Refactoring-assisted migration of monoliths to microservices

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***Abstract*—In the world of software development, the concept of microservices is gaining popularity. This architectural style has received a lot of attention in both business and academia, and converting a monolithic application into a microservice-based application has become a regular practice. Companies with limited resources struggle with migrating their already existing monolithic applications to microservices and software architects and developers frequently face challenges as a result of a lack of complete awareness of alternative migration methodologies making the refactoring process even harder. The goal of this study is to structurally analyse the state of the art in regards to the migration of monolithic applications to microservices architectural style, mainly how tools are helping architects, engineers, and developers in this migration and how automated they are. To address this challenge, a systematic literature review was conducted, resulting in the identification of one hundred and six relevant publications. These publications were organised and grouped to provide a more comprehensive understanding of the current tools available for microservice migration. Finally, we present a high-level idea for an extensible tool that may aid architects, engineers, and developers during the refactoring process by addressing gaps in understanding of various migration tools and approaches, allowing for easy comparison between multiple options.**

I. Introduction

Microservices is an architectural style that evolved from Service Oriented Architecture (SOA). Just like SOA, microservices are an alternative to monolithic architecture. The main contrasts are that, while monolithic applications are software systems with a single, integrated codebase that includes all necessary components, and features [1], microservices tend to be separated, and loosely coupled [2]. Also while monoliths tend to be easier to develop they may scale poorly and are harder to maintain when compared to microservices [3]. Microservices are increasingly being used in the development of modern applications, particularly in the areas of cloud computing and DevOps [4]. Many organizations, including large enterprises and startups, are adopting microservices as a way to build and deploy applications more quickly and efficiently [5]. Microservices are particularly well-suited for distributed, cloud-based environments, where they can take advantage of the flexibility and scalability of the cloud [6]. This type of architecture is already being applied in multiple well-known companies, like Uber, Netflix, eBay [7], and also being followed by the rest of the herd when compared to monolith architecture [8].

Refactoring from monoliths to microservices is a heavily debated topic both in the academic world and the industry. The main takes from this debate are that refactoring is difficult and time-consuming, especially for companies with limited resources who struggle with migrating their already existing monolithic applications to microservices. To help address this, some tools were developed that help with the refactor [23]–[25], but in today's world, where the amount of data and information is constantly increasing, it would be ideal to have a centralised location where architects, engineers, and developers can access and utilise all the tools that are currently available as well as those that will be developed in the future. Unfortunately, at the moment, no tool that offers multiple options for migrations with different possibilities exists.

The goal of this study is to structurally analyse the state of the art in regards to the migration of monolithic applications to microservices architectural style, mainly how tools are helping architects, engineers and developers in this migration, and how automated they are. Furthermore, in the following thesis, the purpose is to develop a tool which aims to aggregate existing tools into a single platform, as well as provide the means to extend and incorporate new tools. This tool will offer a convenient and comprehensive way to access and use a variety of tools that help the refactor from monoliths to microservices as well as provide them with a perspective on several migration proposals, allowing for easily comparable and different combinations options.

To achieve this, the guidelines presented by Kitchenham and Charters [9] were followed while performing a systematic literature review. The research protocol was defined at first and then followed to ensure all results could be reproduced.

According to Kitchenham and Charters [9], research questions should be specified as they will direct the entire review methodology. The research questions formulated are as follows:

RQ1. *What tools already exist that aid in the migration process of monoliths to microservices?*
- *RQ1.1.* *How do they take the monolith as input?*
- *RQ1.2.* *How do they produce the microservice as output?*
- *RQ1.3.* *Are they bound to a specific language?*

RQ2. How can an aggregator of those tools help architects, engineers and developers in their microservice migration?

II. Background

To give readers a foundational understanding of microservices architecture and its key features, we will provide a brief overview of microservices and contrast them with traditional monolithic applications. This will allow readers to clearly understand the differences between the two architectures.

A. Monoliths

Monolithic applications are software systems that are designed as a single, self-contained unit [10]. In other words, monolithic applications are composed of a single, integrated codebase that includes all of the necessary components and features for the application to run [1]. This means that all of the different parts of the application, such as the user interface, business logic, and database access are all contained within a single codebase and are not modularized or separated into distinct components that are separately deployed and executed.

Monolithic architecture is a traditional approach to software development that has been widely used for many years [10]. It is generally characterized by a strong emphasis on simplicity and ease of development. However, monolithic applications can also be more difficult to maintain and update, as changes to one part of the codebase can have unintended consequences on other parts of the system. This can make it challenging to introduce new features or make changes to the application without significant testing and debugging [1].

Despite these challenges, monolithic applications are still widely used in many contexts due to their simplicity and ease of development. They are particularly well-suited for small to medium-sized applications that do not require a high level of modularity or separation of concerns.

B. Microservices

Microservices is an architectural style that structures an application as a collection of loosely coupled services [2]. This means that each microservice is a self-contained unit of functionality, which communicates with other microservices through well-defined interfaces, typically using a lightweight messaging protocol such as HTTP [11].

One key benefit of this approach is that it allows for greater flexibility and scalability [3]. Because each microservice is independent and modular, it can be modified and deployed independently of the other services in the application. This can make it easier to make changes to the system, as it is not necessary to redeploy the entire application every time a change is made. In addition, the modular nature of microservices allows for easier scaling, as individual services can be scaled up or down as needed to meet changing demand [2], [3], [11].

Another advantage of microservices is that they can be developed and maintained by small, autonomous teams [12]. This can be beneficial for organizations with a large codebase or a distributed development team, as it allows for more focused development and faster deployment of changes [13].

However, there are also challenges to consider when adopting a microservices architecture [14]. One challenge is the added complexity of managing a distributed system, as there may be a larger number of moving parts to monitor and troubleshoot [2]. In addition, the communication between microservices can add latency to the system, which may impact the performance of the overall application [14], [15].

Overall, microservices can be an effective way to structure an application, particularly for large, complex systems that require a high degree of flexibility and scalability [2]. However, it is important to carefully evaluate the trade-offs and consider whether the benefits of a microservices architecture are worth the added complexity [14].

C. Refactoring

Refactoring is the process of modifying the internal structure of an existing codebase without changing its external behaviour [16]. When migrating from a monolithic architecture to a microservices architecture, it may be necessary to refactor the existing codebase to break it into independent microservices. This can be a complex and time-consuming process, particularly for large, complex systems [3].

There are several factors to consider when refactoring an existing codebase for a microservices architecture [3]. One challenge is ensuring that the code is modular and loosely coupled so it can be developed and deployed independently as a microservice. This may require restructuring the code, introducing new abstractions and interfaces, and potentially even rewriting parts of the code.

Another challenge is preserving the application's existing functionality while making changes to the codebase. It is important to carefully plan and test the refactoring process to ensure that the application continues to work as expected after the changes are made.

Overall, refactoring an existing codebase for a microservices architecture can be a significant undertaking, and it is important to carefully evaluate the resources and time required to complete the process [3].

III. Systematic Literature Review

A systematic literature review is a type of review that aims to identify, evaluate, and summarize the results of all studies that address a specific research question or topic [9], [17], [18]. It involves following a specific methodology to identify, analyse, and interpret all relevant evidence related to the research question being addressed. The purpose of a systematic literature review is to provide a comprehensive and up-to-date overview of the current state of knowledge on a specific research question or topic. It is a critical appraisal of the existing research and it can help identify gaps in the literature and inform future research directions [9].

As per Kitchenham and Charters guidelines [9], a systematic literature review (SLR) involves three phases: planning, conducting, and reporting. The planning phase involves establishing the review protocol based on the research questions and the need for the review. The conducting phase involves selecting primary studies and applying the criteria established in the review protocol to analyse them. Finally, the reporting phase involves the creation of the report. These guidelines were loosely followed in the development of this review.

A. Research Methodology

To address the research questions posed in Section I, the appropriate research methods were utilised as means to properly investigate the current state of the art. To give guidance, Figure 1 shows a diagram of the review iterations that will be explained in the following sections.

1) Data sources: To access relevant research and information in this field, it is advisable to search several databases that specialise in scientific literature. Table I presents a list of several such databases, including the ACM Digital Library, Science Direct, IEEE Xplore, Wiley, Springer Link, Engineering Village, and Google Scholar. These databases contain a wealth of knowledge and resources, including journal articles, conference proceedings, technical reports, and more, which can be useful for staying up to date on the latest developments in this field.

TABLE I
DATABASES

ID	Search Engine	Website
DB.1	ACM Digital Library	https://dl.acm.org/
DB.2	IEEE Xplore	https://ieeexplore.ieee.org/
DB.3	Springer Link	https://link.springer.com/
DB.4	Wiley	https://onlinelibrary.wiley.com/
DB.5	Science Direct	https://www.sciencedirect.com/
DB.6	Engineering Village	https://www.engineeringvillage.com/
DB.7	Google Scholar	https://scholar.google.com/

2) Search strategy: To ensure a thorough and comprehensive search for relevant publications in this field, we will utilise a breadth-first search approach. This method involves starting with a specific query string and selecting relevant publications from a given database. We will then use a technique called snowballing to expand the search and locate additional relevant publications. Snowballing involves searching for citations and publications that are related to the initially selected publications.

There are two types of snowballing that we will employ in this search: forward snowballing and backward snowballing. Forward snowballing involves searching for citations and publications using Google Scholar for the initially selected publications. This process can be repeated multiple times, with each iteration referred to as a level of snowballing. For this search, we will perform two levels of forward snowballing, in which we extract the references of the initially selected publications (level one) and then select the references of those references (level two).

Backward snowballing involves searching for publications that have been cited by the initially selected publications. This technique can also be repeated multiple times, but for this search, we will only perform one level of backward snowballing. This will include all previous publications found during the forward snowballing step.

By utilising both forward and backward snowballing techniques, we aim to cast a wide net and identify as many relevant publications as possible.

After completing the search for relevant publications in a given database using the specified query string, we will move on to the next database. This approach is advantageous because it allows us to efficiently locate relevant publications while minimizing the number of duplicates that are analysed. By searching multiple databases and using snowballing techniques, we can identify a large number of relevant publications and eliminate the need to analyse many of them in subsequent iterations.

3) Query definition: To identify relevant publications for this research, we will utilise a range of keywords related to the topic of microservices. These keywords will include various phrases and terms used to describe microservices. As for the practices that may help identification of microservices, keywords that help this architectural refactoring should be included, such as "migration", "refactor", "identification". It could also be useful to use "monolith" (and all its possible synonyms) to be the comparison against "microservices", although this can result in some extra publications not related to microservices but instead related to "service-oriented architecture". An expected outcome or conclusion of the publication could be included, "approach" or even "tool". The main keywords that will be used are present in Table II.

TABLE II
KEYWORDS

Focus	microservices
Refactoring	migration, decomposition, identify, refactor, evolve, discover, transition
Target	monolith
Outcome	approach, tool

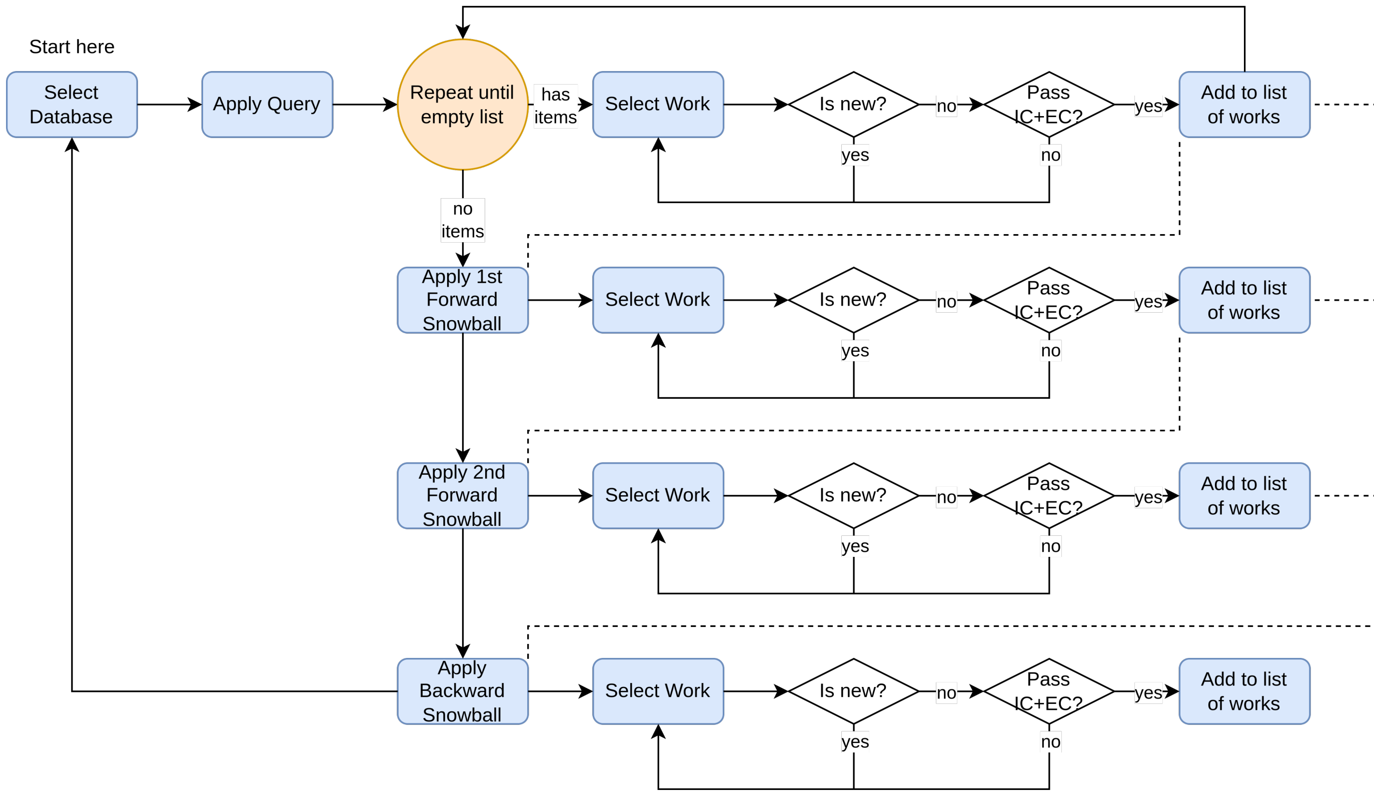
First iteration: The first iteration of the review has the main purpose of determining how many tools exist that are able to solve this research question or, at the very least, help partially with it. In order to do this, one could not be limited to tools that are documented in academic databases therefore, in addition to the databases mentioned in Table I, GitHub, GitLab and even DuckDuckGo were searched for, even though they do not represent a scientific search engine.

By using some keywords mentioned in Table II the following initial trial query was created:

("microservice" OR "micro-service") AND ("migration" OR "identification") AND ("monolithic" OR "monolith") AND ("tool")

Second iteration: In the second iteration of the review process, the focus is on locating publications that describe

Fig. 1. Review iterations



alternative approaches for migrating from monolithic to microservices architectures that may not have been implemented in practice. This will allow an increased understanding of the current state of the art in this area, identify any gaps or areas where further research is needed, and determine what can be improved upon. This information will be useful in guiding the development of our tool and abstraction.

As this was the beginning of a new iteration of the review process, the results of the previous "test run" were not considered when extracting literature. Only after this iteration was completed did we incorporate the previously analysed literature and exclude it from further analysis to avoid duplication of effort. This allowed us to focus on identifying new and potentially relevant publications for our purposes.

Relying on the keywords identified in Table II, the following query was created:

(microservice OR micro?service*) AND (migrat* OR identif*) AND (monolith*) AND (migrat* NEAR/2 (process* OR approach*))*

In the event that the publications located through the snowballing approach are no longer adding significant value to the overall understanding of the topic, a new search query should be applied to the remaining databases. In some instances, the query produced more than two thousand results, which would have been impractical to analyse within the given timeframe. Therefore, we modified the query to focus only on the titles and abstracts of the publications. The revised query that should be used is:

(microservice OR "micro-service") AND (migrat* OR decompos* OR identif* OR refactor* OR evolv* OR extract* OR discover* OR transition*)*

4) Selection Criteria: In order to filter the publications, the title and the abstract will be analysed and should mention at least one of:

IC1. A tool that automates the process of migration of monoliths to microservices.
IC2. Identification of microservices from monolith systems.
IC3. Analysis of tools or approaches for migrating from monoliths to microservices.

In cases of ambiguous abstracts, further inspection of the publication may be done. When this happens, and if relevant publications apply, conclusions should also be taken into account.

As for more pratical approach for exclusion of publications, the criteria will be:

EC1. Publications that are not written in English or Portuguese.
EC2. For Portuguese publications, English must be the language used in the abstract.
EC3. Publication is not accessible.

B. Research Results

The query mentioned in the first iteration Section III-A3 was then applied to DB.1, DB.2 and DB.3 and after applying the selection criteria mentioned in Section III-A4, results were gathered and are presented in Table III.

TABLE III
TOOL SEARCH

Database	**Total number of results**	**Extracted Results**
DB.1	118	3
DB.2	4	0
DB.3	658	3

As for GitHub, GitLab and DuckDuckGo, the query would be essentially typed into their respective search engine and the results gathered as well as the query are presented in Table IV.

TABLE IV
SEARCH ENGINE TOOL SEARCH

Search Engine	**Query**	**Total number of results**	**Extracted Results**
GitHub	https://github.com/search?q=monolith+to+microservice	745	4
GitLab	https://gitlab.com/search?search=monolith%20to%20microservice	0	0
DuckDuckGo	https://duckduckgo.com/?q=monolith+to+microservices+tool	Uncountable	2

Through this search process, we can also trace the references used in these publications to determine if the tools described were based on previous work, but only implemented a specific approach. This will help us to understand the context and origins of these tools and how they fit into the broader landscape of research in this area.

As for the second iteration mentioned in Section III-A3, we then proceeded to apply the query and search the first database. As shown in Table V, from four hundred and fifty results, only twelve passed the selection criteria defined in Section III-A4.

TABLE V
DB.1 RESULTS

Total number of results	**Extracted New Results**
450	12

After reviewing the references of the identified papers and applying forward and backward snowballing techniques, we were able to locate additional related publications and expand the scope of our search as demonstrated in Table VI. This helped us to increase the number of relevant publications that we were able to consider in the next steps of the process.

TABLE VI
DB.1 SNOWBALLING RESULTS

1st Forward	**2nd Forward**	**Backward**
23	2	45

TABLE VII
REMAINING DB RESULTS

Database	**Total number of results**	**Extracted New Results**
DB.5 - 1st	21	1
DB.5 - 2nd	0	0
DB.4	9	3
DB.6	114	12
DB.3	20	0
DB.2	0	0

In the case of Science Direct, as presented in Table VII, two queries were done. The main reason for this is that Science Direct is limited to 7 *OR* conditions, therefore it was necessary to split it into two queries where it does not affect the general condition. In the specific case, the *"evolv"* keyword was moved into a separate query. Also, Science Direct automatically accepts truncations without using the *"*"* char. The two queries are:

1) *(microservice OR "micro-service") AND (migrat OR decompos OR identif OR refactor OR extract OR discover OR transition)*
2) *(microservice OR "micro-service") AND (evolv)*

After iterating over the results and reviewing the references of the newly found publications, we did not identify any additional publications that were worth including in the final list. This marked the end of our general search for relevant publications. We were able to find one hundred and six relevant publications.

C. Publications Grouping

Given the large number of publications that were identified as potential candidates for further analysis, it was necessary to further reduce the list to a more manageable size. To accomplish this, we employed a categorization approach in order to better organize and prioritize the publications for later selection. This allowed us to select and analyse the most relevant publications for our purposes. Through this process, we arrived at three main categories that were derived from RQ1 into which we could place each publication. This will be especially relevant when creating the new tool, by enhancing the possibility of integrating various tools that employ different approaches, in order to provide the developer with multiple perspectives, which may facilitate the ability to make comparisons and informed decisions.

- The **approach** used for identifying microservices from monoliths, Table VIII.
  - *Data flow*.
  - *Dependency analysis*.
  - *Execution log*.
  - *etc*.
- The current **status** of the publication, Table IX.
  - It only explains the *method* at a high level.
  - Has implementation details with the *algorithm* on how to identify.
  - Already has a working *tool*.
- The **language** in which that it targets, Table X.
  - *Java*.
  - *Cpp*.
  - *C*.
  - *Language Agnostic*.
  - *etc*.

The publications that were selected are grouped in Tables VIII, IX and X. It is important to note that the papers analysed in this study were classified into multiple categories, as opposed to a singular classification. To facilitate a more comprehensive understanding, the classified papers can be viewed on the online spreadsheet [1].

TABLE VIII
APPROACH GROUPING

Approach	**Amount**
Data flow	8
Control flow	7
Dynamic analysis	11
Semantic analysis	4
Problem frames	1
Model based	10
Static analysis	13
Dependency analysis	15
Multi objective	1
Feature analysis	7
Data analysis	6
REST	4
Graph based	2
Domain analysis	10
Neural analysis	2
Layer	1
Business analysis	3
Strangler pattern	1
Code change history	1
Contributor based	1
Logs analysis	1
Transactional contexts	1
Execution flow	1
Unknown	2

D. Selected Work

Having evaluated most of the literature in regard to tools that help with the migration of monoliths to microservices, we need to select those that are most relevant for the purpose of this thesis. Given our focus on tools and their implementation, we will prioritise works that have already developed a tool and made it available for a free inspection and use. Therefore, if a publication does not provide a link to the tool or instructions for self-hosting or deploying it, it is not worth further consideration. This will help us to focus our efforts on publications that provide practical and useful information about tools and their implementation.

TABLE IX
STATUS GROUPING

Status	**Amount**
Method	48
Algorithm	7
Tool	25
Unknown	1

TABLE X
LANGUAGE GROUPING

Language	**Amount**
Agnostic	59
Java	16
Ruby	1
Python	3
Unknown	4

E. Publication Analysis

In the following sections, we will provide an analysis of the data collected during the knowledge extraction process from the selected publications. This analysis will allow us to address the primary research question (RQ1) and its sub-questions.

1) Monolith as an input for the tool: The first aspect to be analysed is the input requirements for the tool. Despite the growing interest in microservice migration using automated tools, the field is still in its infancy, and the existing solutions tend to address specific issues rather than being versatile. As a result, the inputs for these tools are often rigid and not easily adjustable. For example, raw source code and OpenAPI specification were possible ways tools use for identifying microservices from monoliths and will be further discussed.

Source Code: One potential method for providing input to a tool is by utilising source code directly. Our research revealed that eighteen of the contributions analysed use source code as input for their tools with multiple using Spring Boot or other equivalent frameworks to help in understanding the overall code structure. One reason for the use of frameworks is that they provide building blocks for developers, meaning the core functionality of the framework is already in place and developers simply fill in the gaps allowing for the framework to apply inversion of control [19]. Since the behaviour of the framework is kept intact, the tool can then safely analyse the overall code and even apply the refactoring.

For instance, Freitas et al. [25] tool, MicroRefact [2], utilises

[1]https://bit.ly/publication-grouping

[2]https://github.com/FranciscoFreitas45/MicroRefact

Java source code to extract structural information by relying on the Abstract Syntax Tree. This information is used to generate a list of candidate microservices. They then leverage Spring Boot decorators, particularly those utilising the Java Persistence API (JPA), to infer the entities of the database and their relationships. This process then results in the output of working Java code for each identified microservice.

OpenAPI: In a microservices architecture, one of the common solutions for communication between different microservices is through HTTP calls. Therefore, it is reasonable to assume that identifying microservices within a monolithic application could be done by examining their REST endpoints since they will be exposed through HTTP protocols. This inspection of REST endpoints can also serve as a guide for decomposing the monolithic application into smaller, independent services. In fact, when the programming language was not a determining factor, OpenAPI was commonly used as the standard for distinguishing microservices from monolithic systems.

The tool proposed by Al-Debagy and Martinek [26] utilises the OpenAPI specification file to identify microservices within a monolithic application. The tool begins by extracting the operation names from the OpenAPI file, which are then input into the Affinity Propagation Algorithm [20]. This algorithm calculates the number of microservices by analyzing the messages exchanged between data points. Afterwards, clustering is performed by utilising the Silhouette coefficient [21] which results in the identification and grouping of similar microservices, helping in the decomposition of the monolithic system.

MsDecomposer [3] [27] uses a similar approach to identify microservices within a monolithic application. The first step is to calculate the similarity of candidate topics and response messages among the APIs. Then, it constructs a graph that represents the similarity between different APIs, where the APIs are represented as nodes and the similarity score is the weight. Finally, it applies a graph-based clustering algorithm on the constructed graph, which helps to identify the candidate microservices.

This highlights that OpenAPI is a language-agnostic method for identifying the architecture of software systems.

Other: Besides the input types that have been previously mentioned, there are other types that may not be able to create a new category but are still relevant to the microservices identification process. For example, using a specific system model as input [28] or utilising the history of changes to understand in addition to common artefacts like classes and methods [29].

2) Microservices as an output for the tool: For microservices identification, it is important to understand how existing tools output their identified microservices in order to cater to the needs of users. The ideal outcome would be a fully functional code ready to be deployed, as it makes the migration process smoother, ensuring that the resulting microservices have all the necessary components and reducing the effort needed for manual migration. From the work that was analysed, tools that output a list of candidates and tools that output source code are more relevant to take into consideration and will be further discussed.

Candidates List: A prevalent approach for identifying microservices in a monolithic system is by producing a candidate list. This approach is used in most of the publications and tools found, and it is a way of providing an organized and structured output of the microservices that can be derived from the monolithic application, in order to facilitate the migration process. The candidate list is commonly used as a guide or checklist for architects, engineers, and developers to assist in the actual partitioning of the application. It typically includes but is not limited to, data entities, interfaces, methods, and other relevant system components that are used as references to guide the migration process.

The tool proposed by Al-Debagy and Martinek [26] uses OpenAPI as input to identify microservices within a monolithic application. One of the limitations of their output is that it only provides a list of candidates, which may not include information about the relationships and interactions between each microservice. This can be an inconvenience when assigning different development teams or groups with the task of applying the migration, as they may not have enough information to understand how the microservices interact and depend on each other, making it harder to assign and split the workload accordingly.

There are other tools available that output a more informative result for microservices identification. Even though they still output candidate lists, where no migration is done yet, these tools provide more detailed information about the relationships and connections between microservices, some of them even including visual feedback such as clusters and call context tree diagrams [24], [30]–[32]. This additional information can be very beneficial for architects and developers, as it makes it easier for them to understand the connections and dependencies between microservices, and make informed decisions about how to proceed with the migration process.

Source Code: Generating the final output of the migration process as source code that is ready to be deployed would be the ideal outcome for most cases, as it would lessen the efforts needed to migrate, but it is not yet commonly used in current literature. Out of the tools that were analysed, only two of them employ this method. One of them is the work of Freitas et al. [25], and another is Mono2Micro [24], [30]–[32] that in an update explained in a YouTube video [4] they now output Java code.

3) Tool target language: The majority of works utilised Java as their primary programming language for input [24], [30], [31], [33]–[39]. This may be attributed to the language's strict syntax rules, which facilitate the examination of source code during the inspection process. Additionally, some of them utilised the Spring Boot framework in conjunction with Java [23], [25], [29], [39]–[41], which further enforces structure

[3]https://github.com/HduDBSI/MsDecomposer

[4]https://youtu.be/NXno1fUoC8U

through the utilisation of decorators. In contrast, those who employed programming languages other than Java, such as Python, utilised corresponding frameworks like Django, to compensate for the language's more lenient syntax constraints [42], [43].

IV. Tool Design

During our analysis described in Section III-E, it was impossible to locate any relevant works that could address the second research question (RQ2). As a result, it will be necessary to tackle this question and strive to answer it.

As of the time of writing this paper, the design of the proposed tool is not yet finalised. We have only developed initial ideas about how we will approach the problem and have created a sketch of the proposed tool architecture, which is shown in Figure 2.

The proposed tool architecture consists of three distinct components. The frontend is responsible for the interface between the tool logic and the user. The tool domain contains adapters for each individual tool and the tool runtime, which receives the monolithic input and generates the candidate microservices. The backend serves as a bridge between the frontend, the database of available tools, and the tool domain.

The main role of the backend component in the proposed tool architecture is to initiate jobs and notify the frontend when a given job has been completed. A job consists of the process of identifying microservices from a given monolithic input, which is then completed when the output containing the identified microservices is produced. To avoid potential bottlenecks when multiple jobs are run concurrently, the backend does not perform these tasks directly but rather delegates them to the individual tools, therefore acting like a bridge.

In the tool domain, the purpose of the adapter is to provide a consistent interface for interacting with the tool runtime, regardless of the specific input and output formats that it uses. This is important because different tools may accept different inputs and produce different outputs, such as JSON or raw code. By using an adapter to translate between these formats, it becomes easier to process the inputs and outputs of the tool and integrate them with the overall tool logic. The tool runtime receives the monolithic input and generates the candidate microservices, while the adapter serves as a "middleman" between the tool runtime and the other components of the architecture.

One of the first decisions that we have considered is which target platform the tool should support. There are three major platforms that are relevant for this purpose: macOS, Windows, and Linux. Determining which of these platforms to focus on would require extensive surveying to ensure that the tool will be used by the intended audience. While market share data suggests that Windows is the most widely used desktop operating system, followed by macOS and Linux [22], this may not necessarily reflect the operating systems used by the architects, engineers, and developers who are responsible for migration. Given the limited time frame, it is infeasible to conduct a thorough survey to determine the preferred operating system of this target audience. As a result, we have decided to adopt a more cross-platform solution. After evaluating the options, we have determined that the browser is the most suitable platform for this purpose.

Ideally, each component of the proposed tool architecture would be deployed as a microservice in a Docker container to facilitate scalability and cross-platform deployment. This is especially important for the tool runtime component, as it is uncertain at this point whether the tools will take advantage of multithreading. By using Docker, we can create a new container for each job, which would allow us to handle multiple jobs concurrently and avoid the need for users to wait for their jobs to complete. Of course, it is possible that certain tool limitations may prevent us from implementing this approach, but it is our goal to use microservices and Docker to the greatest extent possible to ensure the flexibility and scalability of the tool.

Given that the tasks performed by the tool runtime component are asynchronous, the communication between the tool runtime and the backend cannot be based on synchronous HTTP request-response cycles. Instead, we will use a message queue to connect the two components, with the use of message brokers. The backend will send a message to initiate a job, which will be picked up by the appropriate adapter and executed by the tool runtime. Once the job is completed, the tool runtime will send another message to the backend to indicate that it is finished. This approach allows us to process multiple jobs concurrently and avoid potential bottlenecks in the communication between the tool runtime and the backend.

V. Conclusion

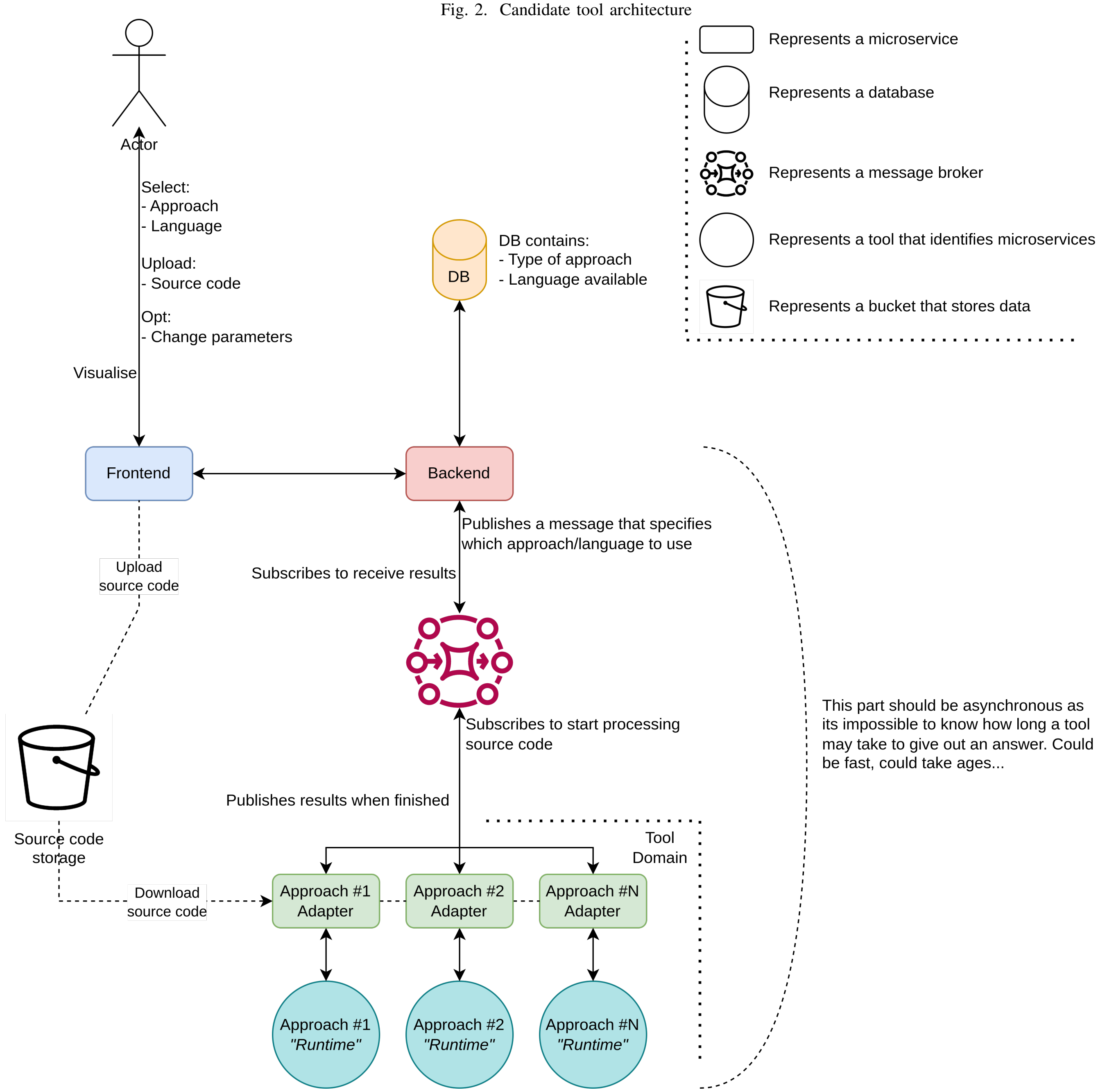
Microservices are becoming more popular in the development of new applications. Many businesses, both large and small, are using microservices to design and deliver applications more rapidly and efficiently [5]. Microservices are especially well-suited for distributed, cloud-based systems, where they may benefit from the cloud's flexibility and scalability [6].

We performed a literature review on the subject of refactoring architecture from monolithic applications to microservices for this study. A total of one hundred and six primary research contributions were chosen, categorised, and analysed using a clear research protocol in order to collect pertinent migration data. A tool's target programming languages, the processes it uses to convert monolithic inputs into microservices, and the output of these identified microservices are the subject of analysis in this study.

Tool input needs were examined first. Despite increased interest in microservice migration using automated tools, the topic is still young, and current solutions have strict inputs rather than being adaptable. Raw source code and OpenAPI were one method tools to identify microservices from monoliths.

As for how existing tools output their identified microservices, the outcome would ideally be fully functional code

Fig. 2. Candidate tool architecture



ready for deployment, as it would make the migration process smoother and ensure that the resulting microservices have all necessary components, thus reducing the effort needed for manual migration. From the research analysed, common outputs from microservices identification tools include a list of candidates and source code.

The proposed tool architecture consists of three distinct components. The frontend is responsible for the interface between the tool logic and the user. The backend serves as a bridge between the frontend, the database of available tools, and the tool domain. Each tool's adapter provides a consistent interface for interacting with the tool runtime. Ideally, each component of the proposed tool architecture would be deployed as a microservice in a Docker container to facilitate scalability and cross-platform deployment. This approach allows us to process multiple jobs concurrently and avoid potential bottlenecks in the communication between the tool runtime and the backend.

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