

Automated Microservice Identification: an Approach to Decomposition into a Modular Monolith Architecture

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Florian Dejonckheere

UNIVERSITY OF TURKU
Department of Computing

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The modular monolith architecture emerged in recent years as the harmonization of the monolithic and microservices architectures. The paradigm offers a compromise between modularity, flexibility, and scalability. Many monolithic applications are being migrated to modular monoliths or microservices entirely, to satisfy increasingly complex and volatile business requirements. This process is labour-intensive, slow, and may take months to years for larger codebases. Modularization of a codebase typically requires the developer to have an intimate knowledge of both the application code and domain.

In this thesis, we investigate the modular monolith software architecture, and how modules are typically determined as part of the modularization efforts. We propose an automated solution based on dependency analysis and machine learning algorithms to aid in the identification of module boundaries, and evaluate its effectiveness using a case study. We discuss the results and draw conclusions about the proposed solution.

Keywords: software architecture, monolith, microservices, modular monolith

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List of Acronyms

DSRM	Design Science Research Methodology
DSRP	Design Science Research Process

1. Introduction

1.1. Scope and goal

This research is centered around three research questions:

Research Question 1: Which challenges and opportunities arise when considering adoption of the modular monolith architecture in an existing codebase?

Research Question 2: What are the existing approaches and tools for automated modularization of monolith codebases?

Research Question 3: How can (*automated technology*) effectively identify optimal module boundaries in a modular monolith architecture?

To answer the first research question, we will first define the modular monolith architecture, and examine what sets it apart from monolithic and microservices architectures. Then, we will proceed to investigate the merits and drawbacks of the software architecture when applied to an existing codebase.

For the second research question, we will enumerate the existing technologies to aid modularization of monolithic codebases, and choose one automated technology for further examination. (*Automated technology*) will then be implemented for a given use case, and compared to manual modularization efforts in terms of accuracy, efficiency, development velocity. This comparison will help us to answer the third research question.

The goal of this research can be summarized as follows:

1. Investigate the merits and drawbacks of the modular monolith architecture
2. Investigate the use of automated technologies to modularize a monolithic architecture

The proposed solution will add value to the field of software engineering, and will be able to be used as a base for future improvements regarding automated modularization of monolith codebases.

1.2. Motivation

1.3. Methodology

A literature review is conducted to answer the first and second research question. For the first research question, the study aims to find a definition of the modular monolith architecture, and to list the advantages and disadvantages of the architecture based on existing literature. For the second

research question, the state of the art in automated modularization technologies is reviewed and summarized.

The third research question is answered by choosing the most appropriate automated technology, and implementing it for a given use case. The implementation is then evaluated based on quantitative and qualitative metrics, and compared to manual modularization efforts.

Finally, the findings are summarized, and an outlook on future work is given.

For the case study, a Design Science Research Methodology (DSRM) is adopted, which is a research paradigm for information systems research focused at creating and evaluating artifacts. In particular, the research and design of the proposed solution follows the six-step Design Science Research Process (DSRP) model [1]. Their model is based on prior research and is designed to guide researchers through the process of analysis, creation, and evaluation of artifacts.

The six steps of the process are:

1. **Problem identification and motivation:** Research problem statement and justification for existence of a solution.
2. **Objectives of a solution:** Definition of the objectives, derived from the problem statement.
3. **Design and development:** Creation of the artifact.
4. **Demonstration:** Usage of the artifact to demonstrate its effectiveness in solving the problem.
5. **Evaluation:** Observation and measurement of how well the artifact supports a solution to the problem.
6. **Communication:** Transfer of knowledge about the artifact and the problem solution to the relevant audience.

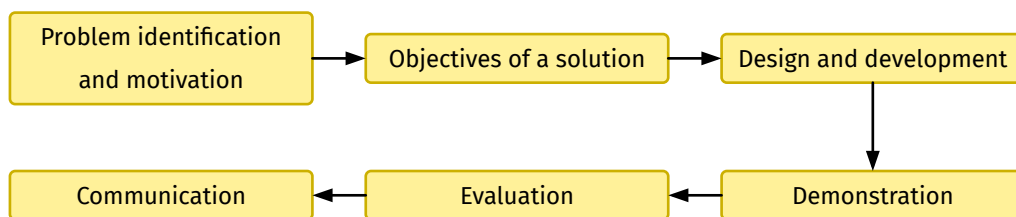


Figure 1: Design Science Research Process (DSRP)

The process is structured sequentially, however the authors suggests that researchers may proceed in a non-linear fashion, and start or stop at any step, depending on the context and requirements of the research.

In this thesis specifically, the DSRP is used to guide the design and development of the automated modularization technology, with a particular focus on the design and development, demonstration, and evaluation steps.

1.4. Outline

The thesis is divided into three parts.

The first part comprises the background and related work. In Chapter 1, the scope and goal of the research is defined, and the research questions are formulated. The stakeholders are identified, and the methodology is explained. Chapter 2 introduces the reader to the research background and necessary concepts. In Chapter 3, the existing literature is reviewed, and the state of the art is presented.

The second part of the thesis, starting with Chapter 4, is dedicated to the first research question. The modular monolith architecture is defined, and its merits and drawbacks are discussed.

The third part aims to solve the second and third research question. Chapter 5 gives an introduction into the automated modularization of monolith codebases, listing the existing technologies. It then continues to focus on one automated technology, (*automated technology*), and explains its implementation. Chapter 7 applies (*automated technology*) on a given case study, and compares it to manual modularization efforts.

Finally, Chapter 8 summarizes the findings, and gives an outlook on future work.

2. Background

2.1. Monolith architecture

2.2. Modular programming

2.3. Microservice architecture

3. Related work

4. Modular monolith architecture

4.1. Background

4.2. Challenges and opportunities

4.3. Modularization

5. Automated modularization

In this chapter, we investigate the state of the art in automated technologies for modularization of monolith codebases. Using a systematic literature review, we identified and categorized existing literature regarding automated modularization of monolith codebases. We also provided a brief overview of the most relevant approaches and tools.

A systematic literature review is used to identify, evaluate and interpret research literature for a given topic area, or research question [2]. The systematic nature of systematic literature reviews reduces bias through a well-defined sequence of steps to identify and categorize existing literature, although publication bias still has to be considered. Studies directly researching the topic area are called *primary* studies, systematic studies aggregating and summarizing primary studies are called *secondary* studies. *Tertiary* studies are systematic studies aggregating and summarizing secondary studies.

The literature review was conducted using a three-step protocol as defined by B. Kitchenham and S. Charters, [2]:

	Step	Activity
1	Plan	Identify the need for the review, specifying the research questions, and developing a review protocol
2	Conduct	Identification and selection of literature, data extraction and synthesis
3	Report	Evaluation and reporting of the results

Table 1: Systematic literature review process

5.1. Plan

Using the systematic literature review, we answered the following research question:

Research Question 2: What are the existing approaches and tools for automated modularization of monolith codebases?

The motivation for the research question is discussed in Chapter 1.

Although systematic mapping studies related to microservices [3], [4] and related to microservice decomposition exist, we are not aware of any systematic literature review specifically focusing on automated decomposition or modularization of monolith codebases. Therefore, we believe that there

is a need for a systematic literature review to identify and categorize existing literature regarding automated modularization of monolith codebases.

As a search strategy, the following platforms were queried for relevant publications:

1. IEEE Xplore
2. ACM Digital Library
3. arXiv
4. Google scholar

Based on a list of relevant topics, we used a combination of related keywords to formulate the search query. The search query was adapted to the specific search syntax of the platform. We refrained from using more generic keywords, such as “architecture” or “design”, as they would yield too many irrelevant results. The topics relevant for the search query are:

- *Architecture*: the architectural styles being discussed in the publications.
Keywords: microservice, monolith, modular monolith
- *Modularization*: the process of identifying and decomposing modules in a monolith architecture.
Keywords: service identification, microservice decomposition, monolith modularization
- *Technology*: the technologies, algorithms, or methods for modularization.
Keywords: automated tool, machine learning, static analysis, dynamic analysis, hybrid analysis

Based the inclusion/exclusion criteria in Table 2, the results were filtered, and the relevant studies were selected for inclusion in the systematic literature review.

	Criteria
Inclusion	<ul style="list-style-type: none"> • Title, abstract or keywords include the search terms • Conference papers, research articles, blog posts, or other publications • Publications addressing automated technologies, algorithms, or methods
Exclusion	<ul style="list-style-type: none"> • Publications in languages other than English • Publications not available in full text • Publications using the term “microservice”, but not referring to the architectural style • Publications aimed at greenfield development of microservice-based systems • Publications published before 2014, as the definition of “microservices” as an architectural style is inconsistent before [4] • Publications addressing manual technologies, algorithms, or methods

Table 2: Inclusion and exclusion criteria

As a final step, the publications were subjected to a validation scan to ensure relevance and quality. To assess the quality, we mainly focused on the technical soundness of the approach or technique described in the publication.

The quality of the publication was assessed based on the following criteria:

- The publication is peer-reviewed or published in a respectable journal
- The publication thoroughly describes the technical aspects of the approach or technique
- The publication includes a validation phase or case study demonstrating the effectiveness of the approach or technique

This step is necessary to ensure that the selected publications are relevant to the research question and that the results are not biased by low-quality publications. In the end, publications were selected for inclusion in the systematic literature review.

Once a final selection of publications was made, the resulting publications were qualitatively reviewed and categorized based on the type of approach or technique they describe.

5.2. Conduct

Using the search strategy outlined in the previous section, we queried the selected platforms and found a total of publications.

Platform	Search results	Selected publications
IEEE Xplore	337	2
Total	337	2

Table 3: Summary of search results

After applying the inclusion/exclusion criteria, we selected publications for inclusion in the systematic literature review. Table 4 provides a summary of the selected publications.

	Type	Publication
1	Proceedings	[5] B. Andrade, S. Santos, and A. R. Silva, <i>A Comparison of Static and Dynamic Analysis to Identify Microservices in Monolith Systems</i> . 2023.
2	Proceedings	[6] G. Mazlami, J. Cito, and P. Leitner, <i>Extraction of Microservices from Monolithic Software Architectures</i> . 2017.

Table 4: Selected publications

5.3. Report

The publications in the systematic literature review were categorized based on the type of approach or technique they describe. The identified categories are as follows:

1. Static analysis
2. Dynamic analysis
3. Hybrid analysis
4. Machine learning
5. Other

6. Proposed solution

7. Case study

7.1. Background

7.2. Analysis

7.3. Evaluation and results

7.4. Discussion

8. Conclusion

8.1. Future work

References

- [1] K. Peffers, M. Rothenberger, T. Tuunanen, and S. Chatterjee, "A Design Science Research Methodology for Information Systems Research", vol. 24, no. 3. 2007.
- [2] B. Kitchenham and S. Charters, "Guidelines for performing Systematic Literature Reviews in Software Engineering". 2007.
- [3] N. Alshuqayran, N. Ali, and R. Evans, *A Systematic Mapping Study in Microservice Architecture*. 2016.
- [4] C. Pahl and P. Jamshidi, *Microservices: A Systematic Mapping Study*. 2016.
- [5] B. Andrade, S. Santos, and A. R. Silva, *A Comparison of Static and Dynamic Analysis to Identify Microservices in Monolith Systems*. 2023.
- [6] G. Mazlami, J. Cito, and P. Leitner, *Extraction of Microservices from Monolithic Software Architectures*. 2017.