboration of people aimed at sharing ideas, experiences, links, or (work) products. Today, Wikis are used to share and reuse work products in LSOs [43] [15] [17] to support the software development process [35] [46]. LSOs using Wikis as an EF or to support individual groups and projects can use them for easy documentation, acquisition, linking, or exchange of knowledge and experts in distributed environments.
- **Blogs:** Web logs (blogs for short) are content distribution platforms to share news on a specific topic (e.g., one's private life) and are used for knowledge sharing [33] or document experiences [5]. LSOs can use blogs for every employee, project or department as an on-going diary of ideas, problems, solutions, observations, market trends, customer news, etc. and to support their reflective activities.
- **Discourse systems:** These successors to bulletin boards are used to systematically discuss relevant topics (e.g., software processes [55]) with or without the help of moderators, and elicit valuable experiences [40] in a distributed but participative environment. LSOs can use them to systematically discuss experiences themself or in order to aggregate experiences into patterns or laws.
- **Folksonomies:** In contrast to systematically developed ontologies or database schemata, folksonomies are "bottom-up" created taxonomies (resp. ontologies) based on tags (keywords) freely assigned by the users of a system (i.e., ontologies with an uncontrolled vocabulary). LSOs can use the tagging technology for developing, enriching, or improving existing ontologies in their EFs.
- **Microformats:** Microformats are used to embed small structured information blocks (e.g., geographic coordinates) into normal documents. This information can then be used to enrich the original document (e.g., by presenting the geo-location on a map). LSOs can use these technologies either to enrich information within documented experiences or by developing microformats for experiences in order to weave experiences into other documents (e.g., design documents).
- **Mashups:** Web 2.0 technologies such as mashups are used to merge content, services, or presentation forms from different sources, which allows the easy and fast development of new information services [29]. In the context of LSOs, this idea would require an EF as a service or data source that is mixed with a main service (e.g., project database) and used to annotate the main service's data (e.g., project effort estimations).

Semantic web technologies enable the structured and machine-readable description of information and support the automated use and easy annotation of this information. Major semantic technologies usable for LSOs are:

- **Semantic Web Languages and Ontologies**: The languages RDF [28], RDF-Schema [13], and OWL [53] define language constructs that can be used to define ontologies in a way suitable for machine reasoning in the context of LSOs. LSOs using ontologies for EFs can easily reuse tools, frameworks, and technologies for the development, structuring, or visualization of experiences.

- **Semantic Wikis / Desktop**: Semantic Wikis, Semantic Desktops, or Semantic Work environments [47] enable the enrichment of content, work products, contact information, etc. with metadata that can be used for reasoning. Today, some Wiki-based EF such as SOP [56] are about to be equipped with a semantic layer and expanded by semantic-based visual aids or a semantic search engine. LSOs can further use Wikis for the fast, collaborative, and asynchronous documentation of experiences and can easily use features to semantically enrich and connect them with other experiences. LSOs can use semantic work environments, in particular, to improve personal information management and collaboration with colleagues.

Artificial Intelligence (AI) technologies enable the automated processing of machine-readable information and support the intelligent, interactive, and social communication or presentation of information. Major artificial intelligence technologies usable for LSOs are:

- **Software Agents**: Intelligent software agents are aimed at supporting or even replacing static algorithms or people. They are designed to adapt their strategies to the current tasks and context. Multi-agent systems and Collaborative Multi-Expert Systems (CoMES) [2] use them to interface with human users (e.g., pedagogical agents [34]) or to support the EF personnel [6]. Agents can further be used by LSOs either to support the EF tasks and to automatically collect experiences or information about the individuals or the organization and, therefore, act as an ambient organizational memory that could reproduce and explain a person's activities in case of his resignation.
- **Inference engines**: Reasoners, resp. inference engines (e.g., Jena, F-OWL, Jess, …), especially for semantic web languages, enable the inference of rules over semantic information using rule languages such as SPARQL or SWRL. LSOs can use these inference engines in EF for quantitative experiences (evidence) [27] to identify similar experiences for aggregation, incomplete experiences for maintenance, or work-related experiences for proactive information delivery.

3 Current Challenges for Learning Software Organizations

While these new technologies enable new ways of capturing, processing, and distributing experiences in LSOs, several challenges are added to the existing ones [12] [31]. Currently, we have identified the following challenges for LSOs:

- **Intelligent Assistance (IA) for EM during daily work**: Proactive and intelligent supply of relevant experiences and knowledge for the work activity at hand is a feature strongly requested by software engineers [45]. However, developing intelligent, context-sensitive, social, and useful assistance for knowledge workers per se, users of an EF, or the EF personnel [4] itself is a non-trivial task.
- **User-centered context-sensitive adaptation of experiences:** In order to enhance the understanding and application of experiences and to make the experience more compliant with cognitive information processing, experience packages have to be adapted to the user and his current context (resp. situation). Learning Spaces [38] are one context-sensitive approach – based on product-line inspired decision models [36] – to enriching experience packages with additional information that enhances reuse and knowledge acquisition. However, the challenge is still to sepa-

rate structure, content, and layout in order to achieve optimal adaptation of the experience, using tailored user, task, or work product models.

- **System-centered context-sensitive adaptation of experiences:** Besides the adaptation of experiences for users, we also require context-sensitive approaches to adapt whole knowledge bases for domain-, process-, or organization-sensitive knowledge-based systems (KBS). Developers of KBS could use the approach in cooperation with productlines to adapt not only the system to the platform and to the organization, but also the knowledge (i.e., knowledge lines) [2] [4].
- **Collaborative authoring of knowledge:** The documentation of experiences and knowledge by an individual always holds the risk that errors are made or that important information is missing. Collaborative authoring or rework approaches for experiences using Wikis [39] or writer's workshops [22] have the benefit of many eyes checking the documented experience (similar to pair programming). However, motivating and convincing users to contribute to and make use of the EB is not an easy task. Additionally, contributing to the EB is time- and effort-consuming. There is a certain resistance that has to be coped with.
- **Aggregation of Experiences**: One common approach to aggregating quantitative experiences (such as empirical studies) is the meta-analysis technique [14]. For the aggregation of qualitative experiences (such as problem solution descriptions) ad-hoc techniques are used, if at all. While some approaches are described for aggregating "knowledge dust to pearls" [10] or aggregating observations into reusable experiences, patterns, and finally laws [44], more systematic and automated approaches are required.
- **Collection of Knowledge Patterns:** Design patterns are well-known throughout the software engineering community; however, the use and collection of patterns regarding knowledge, knowledge management, or KM systems is rare. Nevertheless, the collection of these knowledge patterns [41] [42] and knowledge refactorings has the potential of systematizing LSOs and improving the experience base.
- **Centralization of knowledge in de-centralized environments:** Today, knowledge is distributed in various repositories, shared network drives, or documents throughout the organization and users have different search requirements [20]. In order to retrieve or centralize this wealth of knowledge, systematic and automated approaches are needed that enable and support the integration of this information.
- **Integrating knowledge management and learning management:** Even if the two research areas follow two different perspectives of learning, i.e., organizational and individual learning **[37]**, both can profit from each other in terms of content creation and sharing, explicit support for learning processes, and hence the internalization of documented experiences as well as their externalization.

In summary, we expect to see more semantics to use experiences in (semi-) automated processes, more (free) collaboration to elicit and share experiences, as well as more processing in order to aggregate, adapt, and improve experiences. Many Web 2.0, Semantic Web, and AI technologies have already proven that they are accepted by the users and might be a solution for motivating users to share more experiences, to help disseminate experiences, and to formalize them in order to decrease maintenance or management efforts.

About the Authors

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References

1. Althoff, K.-D., Case-based reasoning, In S.-K. Chang (eds.) in Handbook of software engineering & knowledge engineering, vol. 1, pp. 549-587. World Scientific, Singapore, 2001
2. Althoff, K.-D., Bach, K., Deutsch, J.-O., Hanft, A., Mänz, J., Müller, T., Newo, R., Reichle, M., Schaaf, M., and Weis, K.-H., Collaborative Multi-Expert-Systems - Realizing Knowledge-Lines with Case Factories and Distributed Learning Systems, In 3rd Workshop on Knowledge Engineering and Software Engineering (KESE), 2007.
3. Althoff, K.-D., Bomarius, F., and Tautz, C., Knowledge Management for Building Learning Software Organizations, Information Systems Frontiers, vol. 2, no. 3-4, pp. 349-367, 2000.
4. Althoff, K.-D., Hanft, A., Mänz, J., Newo, R., Schaaf, M., Decker, B., Nick, M., and Rech, J., Intelligent information systems for knowledge work(ers), In 6th Industrial Conference on Data Mining (ICDM'06), pp. 539 - 547, Springer Verlag, 2006.
5. Avram, G., Ras, E., and Weibelzahl, S., Using Weblogs for Eliciting new Experiences and Creating Learning Elements for Experienced-based Information Systems, In 4th International Conference on Knowledge Management, pp. 14, 2004.
6. Bach, K., Reichle, M., and Althoff, K.-D., A Domain Independent System Architecture for Sharing Experience, In Workshop-Woche "Lernen, Wissen und Adaptivität" (LWA), pp. 296-303, Martin-Luther-University Halle-Wittenberg, 2007.
7. Basili, V. R., Bomarius, F., and Feldmann, R. L., Get Your Experience Factory Ready for the Next Decade IEEE Computer Society, 2007.
8. Basili, V. R., Caldiera, G., McGarry, F., Pajerski, R., Page, G., and Waligora, S., The Software Engineering Laboratory - an Operational Software Experience Factory, In International Conference on Software Engineering (ICSE), pp. 370-381, 1992.
9. Basili, V. R., Caldiera, G., and Rombach, H. D., Experience Factory, In J. J. Marciniak (eds.) in Encyclopedia of Software Engineering, vol. 1, pp. 469-476. John Wiley & Sons, New York, 1994
10. Basili, V. R., Costa, P., Lindvall, M., Mendonca, M., Seaman, C., Tesoriero, R., and Zelkowitz, M., An experience management system for a software engineering research organization, In 26th Annual NASA Goddard Software Engineering Workshop, pp. 29-35, IEEE Computer, 2001.
11. Basili, V. R., Daskalantonakis, M. K., and Yacobellis, R. H., Technology transfer at Motorola, IEEE Software, vol. 11, no. 2, pp. 70-6, 1994.
12. Birk, A. and Dingsøyr, T., Trends in Learning Software Organizations: Current Needs and Future Solutions, (eds.) in Professional Knowledge Management, pp. 70-75. 2005
13. Brickley, D. and Guha, R. V., "RDF Vocabulary Description Language 1.0: RDF Schema," http://www.w3.org/TR/2004/REC-rdf-schema-20040210/, last accessed on.
14. Brooks, A., Meta analysis: A Silver Bullet for Meta-Analysts, Journal of Empirical Software Engineering, vol. 2, no. 4, pp. 333 - 338, 1997.

15. Chau, T. and Maurer, F., A case study of wiki-based experience repository at a medium-sized software company, In Proceedings of the 3rd international conference on Knowledge capture, pp. 185-186, ACM, 2005.
16. Dangle, K., Dwinnell, L., Hickok, J., and Turner, R., Introducing the Department of Defense Acquisition Best Practices Clearinghouse, CrossTalk, no. pp. 4-5, 2005.
17. Decker, B., Ras, E., Rech, J., Jaubert, P., and Rieth, M., Wiki-Based Stakeholder Participation in Requirements Engineering, IEEE Software, vol. 24, no. 2, pp. 28-35, 2007.
18. Dingsøyr, T., Knowledge Management in Medium-Sized Software Consulting Companies, Empirical Software Engineering, vol. 7, no. 4, pp. 383-386, 2002.
19. Dybå, T., Enabling Software Process Improvement: An Investigation of the Importance of Organizational Issues, Empirical Software Engineering, vol. 7, no. 4, pp. 387-390, 2002.
20. Feldmann, R., Rech, J., and Wenzler, A. J., Experience Retrieval in Learning Software Organizations: Do you find what you are looking for?, In 8th International Workshop on Learning Software Organization (LSO 2006), 2006.
21. Feldmann, R. L. and Pizka, M., An on-line software engineering repository for Germany's SME - an experience report, In Advances in Learning Software Organizations. 4th International Workshop, LSO 2002, pp. 34-43, Springer Verlag, 2003.
22. Gabriel, R. P., Writer's Workshops and the Work of Making Things Addison-Wesley Longman Publishing Co., Inc., 2002.
23. Haley, T. J., Software process improvement at Raytheon, IEEE Software, vol. 13, no. 6, pp. 33-41, 1996.
24. Humphrey, W. S., Software and the factory paradigm, Software Engineering Journal, vol. 6, no. 5, pp. 370-6, 1991.
25. Jedlitschka, A., Althoff, K.-D., Decker, B., Hartkopf, S., and Nick, M., Corporate Information Network (COIN): The Fraunhofer IESE Experience Factory, In International Conference on Case-Based Reasoning (ICCBR), pp. 54-60, 2001.
26. Jedlitschka, A. and Ciolkowski, M., Towards evidence in software engineering, In International Symposium on Empirical Software Engineering, pp. 261-270, IEEE Computer Society, 2004.
27. Jedlitschka, A., Rech, J., and Pfahl, D., A Semantics-based Evidence Portal for Learning Software Organizations, In 8th International Workshop on Learning Software Organization (LSO 2006), 2006.
28. Manola, F. and Miller, E., "RDF Primer," http://www.w3.org/TR/2004/REC-rdf-primer-20040210/, last accessed on.
29. Merrill, D., "Mashups: The new breed of Web app," http://www.ibm.com/developerworks/library/x-mashups.html, last accessed on June 30 2008.
30. Nonaka, I. and Takeuchi, H., The Knowledge-Creating Company Oxford University Press, New York, 1995.
31. Plaza, E., Semantics and Experience in the Future Web, In European Conference on Case-Based Reasoning (ECCBR), pp. 15, 2008.
32. Ras, E., Just-in-Time Learning with Situational Content Objects, In E-Learn 2005, World Conference on E-Learning in Corporate, Government, Healthcare & Higher Education, 2005.
33. Ras, E., Avram, G., Waterson, P., and Weibelzahl, S., Using Weblogs for Knowledge Sharing and Learning in Information Spaces, Journal of Universal Computer Science, vol. 11, no. 3, pp. 394-409, 2005.
34. Ras, E., Avram, G., Weibelzahl, S., and Waterson, P., Using Weblogs for Knowledge Sharing and Learning in Information Spaces, Journal of Universal Computer Science, vol. 11, no. 3, pp. 394-409, 2005.

35. Ras, E., Carbon, R., Decker, B., and Rech, J., Experience Management Wikis for Reflective Practice in Software Capstone Projects, IEEE Transactions on Education, vol. 50, no. pp. 6, 2007.
36. Ras, E. and Ilin, D., Using decision models for the adaptive generation of learning spaces, In Adaptive Hypermedia 2008, 2008.
37. Ras, E. and Rech, J., Bringing Together Knowledge Management and E-Learning in Software Engineering: The Software Organization Platform, ERCIM News, no. 71, pp. 29-30, 2007.
38. Ras, E. and Rech, J., "Improving Knowledge Acquisition in Capstone Projects Using Learning Spaces for Experiential Learning," in 21st Conference on Software Engineering Education and Training. Charleston, South Carolina (2008)
39. Ras, E., Rech, J., and Weber, S., "Collaborative Authoring of Learning Elements for Adaptive Learning Spaces," in Authoring of Adaptive and Adaptable Hypermedia. Hannover, Germany (2008)
40. Rech, J., Decker, B., Althoff, K.-D., Voss, A., Klotz, A., and Leopold, E., Distributed Participative Knowledge Management: The indiGo System, In R. A. Ajami and M. M. Bear (eds.) in The Global Enterprise: Entrepreneurship and Value Creation. Haworth Press, Binghamton (New York), 2007
41. Rech, J., Decker, B., Ras, E., Jedlitschka, A., and Feldmann, R. L., The Quality of Knowledge: Knowledge Patterns and Knowledge Refactorings, International Journal on Knowledge Management (IJKM), vol. 3, no. 3, pp. 74-103, 2007.
42. Rech, J., Feldmann, R. L., Ras, E., Jedlitschka, A., and Decker, B., Knowledge Patterns and Knowledge Refactorings for increasing the Quality of Knowledge, In M. E. Jennex (eds.) in Knowledge Management, Organizational Memory and Transfer Behavior: Global Approaches and Advancements, Advances in Knowledge Management, pp. 30. 2007
43. Rech, J., Höcht, C., and Haas, V., Using Wikis to Tackle Reuse in Software Project Work, IEEE Software, vol. 24, no. 6, pp. 99-104, 2007.
44. Rech, J. and Ras, E., Aggregation von Erfahrungen in Erfahrungsdatenbanken, Künstliche Intelligenz, no. pp. 6, 2007.
45. Rech, J., Ras, E., and Decker, B., Intelligent Assistance in German Software Development: A Survey, IEEE Software, vol. 24, no. 4, pp. 72-79, 2007.
46. Rech, J., Ras, E., and Decker, B., RIKI: A System for Knowledge Transfer and Reuse in Software Engineering Projects, In M. D. Lytras and A. Naeve (eds.) in Open Source for Knowledge and Learning Management. IDEA Group Publishing, 2007
47. Rech, J., Ras, E., and Decker, B., Emerging Technologies for Semantic Work Environments: Techniques, Methods, and Applications, (eds.) Emerging Technologies for Semantic Work Environments: Techniques, Methods, and Applicationsvol. IGI Global, 2008
48. Ruhe, G., Learning Software Organisation, (eds.) in Handbook of Software Engineering and Knowledge Engineering, vol. Volume I, pp. 19. World Scientific, 2001
49. Ruhe, G., Software engineering decision support - a new paradigm for learning software organizations, Advances in Learning Software Organizations, no. pp. Maurer, F.. - Berlin, Germany, Germany Springer-Verlag, 2003, vi+113 104-13, 24 Refs., 2003.
50. Ruhe, G. and Pfleeger, S. L., Software Engineering Decision Support, In System Sciences, 2007. HICSS 2007. 40th Annual Hawaii International Conference on, pp. 282-282, 2007.
51. Rus, I. and Lindvall, M., Knowledge Management in Software Engineering - Guest Editors' Introduction, IEEE software, vol. 19, no. 3, pp. 26 (13 pages), 2002.
52. Schneider, K. and Schwinn, T., Maturing experience base concepts at DaimlerChrysler, Software Process: Improvement and Practice, vol. 6, no. 2, pp. 85-96, 2001.
53. Smith, M. K., Welty, C., and McGuinness, D. L., "OWL Web Ontology Language Guide," http://www.w3.org/TR/2004/REC-owl-guide-20040210/, last accessed on.
54. Tsandilas, T. and Schraefel, M. C., Usable adaptive hypermedia systems, New Review of Hypermedia and Multimedia, vol. 10, no. 1, pp. 5-29, 2004.

55. Voss, A., Althoff, K. D., Becker, K. U., Decker, B., Klotz, A., Leopold, E., and Rech, J., Enhancing experience management and process learning with moderated discourses: the indiGo approach, Practical Aspects of Knowledge Management, no. pp. Reimer, U.. - Berlin, Germany, Germany Springer-Verlag, 2002, xiii+648 114-25, 15 Refs., 2002.
56. Weber, S., Thomas, L., Armbrust, O., Ras, E., Rech, J., Uenalan, Ö., Wessner, M., Linnenfelser, M., and Decker, B., "A Software Organization Platform (SOP)," in 10th Workshop on Learning Software Organizations (LSO 2008). Rome, Italy (2008)