## Ontology-based Software Architecture Documentation

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# 8 Conclusions

*In this thesis we investigated whether the efficiency and effectiveness of AK retrieval can be improved using ontology-based documentation. We first studied how AK is retrieved from file-based documentation in practice and theory. We then introduced an ontology-based approach for retrieving AK from SA documentation. Next, we proposed and applied an approach to build an ontology for SA documentation in a software project. We conducted experiments to compare the efficiency and effectiveness of AK retrieval between file-based and ontology-based documentation. Finally we compared AK retrieval between two ontologies in ontology-based documentation. In this chapter we revisit the research questions, reflect on contributions, and discuss future work.*

## 8.1 Contributions

Even a perfect SA is essentially useless if its AK cannot be found and understood [9, 21]. SA documentation should be written to satisfy the needs of its users, and organised such that users can quickly find the AK they need and answer their questions [21, 77]. It is common practice to capture AK in file-based documents [80], however, various challenges inhibit efficient and effective AK retrieval from these documents. Recent studies provide evidence that the use of ontology-based documentation improves AK extraction [51] and AK understanding [68] compared to file-based documentation.

Our main Research Question (RQ) is whether we can improve the efficiency and effectiveness of AK retrieval using an ontology-based documentation approach. In previous chapters we investigated RQ1 to RQ5. We summarize their answers in this chapter and discuss how together they provide an answer to the main RQ.

In Chapter 2 and 3 we investigated RQ1; "*how do software professionals retrieve AK from file-based documentation?*". In Chapter 2 we used protocol analysis to investigate the search behaviour of professionals in industry and we identified four search strategies. We found that professionals experience search uncertainty and AK retrieval challenges when they cannot follow document organisation that relates to the questions they need to answer. Use of prior knowledge helps to deal with search uncertainty, however, it is prone to cognitive bias and often results in inefficient and ineffective AK retrieval.

We studied literature about file-based SA documentation in Chapter 3 and identified underlying causes for missing document organisation and AK retrieval challenges. Many of the challenges that are reported by software industry professionals stem from the linear organisation of AK in file-based documentation. This suggests that there is room for improving the efficiency and effectiveness of AK retrieval practices.

We proposed an ontology-based documentation approach when investigating RQ2; "*How can an ontology be used for retrieving AK from documentation?*", in chapter 4. We first discussed how ontologies can be used for organising and retrieving AK in SA documentation. We then described a lightweight software ontology and semantic wiki that are used for AK retrieval in the proposed ontology-based approach. The identified AK retrieval challenges in file-based documentation can be addressed by the ontology-based approach.

We proposed an ontology engineering approach when investigating RQ3; "*How to construct an ontology for SA documentation in a software project context?*", in Chapter 5. We conducted an exploratory case study to evaluate how well our approach works to construct an ontology, given the diversity of AK users, domain complexity, and other contextual factors in a software project. Industry practitioners evaluated the constructed ontology as useful for retrieving AK.

In Chapter 6 we investigated RQ4; "*How do file-based and ontology-based documentation influence the efficiency and effectiveness of AK retrieval?*". We conducted an experiment in two companies during which software professionals answered questions about AK. Use of ontology-based documentation was significantly more efficient and effective than use of file-based documentation.

Part of the available AK organisation was fitting for AK retrieval; it explicitly denoted the AK types and relationships between AK specified in the experiment questions. We analysed search actions of professionals and found that the usage of fitting AK organisation has a positive correlation with the efficiency and effectiveness of AK retrieval. This correlation explains the difference in efficiency and effectiveness between the two documentation approaches.

We conducted a questionnaire among industry professionals, which shows a mostly positive evaluation of ontology-based documentation. A coarse cost-benefit estimation indicates a positive return on investment when replacing file-based with ontology-based documentation in the studied projects.

In Chapter 7 we investigated RQ5; "*How do different ontology-based AK organisations influence the efficiency and effectiveness of AK retrieval?*". We compared AK retrieval from an ontology built based on the expected AK needs of document users, and from an ontology built based on the actual AK needs. The results show that a better understanding of AK needs allows for the construction of ontologies that provide more fitting AK organisation, and thereby improve AK retrieval efficiency and effectiveness.

**Main Research Question**

The findings in this thesis support a confirmatory answer to the main RQ; "*Can we improve AK retrieval efficiency and effectiveness using ontology-based documentation?*".

We phrase the findings using the same terminology as the main RQ, to summarize how the main RQ is answered.

- AK retrieval efficiency and effectiveness can be improved in existing file-based documentation practice in industry (RQ1).
- Ontology-based documentation can address challenges that inhibit efficient and effective AK retrieval in existing file-based documentation practice (RQ2).
- An ontology that is useful for retrieving AK in ontology-based documentation can be built in a software project (RQ3).
- The use of ontology-based documentation can improve AK retrieval efficiency and effectiveness compared to the use of file-based documentation in industry practice (RQ4).
- AK retrieval efficiency and effectiveness in ontology-based documentation can be improved by using ontology-based AK organisation that is built based on a better understanding of AK needs (RQ5).

Though the results of this study indicate that ontology-based SA documentation holds a promising future, there are still many challenges to overcome. More research is needed to replicate and further generalize the findings to different types of software projects, and to explore open questions and future work.