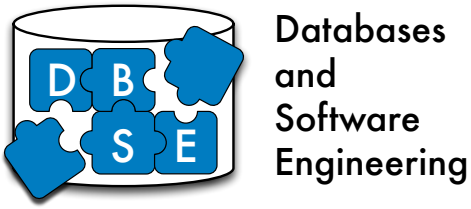
University of Magdeburg

School of Computer Science



Master's Thesis

Supporting Execution and Reporting of Systematic Literature Reviews

Author:

Cheryl Mariam Jacob

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Advisors:

Prof. Dr. rer. nat. habil. Gunter Saake

Prof. Dr.-Ing. Thomas Leich

M.Sc.Yusra Shakeel

Department of Computer Science

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Statutory Declaration

I hereby declare that I have written this master thesis independently without external help and have used only those sources and aids that are mentioned in the references of the work. Literature and definitions which were obtained from other works such as journals and papers are labelled with their source.

11. March 2019

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Abstract

Researchers conduct Systematic Literature Review (SLR) to extract all the existing evidence in their area of research. There is a rapid growth in the number of studies published in the field of software engineering in the past years. SLR helps the researchers to identify and synthesize all the existing evidence relevant to the research question(s). Despite all the effectiveness, SLR is time-consuming and requires a lot of effort. Hence there is a rise in the need for automatic approaches that help the researchers with their study. Data extraction and summarization is one of the crucial steps in the process. Hence we conduct a systematic literature review to gather all the related information and analyze the different approaches used in automating the data extraction and summarization phase. Based on the findings of the review, a semi-automated approach is developed as a prototype to extract and summarize the data found during a review. The validity of the results is examined based on the performance measures such as precision, recall and Recall-Oriented Understudy for Gisting Evaluation (ROUGE) scores. The results show that the extraction and summarization can be partially automated. However, there are some limitations to the approach that has to be further investigated to provide better results to the researchers.

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Acronyms

BOW	Bag of Words
EC	Exclusion Criteria
FN	False Negatives
FP	False Positives
HTML	Hypertext Markup Language
IC	Inclusion Criteria
IDF	Inverse Document Frequency
LSA	Latent Semantic Analysis
NLP	Natural Language Processing
NLTK	Natural Language Toolkit
PDF	Portable Document Format
QA	Quality Assessment
regex	Regular Expression
ROUGE	Recall-Oriented Understudy for Gisting Evaluation
RQ	Research Question
SLR	Systematic Literature Review
SVD	Singular Value Decomposition
TF	Term Frequency
TF-IDF	Term Frequency - Inverse Document Frequency
TN	True Negatives
TP	True Positives

VTM Visual Text Mining

1. Introduction

SLR is a well-defined methodology used to gather all the available evidence that address the defined RQs [A. Kitchenham, 2004]. SLRs were already being used and proven in the medical field. Performing SLRs in the software engineering domain require different guidelines, since it is generally less rigorous and has relatively lesser empirical research when compared to the research in the medical field [A. Kitchenham, 2007]. The traditional review methods might not be comprehensive and hence can introduce a persistent bias [Mallett et al. [2012]. SLR is emerging as a useful methodology in this regard by reducing the bias [Mallett et al., 2012]. A. Kitchenham [2007] mentioned that an SLR mainly consists of three phases: planning, conducting and reporting. SLRs could be complex since a large number of primary studies are being investigated and execution would require a significant amount of time and effort [Feng et al., 2017]. Hence, researchers are eagerly involved in proposing approaches to semi-automate different steps of the process.

To perform SLRs efficiently and effectively, different methods are being proposed, which will support the various steps of the process. The data extraction and reporting phase of an SLR involves the crucial tasks of identifying and reporting direct evidence to answer the defined research questions [A. Kitchenham et al., 2009]. The researchers have a tedious and time-consuming task of going through the studies to answer their research questions Carver et al. [2013]. Hence, any approach useful for reviewers to perform these steps effectively can accelerate the process.

1.1 Motivation of this Thesis

Literature review is an important process for researchers and students. Compared to the traditional method of literature survey, SLR ensures inclusion of most of the relevant evidence in the particular topic. It helps in finding gaps in the research and helps in obtaining unbiased results [Mallett et al., 2012]. Poorly conducted reviews can mislead any experimental study [Piper, 2013]. Performing an SLR is difficult and time consuming [Hassler et al., 2016]. Hassler et al. [2016] also identified lack of tool support for data extraction, data synthesis and analysis of qualitative

data. Marshall and Brereton [2013] also states that SLRs can be time consuming, error prone and hence requires tool support. Insufficient tool support has created hindrance in performing SLRs [Zhang et al., 2011]. We identified that not much work has been done on the extraction and reporting phase when compared to the other phases of the process. In the reporting phase, the outcome of an SLR is mainly reported with graphs and charts to show clustering and classification of documents. At the end of the process, researchers have the tedious task of reading all the selected studies. These researches do not emphasize enough about the need to summarize the text by extracting the information needed by the researchers.

1.2 Goal of this Thesis

In this thesis, we focus on studying the state-of-the-art of data extraction and reporting phase. We also propose a semi-automatic approach to perform and evaluate text extraction and summarization. It concentrates on the execution and reporting of SLRs, where we study the various methods of text mining that have been proposed to support meta-data extraction, extraction of particular sections of the paper and summarization of the information by using keyword search, inclusion/exclusion criteria and quality assessment criteria. This thesis aims at answering the research questions in the summarization process. The quality of the summary is assured by including the quality assessment criteria in the summary. Hence, it creates a multi-document summary of the results.

The goal of this thesis is organized and explicated as follows:

- Determine the current state-of-the-art of extraction and reporting phase of SLRs. The aim is to study the methodologies that were previously proposed to support the data extraction and reporting of SLRs. We also identify and work on the areas that need further improvement.
- Propose a semi-automatic approach to support the steps involved in extracting and reporting the results of SLRs. The approach consists of three tasks. The first task involves implementing a web application to extract the predefined sections of the paper. The data extraction is done by using keyword search and regular expressions to extract predefined sections of the paper. The second task consists of extracting the meta-data of a particular study (author name, title, creation date, publisher, etc.) which is done by using python scripts. The extracted data is stored in the form of a table for further reference. The next task is to perform text summarization on the selected studies to get an overview of the paper contents. The summary is extracted to ensure that the various quality assessment criteria stated by the researchers are satisfied. It also creates a general summary of the paper to extract the most vital contents of the document. The extracted data along with the text summary is then reported on the web application.
- Evaluation of the extraction of predefined sections will be carried out by calculating the precision and recall values. Evaluation for meta-data extraction is done manually. Evaluation for the summarization process is carried out

by using intrinsic and extrinsic methods. The intrinsic evaluation is done by using a question game. These questions are based on the quality assessment criteria stated in the SLR process. The scoring is based on the percentage of questions correctly answered in the summary. The extrinsic evaluation is done by selecting an SLR study that has been already conducted. We extract the primary studies used in that SLR as the input to our tool. The multi-document summary generated by the tool will be compared with the results stated in the SLR using ROUGE scores.

1.3 Structure of the Thesis

In **Chapter two** we provide the background information. We describe the various fundamental research concepts concerning our research topic before building the concept of the thesis. We explain the entire process of SLRs in detail along with other concepts, such as, Text mining and Natural language processing.

In **Chapter three** we describe the literature review and related work. We explain how the systematic literature review was carried out in each step with all the details required for further research or repetition purposes.

In **Chapter four** we provide details of the developed approach. The implementation is divided into three parts. The extraction of the meta-data, extraction of predefined section, and data summarization. This implementation supports the SLR methodology by implementing a semi-automatic approach to support the data extraction and reporting phase of the SLR.

In **Chapter five** we explain the evaluation process. In this chapter we explain the evaluation of the different parts of our implementation. Experiences and problems faced during implementation is also discussed.

In **Chapter six** we summarize the overall findings of this thesis by interpreting them and showing how we have succeeded in adhering to the goals mentioned in the introduction.

In **Chapter seven** we mention the future work that can be performed to improve our proposed approach.

2. Background

In this section, we describe the context to the problem that is addressed in this thesis. It is used to appropriately position the direction of our study. It explains the entire process of SLR in detail along with other concepts that support our research, such as, text mining and natural language processing. We also explain some of the text summarization algorithms and the similarity measures used during the summarization process.

2.1 Systematic Literature Review

A. Kitchenham [2007] introduced the guidelines for performing SLRs in software engineering. It follows a set of systematic steps to find all relevant papers related to the topic of interest. It is the process consisting of aggregating, checking, reviewing the data from the already existing evidences. Unlike the traditional literature review which may omit some important research, SLR makes sure that all the available relevant studies are included [Okoli and Schabram, 2010]. In an SLR, the RQs are formulated to gather all the evidence that helps in answering the questions. SLR uses transparent approaches to make sure that the results are unbiased. In addition to answering the questions, the results will describe the state-of-the-art of literature, limitations in the existing study, and guide the researchers in planning further research. Another important aspect of SLRs is that the researchers can repeat and reproduce it for further research.

A. Kitchenham [2004] highlighted the following key points of SLR:

- It makes sure that the results of the review are unbiased.
- The steps of the literature are mentioned beforehand. It also mentions the Inclusion Criteria (IC)/Exclusion Criteria (EC) and quality checks to ensure good quality of the literature review.
- It helps in finding the gaps in research and bridging them so that further research can be carried.

- The goal of the review is to gather all the evidence by summarizing the process and reporting it.
- Poorly conducted systematic literature reviews can mislead the research.
- The RQ must be as specific as possible. A vague question will provide vague answers that might not answer the RQ.
- If the research is a quantitative study, it is possible to combine the results using meta-analytic techniques.
- The RQs are set according to the topic of interest.
- It has a well defined search strategy.
- Explicitly defines the search keywords, boolean search string and the search venues which can be used for further reference.
- The IC/EC are clearly defined so that the research remains focused on the topic of interest.
- QA criteria are set to check the quality or reliability of the information from the primary studies.

The review process consists of three discrete phases as mentioned by A. Kitchenham [2007].

- Planning Phase
- Conducting Phase
- Reporting Phase

The phases mentioned above are explained in the following sub-sections. They are depicted in the Figure 2.1 on page 7.

2.1.1 Planning Phase

The first step towards a scientific review is identifying the RQs. It comprises of the researcher finding gaps in the area of the research and to come up with the RQ that needs to be answered [A. Kitchenham, 2007]. The researcher must ensure the need to perform the SLR on the stated RQs by performing an initial scoping review. Before starting the SLR process, the researcher must ensure that there is no other SLR with the same RQs. The planning phase makes sure that there is enough evidence available to conduct the research. The planning phase is very important to ensure the legitimacy of the results. Hence, a review protocol containing all the necessary data for the further steps is created. This predefined review protocol is necessary to remove all kinds of bias from the review and to make sure that other researchers can repeat and reproduce the SLR. To support the idea, a systematic literature review is conducted by adhering to the following steps.

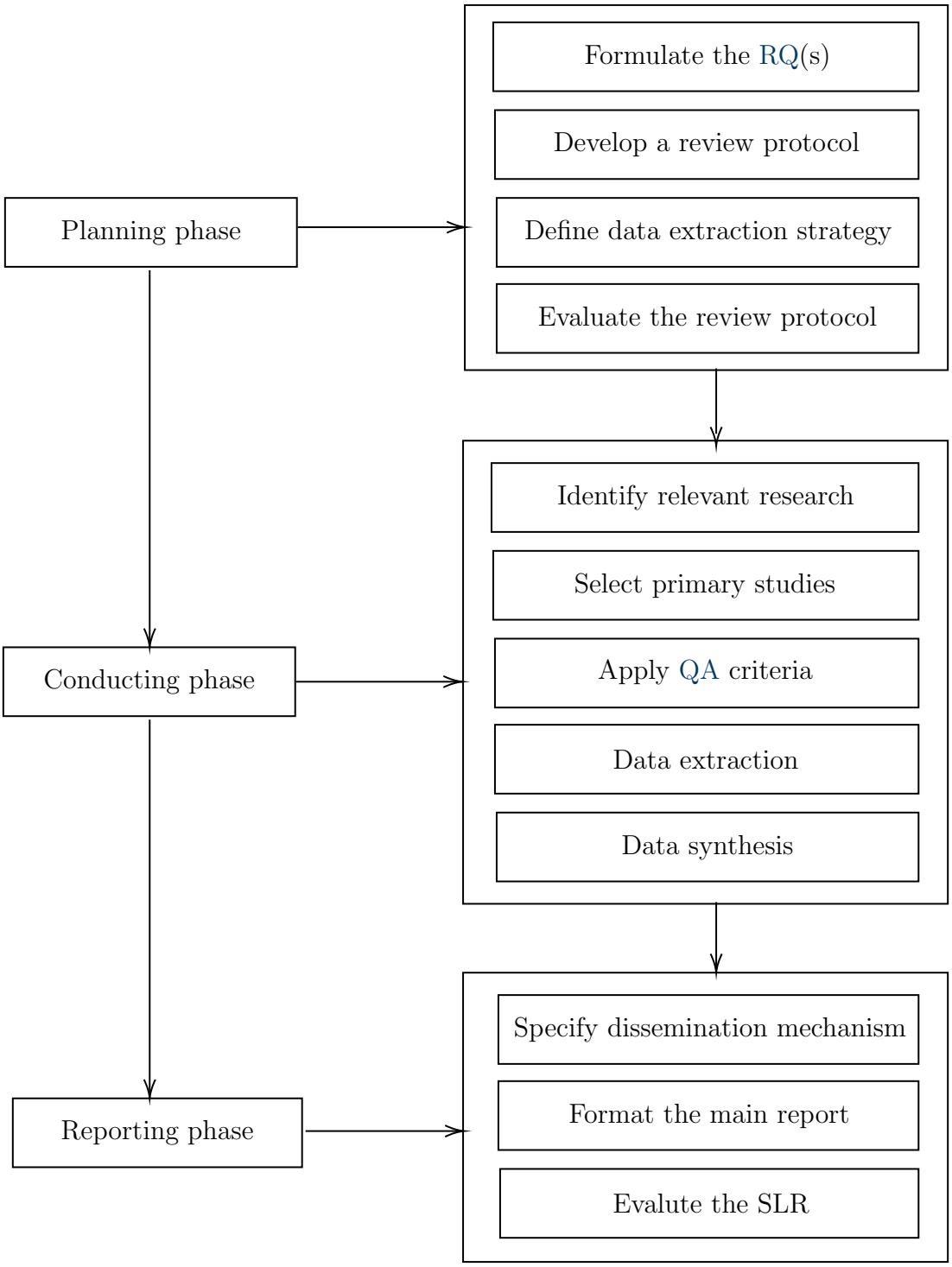

Figure 2.1: SLR phases, adapted from A. Kitchenham [2007].

Formulate the RQ(s):

A well formulated RQ will guide the SLR in answering the question the researcher needs to answer. They are formulated from the problem statement found from the initial scoping review. A study can have multiple RQs. Usually, the main question is broken down into multiple sub-questions. Specifying the RQ is the first methodological step that has to be undertaken by the researcher. To ensure the quality of the RQ, some guidelines have to be followed while formulating the RQ. The following guidelines are adapted from Mason [2014]:

- Clear: It must leave no space for ambiguity or confusion.
- Focused: It should be narrow enough to answer the underlying problem statement.
- Concise: It should be briefly written in few words. It should also be comprehensive by dealing with all the aspects of the study.
- Complex: It shouldn't be too simple which can be answered just by a normal search engine. It should involve investigation and evaluation by the researcher to arrive at the conclusion.
- Arguable: It must be open to debate and disagreement.

Develop a Review Protocol:

It is the plan that describes the proposed procedure to conduct the review. It should be planned before starting the review. It guides the researcher throughout the entire process of review. A review protocol is necessary to reduce bias in the review process and also to restrict overlap with already existing reviews. The different stages of the review protocol are mentioned below:

- **Define the Search Strategy:**

  The search strategy defines the process of searching the studies relevant to the RQ [Aromataris and Riitano, 2014]. It can be an organized structure of the predefined terms used to search a database which consists of the keywords from the RQs to retrieve the relevant [Vassar et al., 2016]b. The search strategy can be a keyword search, boolean search string, searching for exact phrases, wild-card search, citation search [Aromataris and Riitano, 2014]. The search is done either on the full text or by having restrictions to the headline or abstract of the document. The search strategy ensures that the publication bias is reduced as much as possible [Aromataris and Riitano, 2014]. Publication bias occurs when positive findings are more likely to be published faster than negative findings [Begg and Berlin, 1988]. Hence, a literature review with only published data might be biased. Therefore, it makes sure that the results include unpublished reports as well. The entire process is made transparent and documented carefully so that the results can be used for further research.

- **Defining Keywords:**

  The most important words from the RQ that best describe the RQ are defined as keywords. These words are believed to express the meaning and sense of the RQ. While defining the keywords, their synonyms are also taken into consideration. It is always a good practice to search using related words Mian et al. [2005]. This makes sure that the keywords retreive all the studies that are related to the RQ.

- **Defining the Boolean Search String:**

  SLR emphasizes on the usage of the boolean search string in the search strategy [Hassler et al., 2016]. The boolean operators such as "AND" , "OR" , "NOT" are combined along with the keywords to define the meaning of the keywords in order to produce more relevant results. It helps the researchers to immensely narrow down the search results [Dinet et al., 2004]. Boolean search strings can be used in any search engine including the digital libraries.

- **Selecting the Search Venues:**

  Search venues are the digital libraries that contain a huge collection of online databases. Digital libraries provide us with more authoritative and credible results that are not easily accessible on a normal search engine like Google [Behrends, 2012]. IEEE Explore, Springer Link, ACM Digital Library, ResearchGate, Google Scholar are few of the digital libraries.

- **Stating the IC/EC:**

  IC and EC are required to rule in or rule out the results of a search [Salkind, 2010]. IC define the subject that the study needs to address compulsorily. It can also define the characteristics of the study. For example:

  – The study must be conducted on a particular year

  – The study describes a particular topic.

  EC define the characteristics that shouldn't be present in a study while choosing the results. For example, ignore the studies that are not written in English. The studies found from the boolean search are analyzed to check for these criteria. Only those studies that comply with these criteria are selected.

  Stating the QA criteria:

  It is a checklist of factors that need to be addressed in the study. These factors help us in extracting good quality information by stating factors such as:

  – The aim of the study.

  – Limitations of the study.

  The researchers need to manually check the quality of the result. Each result is given a score based on how well they adhere to these criteria. A minimum acceptance score is set to determine the quality of the study. The quality of the study is evaluated based on this QA score.

Define Data Extraction Strategy:

The selected primary studies should be processed to find the relevant information that answers the RQs. The data extraction strategy should be carefully defined since it is an important step in extracting the relevant information. The researchers define the process of extracting information to avoid any bias in further steps [Petersen et al., 2015]. The data can be extracted textually or graphically depending on the nature of the results. Quantitative data can be analyzed and depicted graphically. The qualitative data is usually presented textually but it can also be depicted graphically by finding relations between various data and classifying them accordingly into clusters, for example, document maps.

Evaluate the Review Protocol:

Evaluating the review protocol is one of the crucial steps in the process. The findings are aggregated and reviewed by the internal and external members to validate the correctness of the protocol. The validity of the protocol is checked by the review team as well as external reviewers who hold expertise in the domain [Keele et al., 2007]. Validation includes checking the search string, the IC, EC, and the QA criteria [Tacconelli, 2010]. This reduces the possibility of researcher bias since the protocol is checked to cover all the information required to conduct next stages of an SLR.

2.1.2 Conducting Phase

This section depicts the actual implementation of the review. The protocol that is set during the planning phase is followed in the conducting phase. The search is carried out following the well-defined set of procedures. The conducting phase involves identifying the relevant research, selection of primary studies, and applying the QA criteria. After the results are set, data extraction is carried out by the researcher as the final step in the conduction phase.

Identify the Relevant Research:

The previously mentioned steps are followed to identify the relevant studies. The search strategy mentioned is used as defined in the review protocol. As a result of this process, relevant studies are found from the defined search venues. Snowballing methods are also used on the studies to ensure that no relevant studies are missed out [Badampudi et al., 2015]. This step ensures the completeness of the review protocol. There are two types of snowballing that has to be conducted.

- Forward snowballing: The researchers check for studies that have cited the selected studies in their research. This ensures that all the recent findings related to the selected studies are documented [Badampudi et al., 2015].
- Backward snowballing: This process looks into the references of each paper to find pieces of evidence that support the idea of the studies [Badampudi et al., 2015].

The researchers document the entire process with the results in each step to ensure transparency and reuse of the SLR.

Select Primary Studies:

The studies obtained are revisited to check whether they satisfactorily answer the RQs. The researchers read specific parts of the studies such as title, abstract, introduction, and keywords to get a better understanding of the study. The researchers will screen the studies by checking for bias and applying the IC/EC [A. Kitchenham, 2007]. This step needs to be carried out very carefully to avoid missing out on any important evidence.

Apply QA criteria

Applying the QA criteria is one of the challenging steps in the process since there are no definite rules stated. The QA questions have to be set such that it avoids bias and helps in improving the quality of the results [A. Kitchenham, 2007]. The researchers apply these QA questions on the set of selected studies and create a score for each study based on every QA question stated [Zhou et al., 2015]. The scores are summed up to get a final total which depicts the quality of each paper.

Data Extraction

Once the primary studies are selected, the data needed to answer the RQ has to be extracted. The data extraction strategy stated in the planning phase will help us in avoiding the bias. The data is extracted into data extraction forms [A. Kitchenham, 2007]. The quantitative data about the findings during the process is extracted along with the qualitative data which helps the researchers in answering the RQ. The extracted data is carefully checked with the help of external examiners to find whether it has sufficient evidence to answer the RQ by avoiding all kinds of biases.

Data Synthesis

It involves answering the RQ and summarizing the results found during the SLR process. It also outlines the qualitative results obtained and a short description of the abstract and introduction of the study.

- **Answering the RQs:** The final step of the review involves documenting the results of the SLR. These primary studies are used to answer the RQ. This is the main goal of the entire SLR process [A. Kitchenham, 2007]. It is necessary to document the results of the SLR process for future research. It is used by the researchers and other potentially interested parties to study the methodology and answer further questions arising from the report [A. Kitchenham, 2007]. The report is not only disseminated as a journal or conference paper, but it can also be distributed as a short summary leaflet, press release, posters, magazines or web pages so that it is available to the practitioners.
- **Summarization:** It is the process of reporting the findings of qualitative and quantitative data. The quantitative results are summarized in the form of tables and charts whereas the qualitative results are summarized in the form of text [A. Kitchenham, 2007]. This step can be semi-automated by using supervised and unsupervised approaches. The qualitative summarization can be supervised by indicating the vital focus points of the summary. It can also be

unsupervised by allowing the algorithm to create an extractive or abstractive summary.

2.1.3 Reporting Phase

This step defines a structure to document the entire process and the findings from all phases of the SLR process. The findings include the description of primary studies, results of quantitative summaries, details of meta-analysis etc.

Specify Dissemination Mechanisms

SLR can be reported in many ways such as a press report, leaflet, posters, web-pages, magazines or direct communication [A. Kitchenham, 2007]. The mechanism must be decided beforehand while preparing the protocol. It is decided based on the background of the expected users. If the results are intended to be used by the researchers, then it is reported in the form of a technical paper or a journal.

Format the Main Report

The results can be formatted as a journal, conference paper or a technical report such as a thesis. The journal or a conference paper usually consists of limited information and hence the results are also formatted into a technical report to include all the information in detail.

Evaluate the SLR

Evaluation of the SLR requires one or more person with similar competencies to check for validity and suitability of the research for publication. The technical reports and journal are usually peer reviewed by experts in the particular research topic.

2.2 Text Mining

Text mining refers to extraction of meaningful information from text. It helps in finding hidden patterns and trends in the document and ensures structured output [Shinde and Gill, 2014]. Text mining is a multidisciplinary field that involves various other fields, such as, text analysis, information retrieval, machine learning, data mining, clustering, classification, data extraction, semantic analysis, and text summarization [Babar and Rit, 2013]. It deals with unstructured and fuzzy text and hence makes the process of text mining very complex [Babar and Rit, 2013].

The common approach of text mining is to group the documents based on their similarities. The grouping is done by using text mining techniques such as clustering and classification. It also converts the unstructured and fuzzy text into a structured intermediate format which in turn can be used to perform analysis and extract data [Babar and Rit, 2013].

2.3 Text Summarization

Text summarization is a process where we reduce the size of long texts by extracting the important concepts of the document to reduce the time and effort spent on reading and understanding long text [Mani et al., 1999]. Summarization is usually done by using graph based algorithm to select the important sentences [Patil et al., 2015]. The sentences with the highest ranking are selected accordingly. There are various text summarization libraries that can help us achieve the goal.

The summarization can be extractive summarization or abstractive summarization. Extractive summarization is done by identifying the important sentences from the given text and concatenating them to create a summary. Whereas abstractive summarization mimics the paraphrasing of the corpus instead of simply extracting the sentences [Carenini and Cheung, 2008]. This is harder to implement since it creates a condensed human-like summary. The goal is to select those sentences that can create a meaningful summary and help the users to get the accurate gist of the paper. The summary can also be a multi-document summary by summarizing multiple related documents into a single file.

2.3.1 Aided Text Summarization:

Aided summarization can be either Machine Aided Human Summary (MAHS) where the humans take help from the machine or Human Aided Machine Summary (HAMS) where humans check the summary after the machine summarizes it [Nadella, 2015]. Aided text summarization refers to the process where the necessary paragraphs, context or key-phrases required in the document summary are mentioned beforehand [Nadella, 2015]. The key-phrases are ranked by giving them numerical scores. The key-phrases that are above a particular threshold are considered in the summarization process. Aided summarization algorithms use machine learning techniques to compare the given document and a human-generated input. The algorithm should be able to include the most significant sentences by analyzing the human-generated input. There can be features such as "the first and last line of every paragraph should be included", "the images should be included", "the minimum number of words in a sentence" etc.

2.3.2 Unaided Text Summarization:

The unaided algorithms give us the required results but they also carry a lot of overhead and training data. Unaided algorithms remove the need for training data. These algorithms determine the n-grams in the text. According to the rank given to the n-grams central key-phrases are extracted to build the sentences [Mihalcea and Tarau, 2004]. There are various libraries in python that help us in automatic document summarization. The number of sentences extracted is limited by using a threshold. The final summary must be informative enough to include all the features of the text.

N-Grams : An n-gram is a contiguous sequence of elements from a document. These elements can be letters, words, syllables etc. It is named as unigram (if the size is 1), bigram (if the size is 2) or trigram (if the size is 3).

2.4 Automating Text Summarization

Automatic text summarization is a process of automatically reducing the length of texts by preserving their original meaning [Beliga, 2014]. It makes use of data mining and machine learning techniques. The main idea of the process is to extract the information which represents the entire document. This helps the researchers by reducing the time and effort taken to study the different documents. In this section, we describe the various tools and methods used in extractive and unaided text summarization.

2.4.1 Summarization with NLTK

NLTK is one of the methods used to perform automatic text summarization. Loper and Bird [2002] mentioned the following steps used in the NLTK. In the first step, the text is split into sentences. These sentences are pre-processed and tokenized. For each of these tokens, the weighted frequency of occurrence is calculated. The text is sorted based on the sentences having the highest sum of weighted frequencies. The algorithm filters out the words with very low frequencies and very high frequencies to remove the noise. Hence, it creates an unaided summary of the document.

2.4.2 TextRank

Mihalcea and Tarau [2004] introduce TextRank as a graph-based ranking model written based on the PageRank algorithm. PageRank is an algorithm used by Google to rank the pages that show up on the search page. The number of links to the pages and the quality of the pages are checked to rank the pages. Similarly, TextRank uses an algorithm to find the similarity between sentences and find how one sentence could be connected to another as shown in Figure 2.2. This algorithm is completely language dependent and totally unsupervised [Mihalcea and Tarau, 2004]. TextRank helps in summarizing the document by preserving the original meaning of the document [Mihalcea and Tarau, 2004]. It uses undirected and weighted graphs to model the algorithm. It creates a vertex for each unit extracted from the input text. These vertices are connected to each other with edges, the weights assigned to these edges is the measure of the strength of the connections.

Keyword Extraction:

Keyword extraction is the process of extracting the words that best describe the text [Beliga, 2014]. These keywords are extracted by counting the frequency of words. It is one of the most important tasks in processes such as text mining, information retrieval, NLP, and extractive summarization [Beliga, 2014]. The user can define the number of keywords to be extracted. These keywords are always lexical units. The highest ranked keywords are selected to represent the text.

Sentence Extraction:

The process of sentence extraction is similar to the keyword extraction. The similarity between each sentence to every other sentence is calculated. Figure 2.2, adapted from Mihalcea and Tarau [2004] on page 15 shows us the similarity between the sentences in an article. The sentences are ranked based on the similarity and the highest ranked sentence is selected. Recursively the other related sentences are selected.

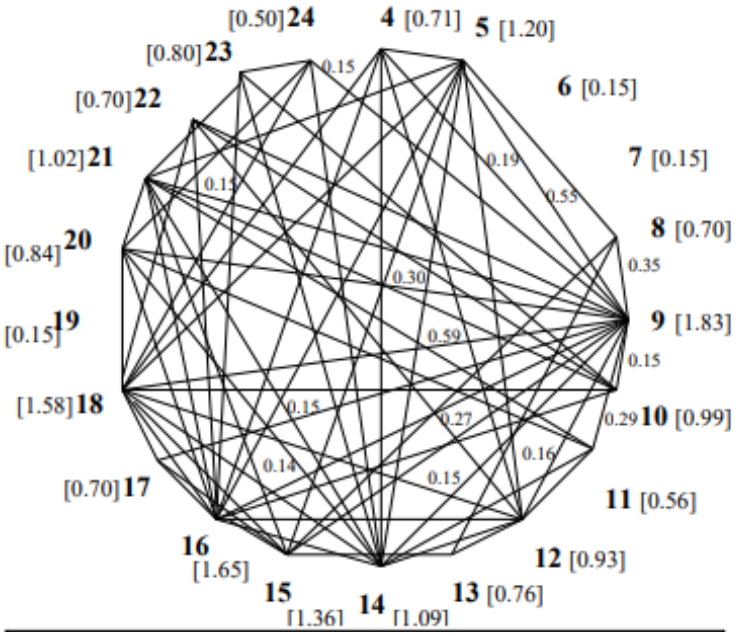

Figure 2.2: Sentence similarity, adapted from Mihalcea and Tarau [2004].

2.4.3 Textum

Torres et al. [2013] defines an algorithm called "Textum" to automatically locate the results from the paper. It makes use of text mining techniques to automate the summarization of unstructured documents. The process consists of 4 stages, which is depicted in Figure 2.3 on page 16. The algorithm imports the text and performs sentence segmentation. In the next step, it automatically finding attributes which helps in classification of the sentences. The algorithm uses 17 different attributes on every sentence to find the highest ranked sentences. These attributes include different measures such as calculating frequency, assigning weights to the keywords, calculating the length of the sentence, finding citations and finding sub-headings of the section. The classification was conducted by using rule-based methods as well as by machine learning approaches. It uses precision and recall to evaluate the outcome of the classification. The summarization is carried out by highlighting the selected sentences in their paragraphs, hence it provides the researchers with an option to read the entire paragraph in order to better understand the concept behind the selected sentences.

2.4.4 LSA Summarizer

Steinberger [2004] makes use of Latent Semantic Analysis (LSA) to identify semantically important sentences. It is a generic text summarization algorithm written to find the similarity between the original document and its summary. It creates an M*N matrix containing the weighted term-frequency vector and the sentences. The algorithm derives a latent semantic structure from the M*N matrix. Singular Value Decomposition (SVD) is applied to this matrix to create independent base vectors or concepts. SVD helps in finding relationships between these vectors to create semantic clusters of the terms and sentences. Recurring patterns will be combined

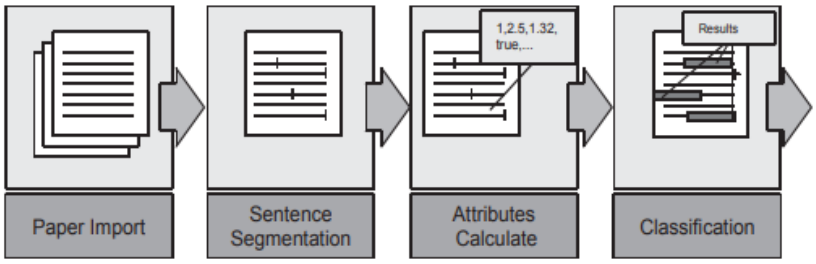

Figure 2.3: Textum algorithm, adapted from Torres et al., [2013].

into a single cluster, so that each singular vector represents a particular concept. The magnitude of these vectors describes the importance of each of the sentences. Hence the most important features are selected in the summarization process.
SVD of an M*N matrix A is calculated in Equation 2.1

$$A = U \sum V^T \tag{2.1}$$

where U and V are left singular and right singular vectors respectively. $\sum$ is a single-valued non-negative diagonal matrix in descending order [Steinberger, 2004]. Steinberger [2004] also stated that the LSA summarizer outperforms other summarizing methods and aims to improve the lemmatization process.

2.4.5 LexRank Summarizer

LexRank summarizer is a graph based algorithm which uses either weighted cosine similarity or TF-IDF function to find the similarity between sentences [Erkan and Radev, 2004]. The algorithm also uses centroid-based summarization which identifies the central sentences that describe the main topic of the document [Erkan and Radev, 2004]. The centroid of each document consists of the words that have high TF-IDF scores. The sentences with the highest number of words from the centroid are selected to create the summary. This algorithm sets a threshold frequency and builds an edge between the two nodes (sentences) if the similarity is above the threshold. The similarities between the sentences are calculated using a modified cosine equation shown in Equation 2.2

$$\text{idf modified cosine(x,y)} = \frac{\sum_{w \in x,y} tf_{w,x} tf_{w,y} (idf_w)^2}{\sqrt{\sum_{xi \in x} tf_{xi,x} (idf_{xi})^2} * \sqrt{\sum_{yi \in y} tf_{yi,y} (idf_{yi})^2}} \tag{2.2}$$

Modified Cosine formula, adapted from Erkan and Radev, [2004]

where x and y represent the two different sentences , $\text{tf}_{w,s}$ is the frequency of occurrences of the word w in the sentence s. idf_w is the inverse document frequency of the word. They also use the PageRank scheme to rank the sentences. The result is the subset of the nodes that have the highest frequency.

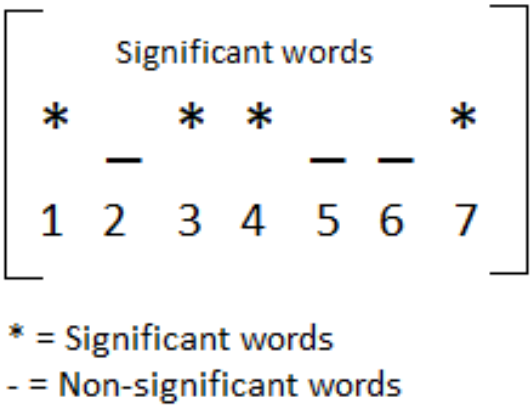

Figure 2.4: Significance Factor, adapted from Luhn [1958].

2.4.6 Luhn summarizer

Luhn summarizer was made to automatically create abstracts for documents [Luhn, 1958]. The document is divided into sentences and the "significance factor" is calculated based on the similarity between the words. The highest ranking sentences are selected in the automatic abstraction process. A limit is set to the distance between two words in order to consider them significant. As a result of this process, multiple clusters are created. The "significance factor" is calculated to establish the extent of the cluster. It is calculated based on the number of significant words in a sentence. A sentence is bracketed by selecting the two significant words at the corners. Only the parts of the sentence that are under the brackets are selected for summarization as shown in Figure 2.4. A limit is set for the number of insignificant words in between the significant words. If the count is beyond the limit, the sentence is discarded.

The "significance factor" is calculated based on the square of the number of significant words in a cluster divided by the total number of words in that cluster, Equation 2.3.

$$\text{Significance factor} = \frac{(\text{Number of Significant words})^2}{\text{Total number of words}} \tag{2.3}$$

2.4.7 Aided Text Summarization Algorithm

The aided algorithm is carried out by taking into account the user inputs which describe the type and topic of the text that needs to be extracted. The supporting input can either be keywords or sentences. If the input is a sentence then the algorithm will find the important keywords from the sentence. The input is compared with the tokenized and parsed text that needs to be summarized. Similarity calculation measures, such as, Cosine similarity, Levenshtein distance and TF-IDF are used to find the most important sentences. The sentences with the highest similarity or the least distance will be selected to create the summary.

2.4.8 Automatic Keyword Extraction

Automatic keyword extraction is the process of automatically extracting words that best describe the document [Beliga, 2014]. They are extracted from a controlled

vocabulary to represent the most relevant information from the document. It uses N-grams and stop-words to control the extraction. Extracting keywords manually can be expensive and time-consuming. Hence, machine learning approaches are used to create this data-set. The keywords can be extracted from the title, abstract, introduction and conclusion. These keywords can be used in building the document index which further helps in classifying and clustering the different sentences of the document [Beliga, 2014]. The extractive summarization mainly uses keyword extraction to build the summary.

2.5 Natural Language Processing

NLP is the field of understanding and generating human created natural language to interact with the computer [Manaris, 1998]. Many machine language algorithms are applied to process the natural language. The input text is analyzed to gather the "features" and a real-valued weight is assigned to each of the features [Khan et al., 2016]. The machine learning algorithm automatically focuses on the most important features to understand the input data. Users can automate things like data summarization, sentiment analysis, and classification by using NLP
The idea of NLP is to split the problem or sentences into smaller pieces to build a pipeline. The text that is split is then tokenized into words or tokens. Each token is fed into a classification model to extract the parts of speech. The processed text undergoes "lemmatization" to understand the most basic form of each sentence. The stop words are identified and filtered out. The next step is to find the dependencies between all the words in our text and group the related sentences together. The final step is the co-reference resolution, which means finding the meaning of pronouns, such as it, he, and she [Geitgey, 2018]. It is a very important step in NLP and hence helps us in creating a very meaningful summary as shown in Figure 2.5.

NLTK:

NLTK is a suite of libraries that help in processing human language data that are used in natural language processing. It helps in performing the NLP tasks such as tokenizing, removing stop words, parsing, classification, and semantic analysis Loper and Bird [2002].

2.5.1 Tokenization

The NLTK provides us with a set of libraries to help us with tokenization. Tokenization is a process where the input text is split into meaningful elements such as sentences, words or paragraphs [Webster and Kit, 1992]. These elements are called tokens. Tokenization can also clean the text by taking care of amalgams and locutions. It is an important step in natural language processing. It is necessary to clean the text before summarization or any other text analysis. This process is also known as lexical analysis that is often combined with a parser.

2.5.2 Parsing

Parsing helps in identifying the exact meaning of a sentence or a document. It helps in defining the structure and relation between different sentences by creating

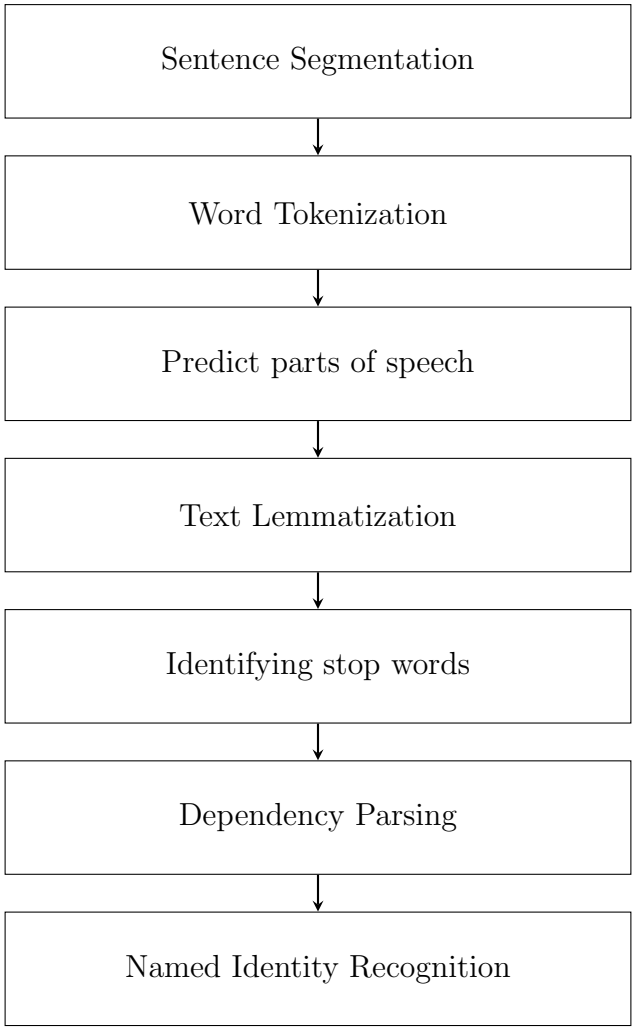

Figure 2.5: Process of NLP.

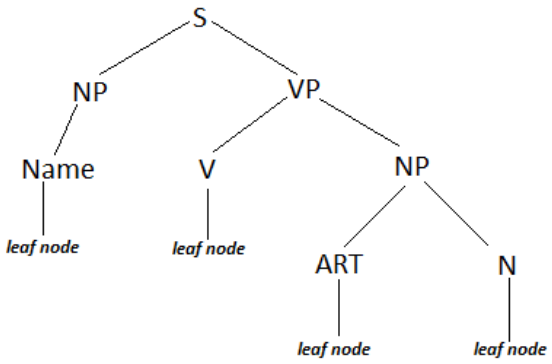

Figure 2.6: Example for a parse tree.

a parse tree that depicts the semantics and syntactic relation between the sentences. The tokenized text is sent to the parser to check whether the tokens form allowable expressions in accordance to the context-free grammar. The parse is then compiled, interpreted or translated to form meaningful output [Kübler et al., 2009].

Parse tree : The parse tree identifies the different parts of speech for every sentence. A single sentence can have more than one parse tree. Each sentence (S) is broken down into noun phrases (NP) and verb phrases (VP) which is further split into respective parts of speech such as noun (N), verb (V), article (ART) and so on. The leaf nodes in the parse tree constitute the words of the sentence as shown in Figure 2.6.

2.5.3 Word Segmentation

Word Segmentation is the process of splitting the input text into separate words. This method is also used in creating Bag of Words (BOW) in data mining. BOW is helpful in feature extraction from text segments. It consists of every word with its respective frequency of occurrence [Webster and Kit, 1992]. Hence it can be used in calculating the term frequency.

Example: BOW = “Word1”:1, “Word2”:2, “Word3”:1, “Word4”:1, “Word5”:2;

2.5.4 Stop Words

Stop words are the non-informative supportive words that are used to build a sentence. Words such as “is”, “are”, “the” are some of the stop words [Geitgey, 2018]. NLTK is programmed to filter such words from the sentences before processing them. Eliminating them reduces the overhead during processing.

2.6 Similarity Measures:

Similarity measure in text mining is the distance between the objects based on their features [Vijaymeena and Kavitha, 2016]. Two sentences are compared to get

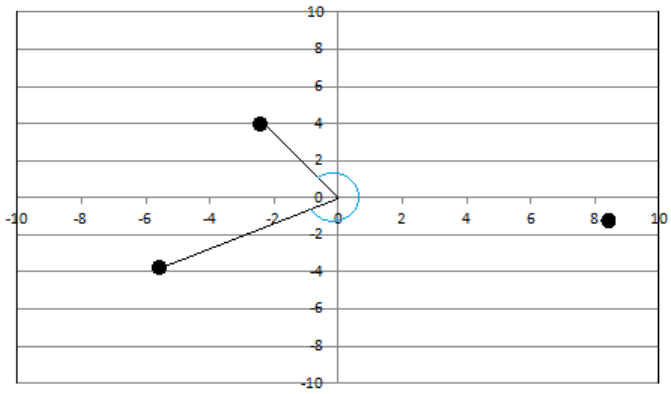

Figure 2.7: Vector space model, adapted from Shulga [2017].

a similarity measure between them. This concept can be used in clustering and classification of the documents or sentences. Cosine similarity is the most common similarity measure that is used in the field of machine learning and text mining.

Similarity Measure between Sentences

The ability to find the similarity between the sentences is a very important task in text mining. Given two sentences the similarity measure should check for semantically similar sentences by considering the natural language constraints. It is used to define a similarity rank between two sentences [Achananuparp et al., 2008].

Cosine Similarity:

The sentences are converted into vectors to form a vector space model. Each vector consists of the vectorized form of a sentence with the corresponding word frequency of each word in that sentence. Each sentence is a point in the vector space model [Achananuparp et al., 2008]. The distance between the two points is calculated by finding the cosine of the angle between them as shown in Figure 2.7. If the angle is 180 degrees, then the cosine of 180 is 0, which means the sentences are least similar. If the angle is 0 degree, then the cosine of 0 is 1, that makes the sentences most similar. Each word represents a dimension of the model. Two sentences (Vector A and B) are then compared with the formula in Equation 2.4.

$$similarity = cos(\theta) = \frac{A.B}{||A||.||B||} = \frac{\sum_{i=1}^{n} A_i B_i}{\sqrt{\sum_{i=1}^{n} A_i^2}\sqrt{\sum_{i=1}^{n} B_i^2}} \tag{2.4}$$

Term Frequency - Inverse Document Frequency

TF-IDF describes the importance of a word in the document. It is the weighting factor that has a higher value if the frequency of the word is higher in a document. This measure is commonly used in text mining and information retrieval.

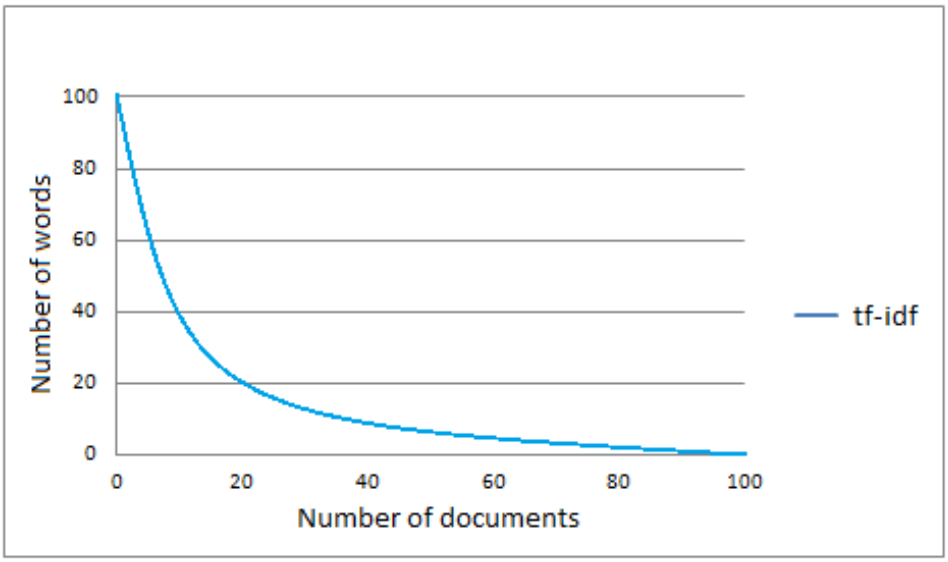

Figure 2.8: Example graph for TF-IDF.

Term frequency is simply the count of a word in a document. Inverse document frequency checks the importance of the word across all documents. It is the logarithmic inverse of the fraction of documents that contain the word divided by the total number of documents [Achananuparp et al., 2008]. TF-IDF shown in Equation 2.5 is the product of Term Frequency (TF) and Inverse Document Frequency (IDF). Hence a higher value of TF and a low-frequency of number of documents contributes to the high value of TF-IDF as shown in Figure 2.8. This helps in filtering out on common terms between documents.

$$tf - idf(t, d, D) = tf(t, d) * idf(t, D) \tag{2.5}$$

D - The set of documents
d - Single document
t - Term

We see that when the number of words are high and the inverse document frequency is low, the TF-IDF score is high and vice versa.

3. Related Work

In this section, we provide details of SLRs we performed that follows the guidelines published by A. Kitchenham [2007]. This literature review focuses on two diverse study types. The first focuses on the semi-automatic methods used in the data extraction and reporting phase of the SLR. The latter focuses on how the QA criteria can be applied to text summarization in a SLR.

3.1 Systematic Literature Review

The SLR consists of three phases namely, Planning, Conducting and Reporting. In the planning phase, we define the RQs, define a search string and state the IC/EC. During the conduction phase, we identify the primary studies, perform study selection, QA and data extraction. Finally, in the reporting phase, we answer the RQs mentioned in the planning phase and document it.

3.1.1 Planning Phase

Planning phase is one of the most important phases that defines and structures the literature review. In this section, we define the RQs, search strategy, IC/EC, QA criteria and the method to be considered for data extraction.

RQs

RQ1: How text mining techniques are used to automate data extraction from the primary studies?

We essentially begin with finding papers that describe different text mining techniques that can help us in the extraction and summarization of the studies. Here we summarize the different text mining methods, such as, clustering, classification, and visualization. We mainly focus on the data extraction and reporting phase of the SLR.

Name	URL
GoogleScholar	https://scholar.google.com
ScienceDirect	https://www.sciencedirect.com
SpringerLink	https://link.springer.com
IEEE Xplore	https://ieeexplore.ieee.org
ACM Digital Library	https://dl.acm.org/

Table 3.1: List of libraries.

RQ2: What are the different methods used to summarize data on a set of primary studies for SLRs in software engineering domain?

The extracted data is summarized in the reporting phase. Reporting is usually done using graphical representations of the data that is needed for further analysis. Here we describe how the different papers summarize or report the data so that it can help the researcher's needs.

Search Strategy

We define the strategy used to perform the search. Automatic keyword search along with snowballing is used to find relevant primary studies.

Search Keywords

We define the keywords that are required to perform the search. The search keywords must include all the keywords from the RQ. This assures that all the relevant papers concerning the RQ are found.

Keywords: Systematic literature review, data summarization, automation, methods, data extraction.

Search String

The boolean search string is written by taking into account the keywords that were defined and all their relevant synonyms. It is written using a combination of boolean operators such as such as AND, OR, NOT, and AND NOT operations and brackets.

String: (Method OR Automate OR Approach) AND ("Data Mining" OR "Text Mining") AND ("Data Summarization" OR "Text Summarization" OR "Data Extraction") AND ("Systematic Literature Review" OR SLR)

Search Venues

The boolean search string is used in the different digital libraries to find the relevant studies. Table 3.1 on page 24 depicts the selected libraries.

IC and EC

Here, we define the various criteria that must be considered before selecting the primary studies. The criteria are written based on the type of studies required. We make sure that the paper satisfies the IC and EC.

IC Criteria:

- The study must address an approach to automate data extraction/reporting in the SLR process : The focus of our approach is based on the automation of data extraction and hence, we look for studies that support our idea.
- Study is conducted between 2007 to 2018 : The "Guidelines for performing Systematic Literature Reviews in Software Engineering" by A. Kitchenham [2007] was published in the year 2007. This study is considered to be the foundation for SLRs in the software engineering domain. Therefore, we find studies conducted after 2007.
- Paper reviewed and officially published in a journal/workshop/conference : Since the papers are officially reviewed, the results will be more precise and proven.
- Articles related to software engineering domain : Since our literature review focuses on the software engineering domain, we filter out the other prominent domains, such as, the medical field.

EC:

- Papers not written in English : Our study and implementation is focused on data extraction in English. Since the studies and tools in other languages will not help our study.
- Abstracts and PowerPoint presentations : These studies are not structured appropriately and hence lacks detailed information of the topic.
- Technical reports and Bachelor/Master/PhD thesis : Since the studies aren't officially reviewed, there might be scope for irregularities in the result.
- Articles with unknown publication type or publisher : Publications with unknown source cannot be considered true to form.

QA

One of the ways to find the quality of the study is to rigorously check how the studies uphold the QA criteria. A set of questions are framed to check the quality of the primary studies. The checklist consists of questions that answer the different stages of the review which are stated below as mentioned by A. Kitchenham [2007].

- Design

- Conduct
- Analysis
- Conclusions

The following questions were set based on the guidelines mentioned by A. Kitchenham [2007]. We also adapt the checklist written by Dybå and Dingsøyr [2008]. They address the quality criteria in all the different stages stated by A. Kitchenham [2007]. Q1 answers the design stage. Q2 answers to the conducting stage. Q4 answers the analysis stage. Finally, Q3 and Q5 answer the questions regarding the conclusion stage.

QA Criteria:

Q1. Are the aims clearly stated?
If the primary study clearly states the objectives and aims of the study, then the paper is awarded a score of 1. If the aim is not at all mentioned then the score is 0. If the aim is defined but not clear, it can get a score between 0-1.

Q2. If the primary study uses a particular technology, is it clearly defined?
If the primary study uses a particular technology and it is explained clearly, it is awarded a score of 1. If the study does not use any particular technology it is still awarded a score of 1. If the primary study uses a particular technology but it is not explained, it is then awarded a score of 0.

Q3. To what extent does the result mention the external validity or future research?
If the studies can benefit the researchers outside the scope of the current study, then a score of 1 is assigned. Else, it is assigned a score of 0.

Q4. Is the purpose of the study clearly defined?
The study is awarded a score of 1 if the purpose and motivation are clearly defined. If the purpose is not mentioned, then it is awarded a score of 0.

Q5. Are the problems, negative results or the limitations mentioned?
If the paper mentions the negative aspects along with the other pros, then the study is awarded 1. Else it is awarded a 0. Every individual study is given 5 different scores based on each of the quality criteria. These scores are summed up to get the final score (Total=5) of each study. Higher the score, better is the quality of the study.

Data Extraction

The primary studies that are selected are used for extracting data from the predefined data fields. The data extraction is mainly done using text mining methods like clustering and classification. This helps us in finding trends and similarities between the documents.
The extracted data is reported using graphical representations. It can be presented in the form of various charts or tables making it easier for researchers to derive a better conclusion.

Attributes Extracted
Title
Authors
Year
Abstract
Introduction
Conclusion

Table 3.2: Data extraction.

Library	Number of Studies found	Number of studies selected
Springer	72	0
Science Direct	243	0
Google Scholar	1330	3
IEEE	742	0
ACM	5726	0
Total	8113	3

Table 3.3: Number of selected studies.

3.1.2 Conducting Phase

In this section, we demonstrate the implementation of the methodology that was described in the planning phase. We look into the details of how the primary studies were selected and processed through the selection process.

Identifying Relevant Research

The search was conducted in various online libraries using the search string that was defined in the planning phase. We found a total of 8113 results in the libraries listed in the Table 3.3. The results were intensively searched manually to check for all the IC/EC to derive the final set of primary studies.

Selection of Primary Studies

The primary studies that satisfy all the search criteria were mainly found on Google Scholar. The studies derived were then used for snowballing to find more relevant papers. The result of this search can be found in Table 3.4 in page 29. Table 3.4 contains the results of various steps, such as, entering the boolean search string in the libraries, selection of papers based on keywords, performing snowballing and checking the IC/EC. This entire process with the number of results in each step is depicted in the Figure 3.1 in page 28.

QA

To check the quality of the study that has been selected, we apply the QA criteria that were previously mentioned in the methodology stated by A. Kitchenham [2007].

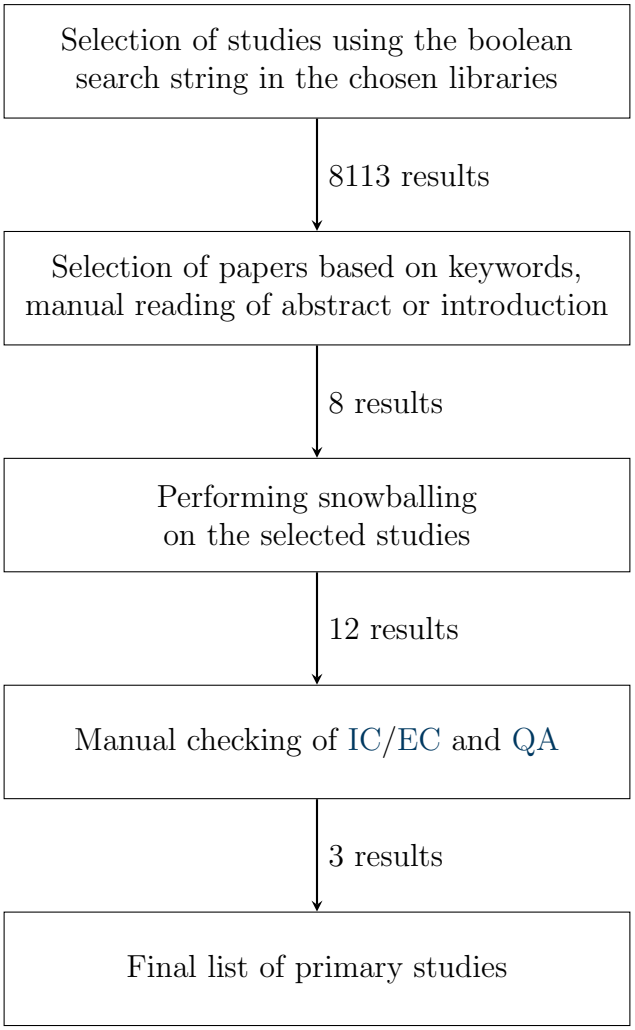

Figure 3.1: Selection of primary studies.

ID	Primary Study Name	Publisher	Year	Citation
PS1	Using Information Visualization and Text Mining to Facilitate the Conduction of Systematic Literature Reviews	Springer Berlin Heidelberg	2013	[Fabbri et al., 2013]
PS2	SLuRp – A Tool to Help Large Complex Systematic Literature Reviews Deliver Valid and Rigorous Results	EAST'12 - Proceedings of the 2nd International Workshop on Evidential Assessment of Software Technologies	2012	[Bowes et al., 2012]
PS3	SLR-Tool - A Tool for Performing Systematic Literature Reviews.	ICSOFT 2010 - Proceedings of the Fifth International Conference on Software and Data Technologies, Volume 2.	2010	[Fernández-Sáez et al., 2010]

Table 3.4: List of primary studies.

Each study that has been selected must have a certain degree of agreement to the QA criteria. Each question gets a score in between 0-1. The primary study is ranked based on a total score of 5. Higher scores reflect better quality of studies. The Table 3.5 on page 30 shows the primary studies along with their scores. The scores are calculated based on the QA criteria defined previously.

Each primary study has a score in the range of 4.0 - 5.0 out of 5.0 which illustrates how well the primary studies conform to each of the QA criteria. Each study shows a small amount of disagreement to at least one of the QA criteria.

According to Fabbri et al. [2013] there are no limitations or negatives mentioned in the entire scope of the paper. Hence it is assigned a score of 0 to Q5. The study by Bowes et al. [2012] hasn't clearly mentioned how the SLuRp tool can be used outside the scope of the paper. Therefore it receives a score of 0.5 for its external validity. Similarly, the study by Fernández-Sáez et al. [2010] also doesn't clearly state its external validity and hence receives a score of 0.5. All the other quality criteria are satisfied completely and hence received a score of 1.

Data Extraction

We extract the meta-data of the study which includes data about the publications and the details of the authors. We also extract specific sections of the study, such as, abstract, introduction and conclusion to get a better idea about the paper. Since this review mainly focuses on finding the text mining techniques used in SLR, we extract sentences from these studies to formulate the summary.

3.1.3 Reporting Phase

This section describes a detailed answer to the RQs that were stated during the planning phase. The 3 papers that satisfied all our criteria is carefully studied to

ID	Primary Study	Q1	Q2	Q3	Q4	Q5	Total(/5)
PS1	Using Information Visualization and Text Mining to Facilitate the Conduction of Systematic Literature Reviews. [Fabbri et al., 2013]	1.0	1.0	1.0	1.0	0.0	4.0
PS2	SLuRp – A Tool to Help Large Complex Systematic Literature Reviews Deliver Valid and Rigorous Results. [Bowes et al., 2012]	1.0	1.0	0.5	1.0	1.0	4.5
PS3	SLR-Tool - A Tool for Performing Systematic Literature Reviews. [Fernández-Sáez et al., 2010]	1.0	1.0	0.5	1.0	1.0	4.5

Table 3.5: QA of primary studies.

answer these questions. In the latter part, it also reports how the entire SLR process was carried out in all the three phases. Based on the report, we identify the areas in the study that need improvement which will be dealt in the further chapters.

3.1.4 Answering the RQs

RQ1: How text mining techniques are used to automate data extraction from the primary studies?

Data extraction is mainly done by using various text mining methods. Here we describe how the different studies use text mining techniques such as clustering, and classification to automate the process of data extraction.

The "StArt" tool proposed by Fabbri et al. [2013] uses text mining techniques like similarity calculation to extract the data. It also deals with a large amount of data to find hidden patterns and trends through visualization. It makes use of information visualization to integrate the information from all the papers. It extracts quantitative data such as the percentage of studies that passed the IC/EC and the number of studies found using the search string.

The study also describes the usage of a text mining tool called "PEx". The documents selected for the data extraction are converted into ASCII format using text from different parts of the articles (title, abstract, references etc). PEx helps in processing the abstract by removing stop words, calculating term frequency and hence, creates clusters of the documents.

The "SLuRp" tool proposed by Bowes et al. [2012] supports data aggregation and statistical analysis using SQL statements. It makes use of online databases to query the necessary studies and uses Java to semi-automate the data extraction. SLuRp provides the users with a coding form to record the extracted qualitative data and

a performance form to record the quantitative data from each study. It is executed by using classification and mappings.

This paper also states another tool by Felizardo et al. [2011] which uses Visual Text Mining (VTM) techniques to automate the clustering and classification of the papers. This tool makes extensive use of text mining and visualization techniques.

Fernández-Sáez et al. [2010] describes the usage of "SLR tool" that uses classification schemes to classify the primary studies to perform data synthesis and analysis. The tool takes care of all the stages of the planning phase, checks for the IC/EC and then uses the classification scheme to allow the researchers to specify the category and subcategory according to their choice. The visual data that is obtained here is used to synthesize the data and extract conclusions out of the primary studies. It also makes use of clustering to find patterns and trends in the studies.

RQ2: What are the different methods used to summarize data on a set of primary studies for SLRs in software engineering domain?

The extracted data is summarized and reported in the reporting phase. Here we describe how the different papers summarize/report the data so that it can help the researcher's needs. Summarization can help in better visualization and also helps in deriving a conclusion for the particular study.

Fabbri et al. [2013] mentions "StArt" as a tool that emphasizes the need for data summarization. This tool also creates a link to the full text of each paper used in the summarization. Here the reporting is done by displaying the data through visualization and Excel formatted reports. The final report that contains the extracted data from the primary studies is presented by using graphics and spreadsheets. "Traceability" is one among the most important topics of interest within the paper. It depicts how the studies are related to one another. The researchers can easily group the studies based on one of the categories such as year, author, and keyword by selecting the appropriate category. The categorization is done by using text mining method such as similarity calculation. For each pair, the similarity is calculated and a similarity score is assigned by using a vector processing model proposed by Salton [1989]. The paper also mentions another tool "PEx" proposed by Maldonado et al. [2007]. It creates a abstract by removing stop words, calculating term frequency. It calculates similarity measures to create a document map by using VTM.

Bowes et al. [2012] describes the tool named "SLuRp". It records the data from all the studies by automatically aggregating and displaying the results into reports. It makes use of two main methods, tabular and graphical. The graphical results are illustrated using different types of charts or plots. The graphical representation brings out the tendency of the paper to incline towards the bias in the results. The tabular results are presented in different ways such as Hypertext Markup Language (HTML) or LaTeX. It is used when there are qualitative data that can be summarized using mathematical operations. The extracted data will be linked to the paper using citation links. It will be also linked to the exact paragraph from where the data is extracted. This helps the researchers to study the entire paragraph when the extracted data is within their scope of interest. The data that is reported usually consists of the percentage/number of papers that pass or fail the quality criteria and IC/EC.

Fernández-Sáez et al. [2010] mention that the summarization or reporting must consider all the information related to all the 3 phases of the review. The SLR tool mentioned here follows the same process. During the summarization, the extracted data is transformed into visual data where it allows the researchers to get a better idea and faster conclusion of the studies. The data is exported into Excel files for further analysis. It creates a general summary of all the documents and also creates summaries according to the categories selected during classification by generating different charts. It further generates reference files such as BibTeX/EndNote which is exported into a document file.

In all the papers, the extracted data is automatically transformed into graphical representations like charts and tables. These graphical representations provide better and faster understanding to the researchers about the primary studies that are being used. They help the researchers in finding the trend and in getting an overall meta-data about the studies being used.

3.2 QA Check

To support our idea of including QA in the summarization, we intended to perform another SLR. A initial review was conducted to see if there exists any research that uses the QA criteria mentioned in the planning phase of the SLR process as the evaluation criteria in the summarization process. The results from all the search venues were carefully studied based on the keywords, manual reading of abstract and introduction. There were no studies that matched our criteria. Based on the outcome of the SLR, it can be said that there are no researches aimed at using the QA criteria during the text summarization. Hence it was not possible to continue the research or to answer the RQ. This helps in building the concept for this thesis. Adding the QA criteria as a measure to evaluate the outcome of the summary can be very helpful in assessing the information that the researchers are looking for. Using the QA criteria as the input, a supervised algorithm can be built to support the need. Henceforth, the focus of this thesis will include the use of QA criteria in the text summarization phase of the SLR.

3.3 Summary

In this section, we illustrated the entire SLR process. We look into the data in each and every step of the process. The initial search was conducted to find relevant studies that described different methods to automate data extraction and summarization. The search which initially started with 8113 results were filtered out to get 3 results that matched our distinct criteria. When we look into the reporting phase of our SLR, we see that summarization is done through visualization or through reporting the extracted data based on the different processes of SLR. We see the need for summarizing the studies textually so that the researcher gets a brief idea about a particular study. We also see the need for answering the QA questions during the summarization. The studies that were found during the SLR process mentions summarization as a part of the SLR process but doesn't emphasize the need and importance to support the automation of this feature.

To evaluate the quality of the summarized data, we have written QA criteria which makes the summary to undergo a rigorous quality check. In the further chapters, we focus on extracting the meta-data, predefined data fields from the studies and also provide a gist to the selected studies.

4. Methodology

In this section, we explain the approach we propose for the semi-automatic extraction and summarization process of the SLR. The implementation is mainly divided into three sub-parts as shown in Figure 4.1. To provide a complete report of the SLR process, we include meta-data extraction, extraction of the user-defined section of the paper and summarizing the entire document in our approach. The summarization is further divided into extractive summarization and keyword based summarization to execute our idea of answering the QA questions in the summarization. This makes sure that all the aspects of the document are reported by creating a multi-document summary for the given set of documents.

To perform SLRs efficiently and effectively, different methods are being proposed to support the various steps of the process. The reporting phase of SLR involves the crucial tasks of identifying and reporting direct evidence to answer the defined RQ. The researchers have a tedious and time consuming task of going through all the included studies to answer their RQ. Hence, any approach useful for reviewers to perform these steps effectively might accelerate the process. In this section, we explain the proposed idea to support data extraction and summarization of the information by using various text mining techniques. The sub-parts mentioned in Figure 4.1 were chosen for the implementation to help the researchers in speeding up the process of conducting SLRs.

- Meta-data of a Portable Document Format (PDF) file is the data that describe the attributes of the file [Brand et al., 2003]. The meta-data helps in extracting the basic information about the document. Milstead and Feldman [1999] mentioned that it also supports cataloging and indexing of the documents. It helps the researchers and other users to filter out the documents and hence making it easier to follow the SLR methodology. The extracted meta-data ensures that the information is stored and re-used for further research. It can also be used in search engines to find similar and relevant data for future work.
- Extracting specific sections of the PDF such as “Introduction”, “Abstract” and “Conclusion” can help the researchers in getting a deeper understanding of

the document. Most researchers read these sections to get the gist of the documents. These sections are believed to be the most important sections in a paper [Doumont, 2010].

- Summarizing the document is the main task of the proposal. A textual qualitative summary is created to help the researchers in understanding the document within a short period of time [Allahyari et al., 2017]. The extractive summarization helps in summarizing the paper as a whole, whereas the keyword based data extraction is done by using user-defined keyword search throughout the document to find particular topics that are interesting to the researchers. The keyword and its synonyms are searched in the primary studies to find relevant sentences. This ensures that all the aspects of the document are covered in the summary.

The implementation of lour proposed approach is carried out by using Python 3, a high level interpreted programming language [Sanner, 1999]. The project is made available as a web application using the Django web framework. Django is used for its features such as quick, transparent and high-quality code writing [Zublenko, 2016]. The project also uses Jinja as the templating engine to perform powerful automatic HTML escaping. The decision of using Python3 depend on the fact that it is associated with a huge collection of libraries for text mining and natural language processing, such as, NLTK, gensim, numpy, and scripy.

4.1 Meta-data Extraction

The meta-data of the document is the high-level information that describes the document. The meta-data of the documents help the researchers in extracting the title, authors, keywords, publishers, date of creation, creator, and producer. Franks [2006] states that the meta-data acts as a tool to classify and categorize the information that also helps in giving us an insight of the paper. This can help the researchers to further filter out some documents if it does not fulfill their criteria. Hence, we incorporate the process of extracting meta-data into our tool to help in effective categorization and to provide the users with the context of the study.

Python has a lot of different libraries to implement the meta-data extraction. The implementation is carried out by using the PyPDF2 python toolkit. PyPDF2 was used because of its simplicity and it satisfies our requirements of extracting only the meta-data. PyPDF2 can also be used to extract other data from the PDF file and manipulate them. We also explored other libraries such as pdfminer, pdfminer3k, and TIKA. They contain tons of other features along with the meta-data extraction. They are mainly used for PDF parsing and data analysis.

PyPDF2 retrieves the PDF file's meta-data information if it exists. PyPDF2 uses "PdfFileReader" to get the document information. We found that some PDF files use meta-data streams instead of dictionaries, and hence this function will not be able to access these meta-data streams. Every document has two types of properties, the raw property and the non-raw property. The non-raw property returns a "TextString" object and hence works well while displaying the results to the users. If

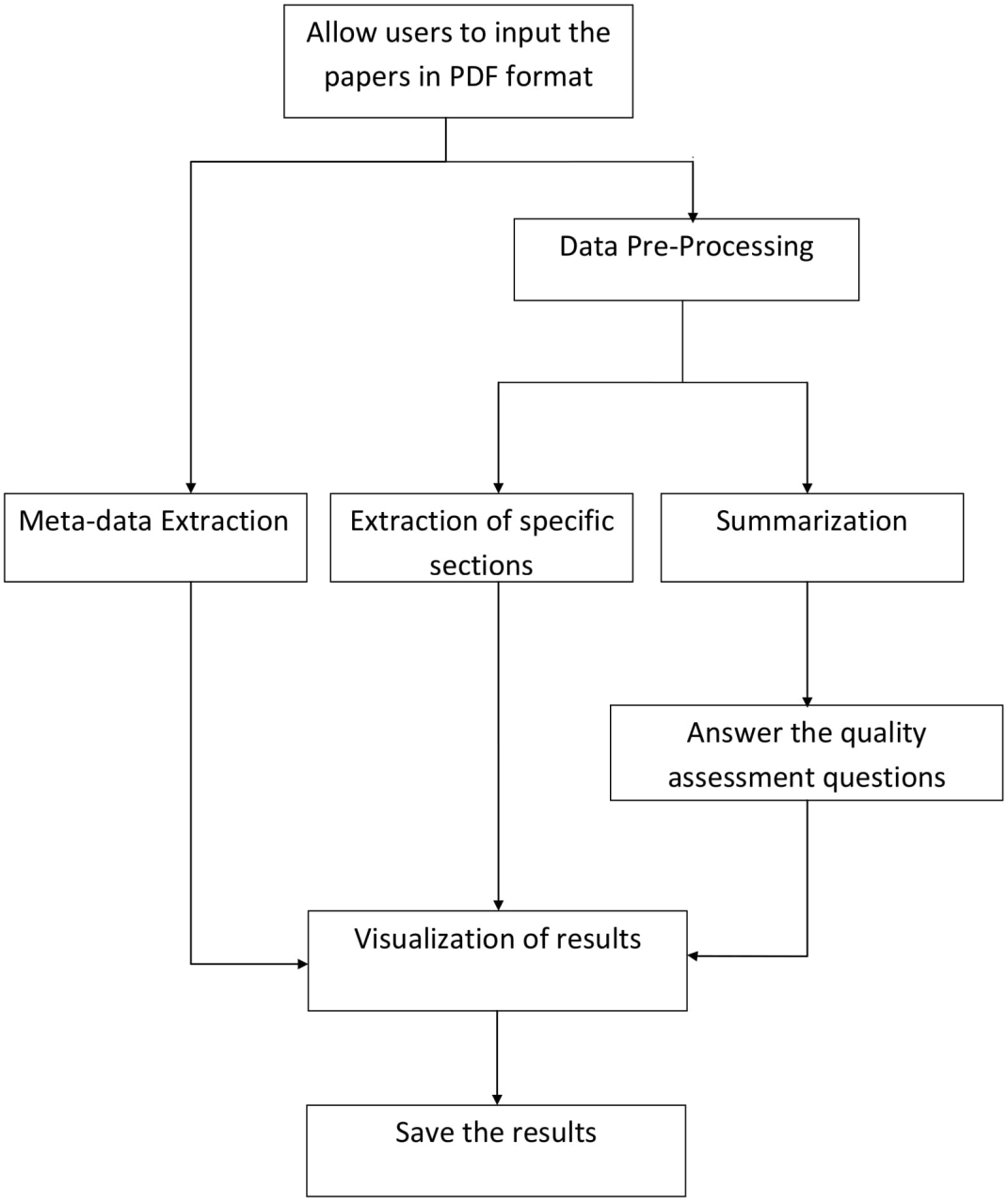

Figure 4.1: Proposed approach for summarization and data extraction.

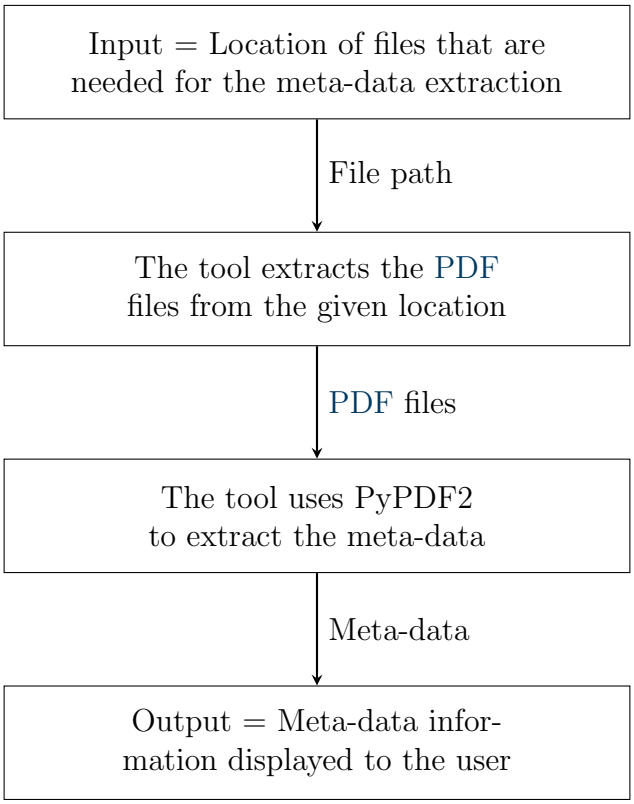

Figure 4.2: Meta-data extraction process.

PyPDF2 was unable to find any meta-data, a null string is returned. The extracted data is then stored in a file. Table 4.1 shows the data extracted from one of the input files. The properties such as "Title", "Author", "Subject", "Creator", "Producer", "Creation date", and "Keywords" can be extracted. Figure 4.2 describes the steps involved in the process.

Type of Meta-data	Meta-data
Title	SLR-TOOL A Tool for Performing Systematic Literature Reviews
Author	Ana M. Fernández-Sáez, Marcela Genero Bocco, Francisco P. Romero
Creation Date	D:20111007115732+02'00'
Creator	Toolkit http://www.activepdf.com
Keywords	Systematic Literature Review, SLR, Tool, Text mining
Producer	Acrobat Distiller 10.0.1 (Windows)

Table 4.1: Extracted meta-data.

4.2 Automatic Extraction of Specific Sections

This feature was implemented to help the readers who are interested in understanding some specific sections of the study. Doumont [2010] stated that the readers are primarily interested in the contents present in the introduction and conclusion sections of the study. It is also stated that the readers want to know the motivation and the outcome of the study and the abstract is considered to be in parallel to the introduction and conclusion. This indicates that these sections play a vital role in the initial filtering and understanding of the results. It is important to know why the work was carried out (motivation), what work has been done (introduction), and what are the findings of the study (conclusion).

Our tool helps in implementing this by extracting the sections "Abstract", "Introduction", and "Conclusion". The user selects one of these sections for every document according to their requirement. The extraction of these sections is carried out by using Regular Expression (regex) and the regex python library (re). The data cleaning is done to remove unwanted spaces and newline characters. The first step is to split the text by using the newline character. Listing 4.1 searches for one or more occurrence of the newline character.

Listing 4.1: Splitting the sentences

```
re.split(r'\n+', text)
```

Listing 4.2 searches for the occurrence of the selected sections in the subheadings.

Listing 4.2: Searching a section

```
(?<!\S)\d' +'.*'+ '\s*'+ section
```

Once the selected section is found, the corresponding paragraphs associated with it is extracted using Listing 4.3. The sentences are extracted until the next occurrence of another section is found.

Listing 4.3: Extracting the section

```
'(?<!\S)\d' +'.*'+ '\s*'+ '[A-Za-z]'
```

It makes use of negative look behind `(?<!\S)` which says that there are no white spaces before the `\d` character. When the algorithm finds the next section, the loop breaks and returns the specific section.
It was later observed that the sections can also begin with roman numbers. Hence, the algorithm was changed accordingly to search for roman numbers in the section labels as shown in Listing 4.4.

Listing 4.4: Extracting the section with roman numbers

```
'I|X|IV|V?I{0,3}' + '.*' + '\s*' + '[A-Za-z]+'
```

Figure 4.3 on page 40 depicts the step by step process used in extracting the sections.

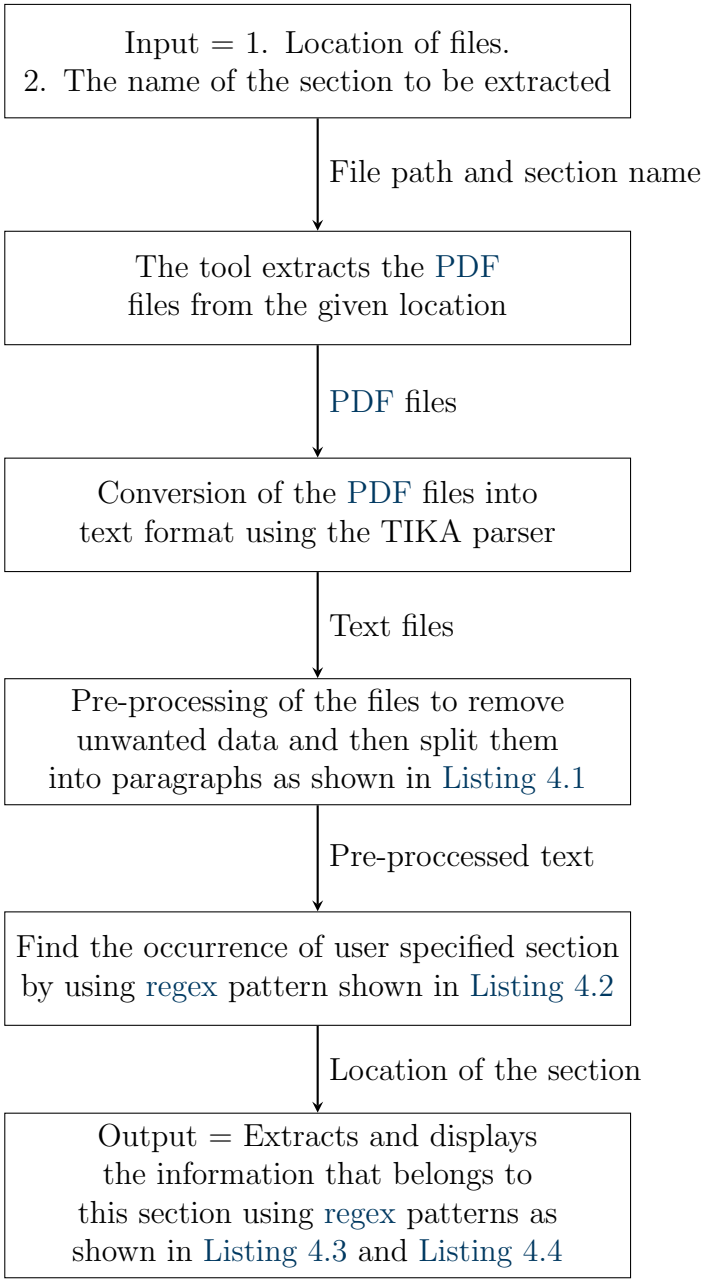

Figure 4.3: Process of extracting specific sections.

4.3 Semi-Automatic Summarization

Summarization is done on the entire document to present the most important concepts of the document. Summarization is independent of the structure or the syntax of the document. It helps the users to get a well structured document that contains the objectives and important features [Ouyang et al., 2009]. It integrates the core ideas of the document in a meaningful way ignoring the irrelevant information and by removing redundancies [Ouyang et al., 2009]. A good summary should be complete, accurate, and impartial. Due to the ever increasing amount of text data that are available, discovering relevant information is time-consuming. Hence, there is a great need to reduce this text and create summaries. Automatic summaries are also less biased than human written summaries [Torres-Moreno, 2014]. Therefore, we introduce the feature of text summarization in our tool.

The summarization is divided into extractive summarization and keyword based summarization. The extractive summarization algorithm automatically summarizes the document to include important concepts by checking the frequency of keywords. To support our idea of answering the QA questions, we use a keyword-based summarization algorithm to summarize the document. The process is semi-automatic because of the keywords that have to be manually added to answer the QA criteria.

Before proceeding with the implementation, the PDF studies are converted into text documents. Later, data cleaning is done to remove unwanted spaces and new line characters. The sections such as bibliography and acknowledgements are also removed from the text document. The summary is also free from unnecessary links that can hinder the quality of the summary as shown in Listing 4.5.

Figure 4.4 on page 42 shows us the initial steps of the process.

Listing 4.5: Removing links

```
re.findall('https?://(?:[-\w.]|(?:%[\da-fA-F]{2}))+', str(s))
```

4.3.1 Extractive Summarization

Extractive summarization is the process of extracting the sentences that best describe the document. It can be carried out by using various algorithms such as "TextRank", "LSA summarizer", "Luhn summarizer", "Textum", "LexRank summarizer", "gensim" etc. The algorithms that displayed the highest accuracy were used for the implementation. Figure 4.5 on page 43 shows the process involved in creating the extractive summary.

Appraoch 1: TextRank

Mihalcea and Tarau [2004] introduces TextRank as a graph-based ranking model written based on the PageRank algorithm. Mihalcea and Tarau [2004] mentioned that graph based algorithms and Google's PageRank algorithm have been running very successfully. The author argues that it works well because it decides the importance of a vertex by considering the global information from the entire graph. He concludes that the cohesive web model built by the tool approximates to the model created by humans in the process of summarization.

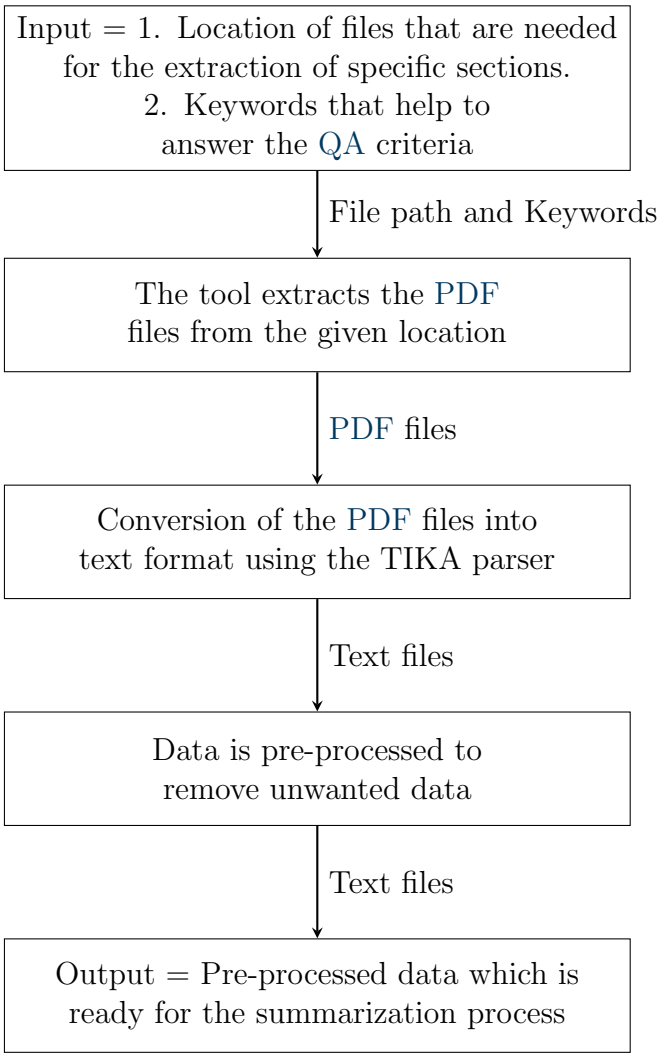

Figure 4.4: Data summarization.

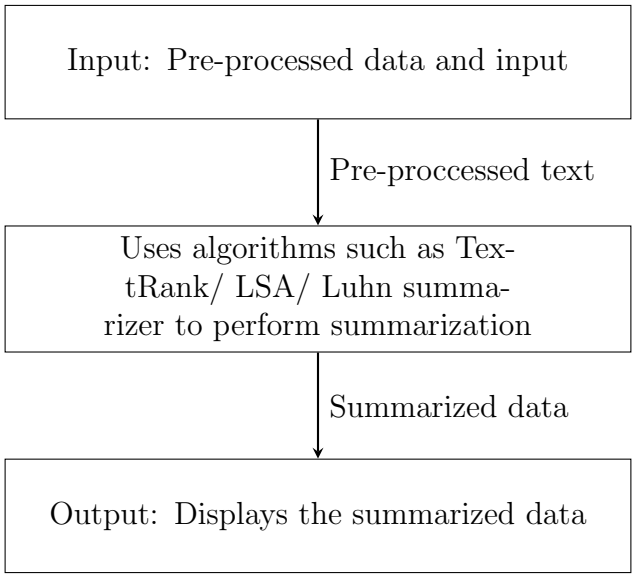

Figure 4.5: Process of extractive summarization.

TextRank helps our implementation by performing extractive summarization. TextRank uses different similarity measures to find the similarity between sentences and finds how one sentence could be connected to another as shown in Figure 2.2. It creates a vertex for each unit extracted from the input text. These vertices are connected to each other with edges. The weights assigned to these edges are the measure of the strength of the connections. The sentences are ranked based on the score given to each sentence. The top "n" sentences are selected for the summary. TextRank provides us the summary by preserving the original meaning of the document.

The document to be summarized is converted from PDF to text file using the TIKA parser to read all the contents of the file. This text is later used in the TextRank algorithm. The TextRank summarizer first splits the text into sentences at ".". These sentences are pre-processed to prepare it for the summarization Listing 4.6.

Listing 4.6: Clean text

```
sentences = clean_text(text, language)
```

These sentences are used to build a graph which denotes the similarity coefficient between the sentences as shown in Listing 4.7.

Listing 4.7: Build graph

```
graph = build_graph([sentence.token for sentence in sentences])
set_graph_edge_weights(graph)
```

All nodes with weights equal to 0 are considered unreachable and hence, removed from the graph as shown in Listing 4.8.

Listing 4.8: Remove unreachable nodes

```
remove_unreachable_nodes(graph)
```

If the graph is empty, the algorithm returns an empty string and ends the process as shown in Listing 4.9.

Listing 4.9: Check for empty graph

```
if len(graph.nodes()) == 0:
        return ' '
```

The nodes of the graph are ranked using PageRank to get a dictionary of sentences with their respective scores as shown in Listing 4.10.

Listing 4.10: Rank the sentences

```
scores = pagerank(graph)
add_scores_to_sentences(sentences, scores)
```

Based on the rank given to the sentences and the selection criteria, the most important sentences are extracted. Words can be sent into this method to tune the extraction process. Similarly, the "ratio" is used to reduce the number of sentences as shown in Listing 4.11.

Listing 4.11: Get the most important sentences

```
extracted_sentences = most_important_sentences(sentences,
ratio, words)
```

The extracted sentences are sorted in the order of their appearance in the original text as shown in Listing 4.12.

Listing 4.12: Sort the sentences

```
extracted_sentences.sort(key=lambda s: s.index)
```

There are chances that some unwanted sentences such as references are added to the summarization. To avoid such sentences, only those sentences with words more than 50 are selected in our summarization. Finally, the results are formatted by joining the sentences and returned to the user as shown in Listing 4.13.

Listing 4.13: Format the sentences

```
format_results(extracted_sentences)
```

Appraoch 2: LSA

Steinberger [2004] makes use of LSA to identify the semantically important sentences. It is a generic text summarization algorithm written to find the similarity between the original document and its summary. It uses TF and SVD to implement the summarization. Steinberger [2007] mentioned that the results of the summarizer were comparable to other well known summarizers. Steinberger [2004] also stated that in some set of documents, LSA summarizer outperforms other summarizing methods.

First step of the LSA implementation is to create a dictionary mapping of key (unique words) - value (row index) pairs as shown in Listing 4.14.

Listing 4.14: Dictionary mapping

```
for w in words if w not in stop_words
dict((w, i) for i, w in enumerate(unique_words))
```

Next step is to create a M*N matrix of |unique words|*|sentences| where the cells contain number of occurrences of words (rows) in sentences (cols). For every word that is not a stop word, the count is increased by 1 as shown in Listing 4.15.

Listing 4.15: Matrix creation

```
for col, sentence in enumerate(sentences):
  for word in map(stem_word, sentence.words):
     if word in dictionary:
        row = dictionary[word]
        matrix[row, col] += 1
```

Once the matrix is created, we compute the term-frequency for each sentence in the given matrix. Term frequency is normalized using a smoothing factor to mitigate the anomaly that is observed in longer documents. Higher term frequencies are observed in longer documents because it tends to repeat the same words over and over again. Hence a maximum word frequency is set for every sentence by numpy as shown in Listing 4.16.

Listing 4.16: Term-Frequency

```
for row in range(rows):
  for col in range(cols):
    frequency = matrix[row, col]/max_word_frequency
    matrix[row, col] = smooth + (1.0 - smooth)*frequency
```

SVD is applied to this matrix to create independent base vectors. SVD helps in finding relationships between these vectors to create semantic clusters of the terms and sentences. Recurring patterns will be combined into a single cluster. Each singular vector represents a particular concept. The magnitude of these vectors describes the importance of each of the sentences. Hence, the most important features are selected in the summarization process.

Approach 3: Luhn Summarizer

Luhn summarizer is an extractive summarizer that works on the idea that authors tend to repeat their words in the process of writing [Luhn, 1958]. This is taken as a means of emphasis on the importance of the words. If certain words are more often seen together with each other, it is considered to be more significant in the document. The algorithm has two phases. In the first phase, stop words are identified and the significant words are selected by using frequency analysis. A subset of common words that are not in the list of stop words are selected as significant words. The frequency of every significant word is calculated. Words having a frequency greater than a threshold will be selected as the most frequent words. It is shown in Listing 4.17

Listing 4.17: Significant words

```
significant_words = for w in words if w not in stop_words
words = model.most_frequent_terms(significant_words)
selected_words =  t for t in words if frequency(t) > n
```

The second step is to score each sentence. The frequency of the sentence is calculated based on a significance factor. It is the square of significant words divided by the total number of words in a sentence. If a sentence has 100 words and all the words are significant, then the significance factor is 100. It is shown in Listing 4.18.

Listing 4.18: Significance factor

```
if w in top_words:
    important_words += 1
 Significance factor= important_words^2 / total_number_of_words
```

In the final step, the sentences with the highest significance factor is used for the summarization.

4.3.2 Keyword based Summarization

To make our summary adhere to the QA criteria, we include keyword based summarization as an additional step. The summarization is done by extracting those sentences that have the keywords specified by the user. The algorithm takes the QA criteria and the study as input. The following QA criteria were used in the implementation.

- Q1. Extracting the the aim/goals.
- Q2. Extracting the limitations.
- Q3. Extracting the future work.
- Q4. Extracting the evaluation study.

Keyword extraction is done by removing stop words from the QA criteria to get the search keywords. We use "WordNet", a lexical database to find the synonyms for our keywords. WordNet groups together nouns, verbs, adjectives, and adverbs into sets called "synsets". WordNet consists of a hierarchical structure of words with super-subordinate relation. It makes use of semantic similarity to extract all the available sentences containing the keywords. Listing 4.19 shows how the synonyms are extracted for every keyword

Listing 4.19: Finding synonyms

```
for synset in wordnet.synsets(key):
    for name in synset.lemma_names():
        keywords.append(name)
```

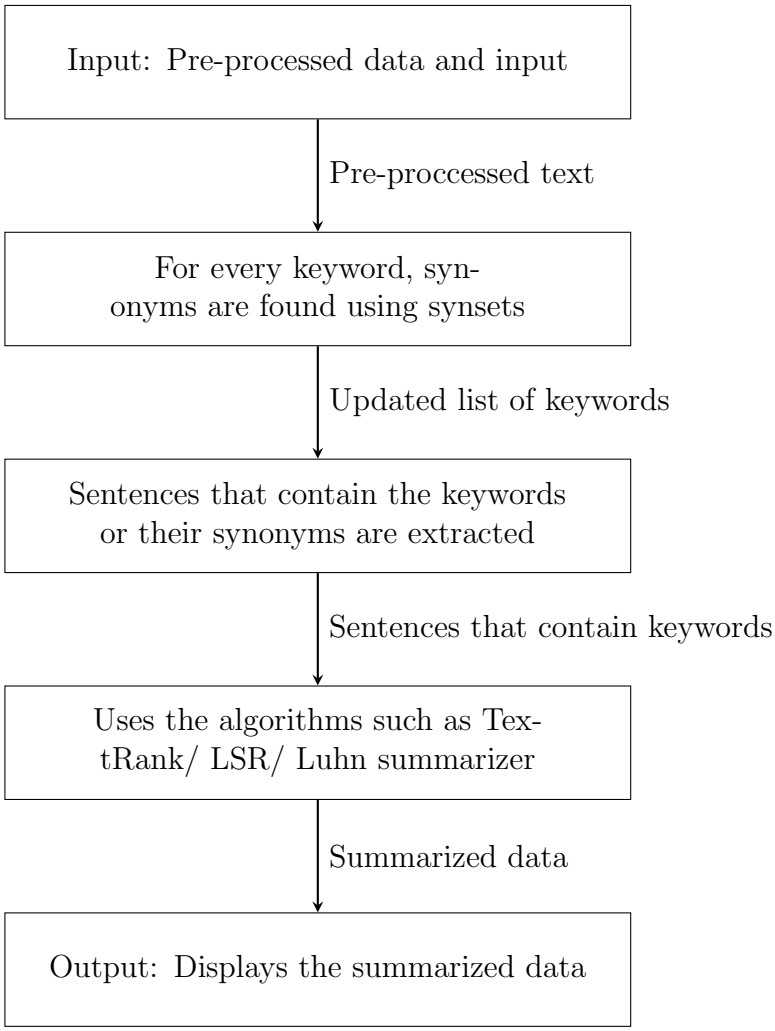

Figure 4.6: Process of keyword based summarization.

For every QA criteria, the keywords and their synonyms are searched in the original text. The corresponding sentences that match the keywords are extracted from the study. The sentences are grouped together for every QA criteria. This gives us a long list of sentences that match the keywords. To summarize the findings, the "TextRank" algorithm is applied again for every QA criteria to get the desired number of sentences. Figure 4.6 on page 47 depicts the steps involved in the keyword based summarization process.

4.4 Summary

In this chapter, we explained the implementation details of our approach. We started by explaining how the meta-data extraction was carried out. We then explained the details of extracting specified sections of the study. Finally, we explained how the data summarization was implemented. The two methods of data summarization are combined together for every study to get the desired results. The QA questions are successfully answered in the summarized text. The summary is well structured,

making it easy to read and understand the context of the study in a very short amount of time.

5. Evaluation

In this section, we explain the experimental setup and discuss the results of our approach. Evaluation is important to verify the significance of the approach for the researchers conducting the SLR. We discuss the results of the three different parts of our approach. We begin by discussing the results of meta-data extraction. Later, we evaluate the approach used to extract the specific sections by using precision and recall as the evaluation method. Finally, we discuss the results of summarization by using intrinsic and extrinsic methods.

5.1 Meta-data Extraction

The evaluation is performed by checking the different meta-data extracted from a number of studies. During the evaluation, it was found that some studies have incomplete meta-data if the author has not added the necessary information. Since our implementation makes use of python libraries to extract the meta-data, it is not possible to extract the meta-data if the author has not added the information. Table 4.1 shows an example of the extracted meta-data when the author has added complete. The evaluation is conducted on 25 different studies which are listed in Table 5.2. These studies were randomly selected from the digital libraries to check the performance of the tool in the real world scenario. The result is the percentage of correctly extracted meta-data. Table 5.1 shows us the results of evaluation. Figure 5.1 shows us the snapshot of the results obtained from the tool.

Advantages:

- The tool helps the readers in classifying the documents based on their meta-data.
- It helps in filtering out results without going through every document.

Disadvantages:

- If the PDF document is not associated with any meta-data, the tool returns a null value.

Type of meta-data	Percentage
Title	68%
Author	63%
Creation date	100%

Table 5.1: Evaluation of meta-data extraction.

Results of Evaluation

The results of evaluation show us that out of 25 studies, the title is extracted from 17 studies which gives us a success rate of 68%. Similarly, the name of the author was extracted from 16 studies (success rate of 63%) and the creation date was extracted from all the 25 studies (success rate of 100%). The extraction of some meta-data failed since the author did not add the meta-data information while creating the document. To overcome this problem, other approaches such as text mining using regex can be used to extract the meta-data from the text.

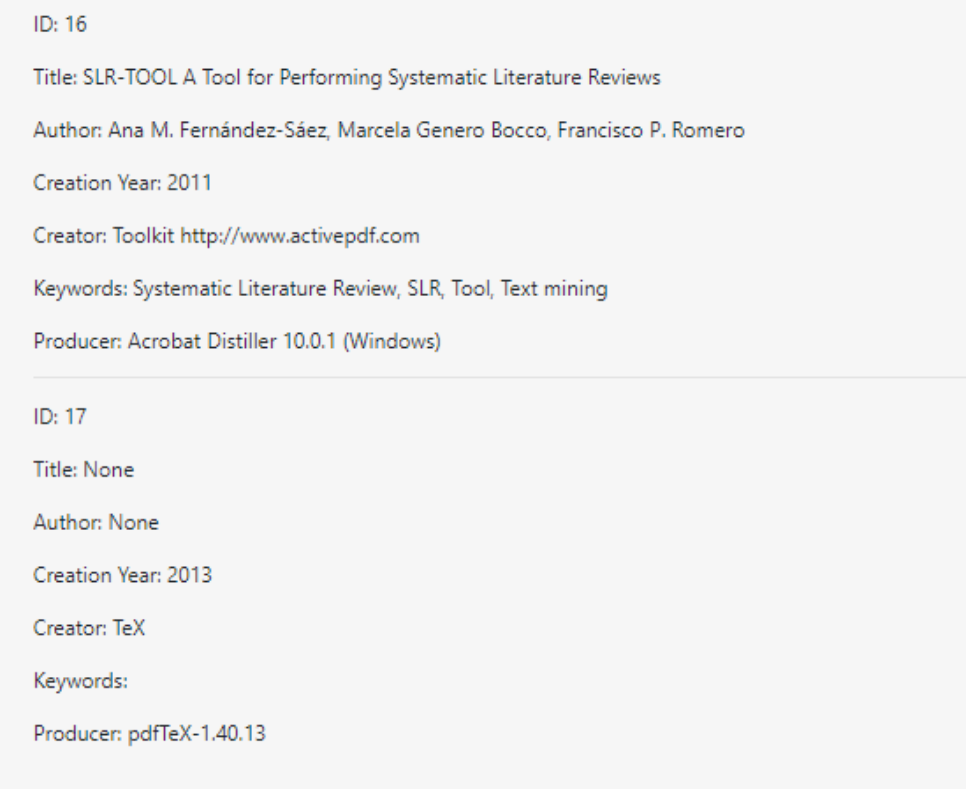

Figure 5.1: Snapshot of meta-data extraction.

5.2 Extraction of Specific Sections

To evaluate the extraction of specific sections, the algorithm was tested on 25 different PDF files. Table 5.2 gives the list of studies used in the implementation. These studies belong to the software engineering domain and were randomly selected from

Title	Year
Text mining- state of art	2000
Procedures for Performing Systematic Reviews by Barbara Kitchenham	2004
SUMMAC: a text summarization evaluation	2004
Performing Systematic Literature Reviews in Software	2006
Applying Systematic Reviews to Diverse Study Types: An Experience Report	2007
Systematic Mapping Studies in Software Engineering	2008
Motivation in Software Engineering- A systematic literature review	2008
Strength of Evidence in Systematic Reviews in Software Engineering	2008
Problem-Based Learning for Engineering Students: An Evidence-Based Comparative Study	2009
Ontology- Based Knowledge Management System and Application	2011
BNOSA: A Bayesian network and ontology based semantic annotation framework	2011
Light-weight tool support for semantic annotation of textual documents	2011
SLR-TOOL A Tool for Performing Systematic Literature Reviews	2011
SLuRp – A Tool to Help Large Complex Systematic Literature Reviews Deliver Valid and Rigorous Results	2012
Using Information Visualization and Text Mining	2012
Automatically Locating Results to Support Systematic Reviews in Software Engineering	2013
Graph-based semantic annotation for enriching educational content with linked data	2013
Tools to Support Systematic Literature Reviews in Software Engineering- A Mapping Study libre	2013
Text Mining and Semantics: a Systematic Mapping Study	2013
Tools to Support Systematic Reviews in Software	2014
Ontology-based annotation and retrieval of services in the cloud	2014
Quality Assessment of Systematic Reviews in SE a tertiary study	2015
Integrating Library Instruction into the Course Management System for a First-Year Engineering Class	2015
Semantic Web in data mining and knowledge discovery: A comprehensive survey	2016
PDFdigest: an Adaptable Layout-Aware PDF-to-XML Textual Content Extractor for Scientific Articles	2018

Table 5.2: List of studies used for meta-data extraction and extraction of specific sections.

the digital libraries to check the performance of the tool. Figure 5.2 shows us a snapshot of the extracted section. Every extracted section is given a score from 0-1. Evaluation measures such as precision and recall were used to check the quality of extraction. The data is classified based on the following metrics.

- True Positives (TP) – The extracted paragraph matches the ground truth.
- False Negatives (FN) – The paragraph is not extracted.
- False Positives (FP) – Paragraph is wrongly labeled.
- True Negatives (TN) – Nothing is extracted because there was no data present.

Precision Equation 5.1 and Recall Equation 5.2 are calculated by the following formulas respectively.

$$\text{Precision} = \frac{\text{TP}}{(\text{TP} + \text{FP})} \tag{5.1}$$

$$\text{Recall} = \frac{\text{TP}}{(\text{TP} + \text{FN})} \tag{5.2}$$

If the extraction is complete it is awarded a score of 1. If the extraction failed completely, it is awarded a score of 0. If there is a partial extraction, it is awarded a score in between 0-1.

The following tables show the different confusion matrices and Table 5.6 shows the final values obtained during evaluation.

Confusion Matrices for the Extraction of Specific Sections

TP= 20	FP=0
FN=5	TN=0

Table 5.3: Confusion Matrix for Extracting Abstract.

TP= 15	FP=2
FN=8	TN=0

Table 5.4: Confusion Matrix for Extracting Introduction.

TP= 15	FP=3
FN=5	TN=2

Table 5.5: Confusion Matrix for extracting Conclusion.

Justification of Results

Table 5.3 shows that among 25 studies, the tool successfully extracted the exact paragraph out of 20 studies (TP) and failed to extract the desired result for 5 (FN) other studies. The extractions failed since the abstract of the study was not recognized as a new paragraph in some of the studies. Some other studies had formats that were not recognized by the tool such as a tabular format. It also had different text format for the heading (Example : A B S T R A C T).

Table 5.4 shows that among 25 studies, the tool successfully extracted the exact paragraph for 15 studies (TP) and failed to extract the desired result for 8 other studies (FN). The tool also extracted the wrong data for 2 studies (FP). The extraction failed since the introduction sections had a different sub-heading name (FN). In a few studies, the tool tried to extract the introduction from the table of contents and hence failed in extracting the information (FN). We also encountered partial results when the text from the footer came in between the paragraph. Hence it was considered as (FP). When there was no introduction section in the study, the tool found the keyword elsewhere in the study and extracted wrong information (FP).

Table 5.5 shows that among 25 studies, the tool successfully extracted the exact paragraph for 15 studies (TP) and failed to extract the desired result for 5 other studies (FN). The tool also extracted the wrong data for 3 studies (FP). There were no data present in 2 papers and hence it was not extracted (TN). The tool failed to extract the information when the conclusion section had a different name (FN). The tool also tried to extract the conclusion from the table of contents and hence failed to extract the text (FN). Few studies had a brief conclusion section within the abstract and hence our tool extracted the wrong data (FP). When there was no conclusion section in the study, the tool found the keyword elsewhere in the study and extracted wrong information again (FP).

Results of evaluation

Section	Precision	Recall
Abstract	1.00	0.80
Introduction	0.87	0.65
Conclusion	0.83	0.75

Table 5.6: Evaluating the extraction of sections.

The precision and recall is calculated based on Equation 5.1 and Equation 5.2. Table 5.6 depicts the values of precision and recall using the confusion matrix for every

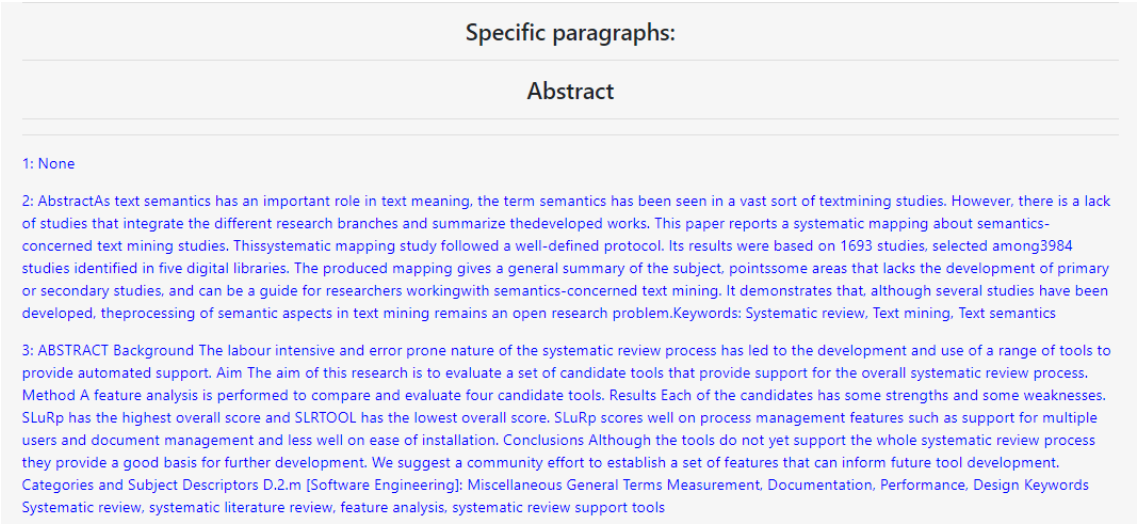

Figure 5.2: Snapshot of extraction of specific sections.

section. Higher precision values relate to a lower rate of wrongly extracted sentences (FP). Whereas, higher recall values relate to a lower rate of falsely extracted null values (FN). High scores for both show that the summarizer is returning accurate results with a majority of positive results.

Advantages:

- It helps the researchers in quickly reading the important sections of the paper.
- It provides readers with the motivation and outcome of the study.

Disadvantages:

- If the section has a different name, the tool fails to extract it.
- It could also fail when the paper has an unknown format.

5.3 Summarization

The summarization is evaluated by considering two different SLR studies and extracting all the primary studies used in the study. These primary studies are used as the input to our tool. The tool summarizes all these studies to create a multi-document summary. Figure 5.3 shows us a snapshot of the summarized data. The result of this summarization process is compared with the results of the SLR study. The evaluation is done by using intrinsic and extrinsic methods. We selected two well written SLR studies where the results of the studies were clearly stated. Table 5.7 and Table 5.8 show the two different SLR study examples. The SLR study is tagged as the reference paper and their primary studies as the input.

We use ROUGE score for the intrinsic evaluation which is one of the widely used measures of evaluating the results of automatic summarization [Graham, 2015]. It works by comparing the generated summary against the reference summary. ROUGE-N

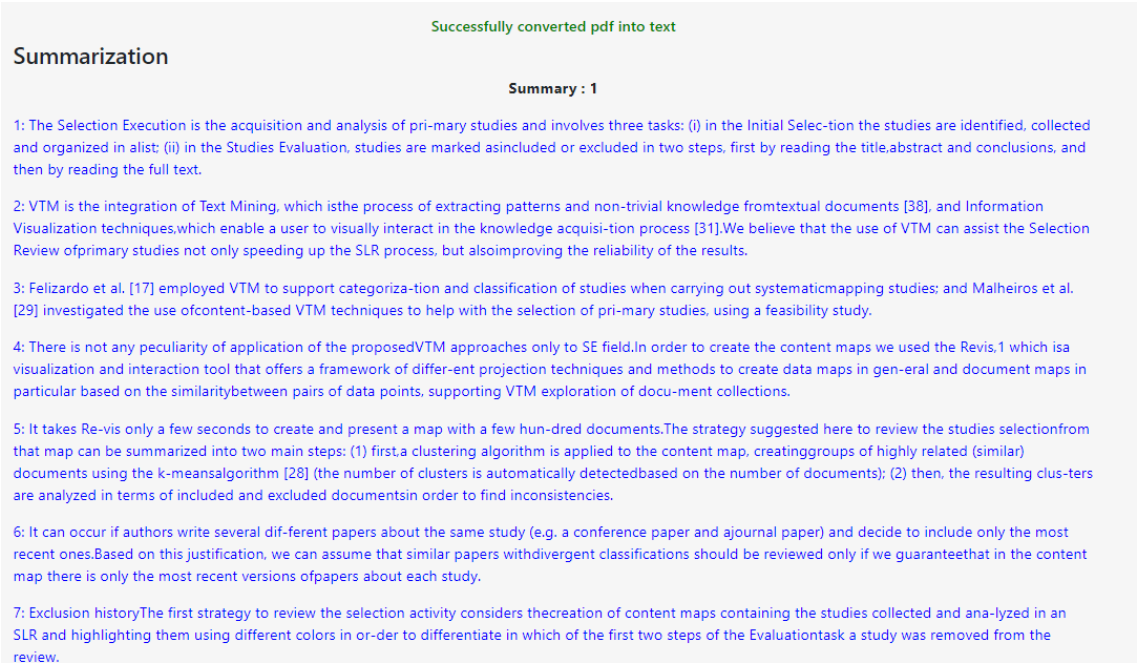

Figure 5.3: Snapshot of the summarized data.

refers to the overlapping of N-grams between the generated summary and the reference summary [Lin 2004]. ROUGE-1 refers to the overlapping of unigrams between the two summaries. Whereas, ROUGE-2 refers to the overlapping of bigrams between the two summaries. The formula used for the calculation of the ROUGE score is explained using the simplified equation in Equation 5.3.

$$\frac{\sum_r \sum_s match(gram_{s,c})}{\sum_r \sum_s count(gram_s)} \tag{5.3}$$

Where, $\sum_r$ refers to every reference summary and $\sum_s$ refers to every sentence in the generated summary. It loops through every n-gram in a single reference summary and counts the number of times a matching n-gram is found in the candidate summary. The denominator counts the total number of n-grams across all the reference summaries.

Extrinsic evaluation is carried out using the question game. In this method, a set of questions are prepared that are expected to be answered by the summary. The quality of the extracted summary is decided based on whether these questions are answered. We use some of the QA questions stated during the SLR to perform the extrinsic evaluation.

5.3.1 Intrinsic Evaluation

In this section, we use the ROUGE scores to compare the summaries created by using the various summarizers. We use ROUGE-1 to compare the summaries. Since we are comparing a human-written summary with the machine-generated automatic summary, we believe that it is more appropriate to compare unigrams rather than

Title	Year	Type
Effective Engineering Information Literacy Instruction: A Systematic Literature Review	2018	Reference
Effect of Guided Research Experience on Product Design Performance: A Pilot Study	2003	Input
Effect of library instruction on undergraduate electrical engineering design projects	2007	Input
Problem-Based Learning for Engineering Students: An Evidence-Based Comparative Study	2008	Input
Using Videos to Teach the Ethical Use of Engineering Information	2008	Input
Continuing library instruction via on-line tutorials	2009	Input
Enhancing Engineering Students' Knowledge of Information Literacy and Ethics through an Interactive Online Learning Module	2010	Input
Challenges for information literacy education at a university of technology	2010	Input
One or Many? Assessing different delivery timing for information resources relevant to assignments during the semester. A work-in-progress	2012	Input
Work in Progress: Collaboration for Quality: a Librarian-Faculty Partnership to Assess Students' Information Literacy in Freshman Engineering	2013	Input
If the Engineering Literature Fits, Use It! Student Application of Grey Literature and Engineering Standards	2015	Input
Integrating Library Instruction into the Course Management System for a First-Year Engineering Class: An Evidence-Based Study Measuring the Effectiveness of Blended Learning on Students' Information Literacy Levels	2015	Input
Using Direct Information Literacy Assessment to Improve Mechanical Engineering Student Learning - A Report on Rubric Analysis of Student Research Assignments	2015	Input

Table 5.7: SET 1 of studies used for summarization.

Title	Year	Type
Tools to Support Systematic Literature Reviews in Software Engineering: A Mapping Study	2013	Reference
Automated Information Extraction from Empirical Software Engineering Literature: Is that possible?	2007	Input
Using Context Distance Measurement to Analyze Results across Studies	2007	Input
An Approach Based on Visual Text Mining to Support Categorization and Classification in the Systematic Mapping	2010	Input
Analysing the Use of Graphs to Represent the Results of Systematic Reviews in Software Engineering	2011	Input
Using Visual Text Mining to Support the Study Selection Activity in Systematic Literature Reviews	2011	Input
Linked Data approach for selection process automation in Systematic Reviews	2011	Input
SLuRp – A Tool to Help Large Complex Systematic Literature Reviews Deliver Valid and Rigorous Results	2012	Input
Using GQM and TAM to evaluate StArt – a tool that supports Systematic Review	2012	Input
A visual analysis approach to validate the selection review of primary studies in systematic reviews	2012	Input
Towards Evidence-Based Ontology for Supporting Systematic Literature Review	2012	Input
A Federated Search Approach to Facilitate Systematic Literature Review in Software Engineering	2012	Input
Slrtool: A Tool to Support Collaborative Systematic Literature Reviews	2014	Input

Table 5.8: SET 2 of studies used for the summarization.

bigrams. Table 5.9 and Table 5.10 shows the results of our intrinsic evaluation on two different SLR studies.

The tool uses the ROUGE score calculator provided by the sumy evaluation framework for text summaries.

Algorithm	ROUGE score
TextRank summarizer	59%
LSA summarizer	64%
Luhn summarizer	69%

Table 5.9: ROUGE score - SET 1.

Algorithm	ROUGE score
TextRank summarizer	65%
LSA summarizer	63%
Luhn summarizer	64%

Table 5.10: ROUGE score - SET 2.

If the ROUGE score is 69%, it means that 69% of the generated summary matches the reference summary. The ROUGE score reduces when we use ROUGE-2 since there are lesser possibilities of having bigrams while comparing human-written summary with the machine-generated summary.

5.3.2 Extrinsic Evaluation

In this section, we use the QA criteria as the questions in the question game. Every summary is manually checked to see if the questions are answered in the summary. These answers are then evaluated using precision and recall as the evaluation metrics.

- True Positive - The data was accurately extracted.
- False Negative - The data is present but not extracted.
- False Positive - The wrong data is extracted.
- True Negative - The data was not present and hence not extracted.

The following QA criteria were used:

- Q1. Extracting the aim/goals of the study.
- Q2. Extracting the limitations of the study.
- Q3. Extracting the future work.
- Q4. Extracting the evaluation study.

Confusion Matrices for SET 1

TP = 8	FP = 3
FN = 1	TN = 0

Table 5.11: Confusion matrix for evaluating first set with Q1.

TP = 4	FP = 4
FN = 1	TN = 3

Table 5.12: Confusion matrix for evaluating first set with Q2.

TP = 9	FP = 1
FN = 2	TN = 0

Table 5.13: Confusion matrix for evaluating first set with Q3.

TP = 5	FP = 3
FN = 4	TN = 0

Table 5.14: Confusion matrix for evaluating first set with Q4.

Justification of the Results for SET 1

The evaluation is carried out on 12 SLR studies from the first set of studies. Table 5.11 shows that the tool extracted Q1 (Aim of the study) from 8 studies (TP) and failed to extract it from 1 study (FN). The tool also extracted the wrong information for Q1 from 3 studies (FP). Table 5.12 shows that the tool extracted Q2 (Limitations of the study) from 4 studies (TP) and failed to extract it from one study. The tool also extracted the wrong information for Q2 from 4 studies (FP). Table 5.13 shows that the tool extracted Q3 (Future work of the study) from 9 studies (TP) and failed to extract it for 2 other studies (FN). The tool also extracted the wrong information for Q3 from 1 study (FP). Table 5.14 shows that the tool successfully extracted Q4 (Evaluation study) from 5 studies (TP) and extracted the wrong data from 3 studies (FP).

FNs occurred since one of the PDF file was in a non-searchable format. In some other studies the tool failed to extract the data when they were present under unknown sections (FN). Similarly, some sentences were extracted from the study when the algorithm found the specific keywords but the keywords actually belonged to a different context (FP).

Results of Extrinsic Evaluation for SET 1

QA criteria	Precision	Recall
Q1	0.80	0.88
Q2	0.50	0.80
Q3	0.90	0.82
Q4	0.63	0.55

Table 5.15: Precision and recall - SET 1.

Table 5.15 shows the precision and recall values for the stated QA for the first set of the studies. It was calculated using Equation 5.1, Equation 5.2, and the above confusion matrices. It can be said that SET-1 has an average precision of 0.71 and an average recall of 0.76. High precision in Q1 and Q3 relates to a low rate of wrongly extracted sentences (FP). Whereas, high recall in Q1, Q2, and Q3 relates to a low rate of falsely extracted null values (FN). High scores for both in Q1, Q3 show that the summarizer is returning accurate results with a majority of positive results. Similarly, lower precision value in Q2 relates to a higher rate of wrongly extracted sentences (FP) and lower recall in Q4 relates to a higher rate of falsely extracted null values (FN).

Confusion Matrices for SET 2

TP = 10	FP = 2
FN = 0	TN = 0

Table 5.16: Confusion matrix for evaluating second set with Q1.

TP = 6	FP = 5
FN = 1	TN = 0

Table 5.17: Confusion matrix for evaluating second set with Q2.

TP = 6	FP = 3
FN = 3	TN = 0

Table 5.18: Confusion matrix for evaluating second set with Q3.

TP = 5	FP = 6
FN = 1	TN = 0

Table 5.19: Confusion matrix for evaluating second set with Q4.

Justification of the Results for SET 2

The evaluation is carried out on 12 SLR studies from the second set of studies. Table 5.16 shows that the tool extracted Q1 (Aim of the study) from 10 studies (TP) and extracted the wrong information for Q1 from 2 studies (FP). Table 5.17 shows that the tool extracted Q2 (Limitations of the study) from 6 studies (TP). It also failed to extract the limitations from 1 study (FN). The tool also extracted the wrong information for Q2 from 2 studies (FP). Table 5.18 shows that the tool extracted Q3 (Future work of the study) from 6 studies (TP). It failed to extract the future work from 3 studies (FN). It extracted the wrong information for Q3 from 3 studies (FP). Table 5.19 shows that the tool successfully extracted Q4 (Evaluation study) from 5 studies (TP) and extracted the wrong data from 6 studies (FP). It failed to extract the data for Q4 from 1 study by providing null results (FN).

FPs occurred when the tool extracted sentences that had the specified keywords but they actually belonged to a different context. Similarly, FNs occurred when the information was present in the study with different keywords that were not known to the tool. Hence, the tool failed to extract these results.

Results of Extrinsic Evaluation for SET 2

QA criteria	Precision	Recall
Q1	0.83	1.00
Q2	0.54	0.86
Q3	0.66	0.66
Q4	0.45	0.83

Table 5.20: Precision and recall - SET 2.

Table 5.20 shows the precision and recall values for the stated QA for the second set of the studies. It was calculated using Equation 5.1, Equation 5.2, and the above confusion matrices. It can be observed that SET-2 has an average precision of 0.62 and an average recall of 0.84. High precision in Q1 relates to a low rate of wrongly extracted sentences (FP), and high recall in Q1, Q2 and Q4 relates to a low rate of falsely extracted null values (FN). High scores for both in Q1 show that the summarizer is returning accurate results with a majority of positive results. Similarly, lower precision value in Q4 relates to a higher rate of wrongly extracted sentences (FP).

Advantages:

- The summarization process helps the readers in getting a gist of the long documents.
- It helps us in answering the QA questions.

Disadvantages:

- Since the QA criteria are generic, it may exclude some features that are specific to the study.
- The algorithm might extract the wrong data because the context of the text is not considered during the keyword based extraction.

5.4 Threats to Validity

In this section, we discuss the limitations of the proposed methodology. During the extraction of meta-data, it was observed that there are few files that do not have any meta-data associated with them. During the creation of these files, if the authors could not added the correct meta-data, this approach fails to get the necessary output.

Similarly, during the extraction of specific sections of the paper, we realized that various papers have different formats. For example, we came across papers that used roman numbers for numbering the sections instead of numbers and hence, we changed the regex to include the same. The structure of the PDF documents vary immensely and hence makes it difficult to define a certain set of regex for extraction. We have also come across spelling mistakes and different naming conventions while extracting the specific sections. Such unexpected formats could not be handled by the tool and hence, this method might fail to extract exact results if the study is not well formatted.

During the summarization process, it was found that different algorithms work well with different studies. Therefore, we have mentioned three different algorithms which summarize the best. Additionally, in the keyword based summarization, there are some limitations with the choice of the QA criteria. Certain aspects might not be covered since the QA criteria that are stated are more generic. Hence, some topics specific to the study could be omitted if the extractive summarization did not include them in the results. The tool might also extract the wrong data because our tool does not consider the context of the keywords in the study during the keyword based extraction.

5.5 Summary

In this chapter, we performed the evaluation of our approach using various criteria. We started by stating the procedure to evaluate the tool. We analyzed the results by using the evaluation methods to draw meaningful conclusions. We also stated the threats to validity and hence concluded the chapter. During the evaluation, we discussed the difficulties faced during the extraction of meta-data, extraction of specific sections as well as the summarization process. The advantages and shortcomings of the different methods were also mentioned. The extraction of meta-data provided us with results above 63%. The result also showed 100% accuracy in extracting meta-data of one of the papers. The extraction of specific sections provided us with the highest precision of 1.00 and the lowest precision of 0.83. It has also shown the highest recall of 0.80 and the lowest recall of 0.65. They depict how well the tool has performed in extracting the data. The process of summarization has also been evaluated using extrinsic and intrinsic methods with two different data-sets. The intrinsic evaluation provided us with ROUGE scores all above 63%. The extrinsic evaluation provided us with precision above 0.50 (except for Q4) and recall above 0.66 (except for Q4). We have also come across precision as high as 0.90 and recall as high as 1.0. We have seen that different algorithms work well with different data-sets. For example, the Luhn summarizer worked well with SET 1 but during the evaluation of SET 2, TextRank showed better results. The results of the evaluation

depict that the tool can be used as a prototype to automate the data extraction and reporting of the SLR.

6. Conclusion

A. Kitchenham [2007] mentions that a research is valid when it is performed thoroughly and completely in a fair manner. An "SLR synthesizes existing work in a manner that is fair and seen to be fair" - A. Kitchenham [2007]. SLR methodology protects the research against different kinds of bias and helps in finding real effects by combing the data from all the studies.

A. Kitchenham [2007] states that one of the most common reason to undertake an SLR is to summarize the existing evidence available in the particular area of research. The researchers who perform the SLR has to differentiate between the information which supports their study and the information which does not support their study. In this thesis, we began by analyzing the existing approaches to extract and summarize the data. Based on the findings, we conclude that there is some research made in this regard, specially on the reporting phase but it lacks the functionality of automatic multi-document summarization of the results. Therefore we proposed an approach by defining the RQs that focus on efficiently summarizing the findings.

Our approach aims at reducing the time and effort taken by the researchers in extracting and summarizing the findings of their research. The method we proposed is based on text mining techniques, such as, NLP, keyword extraction and sentence extraction. Our approach focuses on data summarization of multiple documents as well as help in meta-data extraction for better filtering and extraction of specific sections of the study to provide the users with additional information regarding the study. Summarization is implemented as an extractive summary which includes extraction of certain user specified information by using keyword based summarization to answer the QA criteria. The sentences were scored based on different criteria and the sentences with the highest similarity were chosen to compose the summary.

To evaluate the tasks, we used precision and recall to check the completeness in extracting the user defined sections. Similarly in evaluating the summary, intrinsic and extrinsic methods were used. During the intrinsic evaluation, two well written SLR studies were taken into consideration. Their primary were applied to the tool as inputs to perform summarization. The summary provided by the tool was compared

to the results of the original SLR study. The comparison was done using ROUGE scores. Similarly, the extrinsic evaluation was carried out by using the question-answer game which uses the QA criteria as the questions to check if the tool answered all those questions.

Findings of the Study:

- During the SLR we found out that there is not enough research on automating the data extraction and summarization phases of the SLR.
- Due to the increase in the number of studies published in the field of software engineering in the past years, there is an increasing need to automate the data extraction and summarization phase of the SLR.
- We found out that the various aspects of the study, such as, the meta-data, specific sections, the summary of the study can be extracted using regex and different text mining techniques. Our tool successfully extracted these aspects from the studies and also show satisfactory results during evaluation.
- The evaluation was carried out by using evaluation measures, such as, precision, recall, and ROUGE scores.
- Hence, we can reduce the time and effort taken by the researchers by using our tool that semi-automates the process of data extraction and summarization.

However, to improve the validation of the tool, we recommend some further improvements in the next section. We conclude this thesis work by stating the shortcomings of our approach as well as stating a few methodologies that could be implemented in the future to overcome the shortcomings of this approach.

7. Future Work

In this section, we suggest few steps that can be taken to improve our tool. During the evaluation, we came across several aspects that can be improved in the future. The most important improvement needed is to increase the accuracy of the results.

Having empty meta-data in the papers have reduced the accuracy of extraction. We suggest using methods that use regex to extract the meta-data from the contents of the studies if the meta-data is not available. They make use of complex regex to improve the accuracy and might work as a more effective process.

The extraction of specific sections of the studies can also be improved by considering the different formats of the papers. Hence, we suggest to incorporate a method that distinguishes between the different study formats and use extraction methods that are specific to each type of study. We believe that this will help us in achieving better precision during extraction. The tool can also be extended to find the other sections of the paper, such as, methods and results.

We also suggest improving the summarization process by various methods. The keyword based summarization can be improved by adding more QA criteria which are more specific to the study. We can also improve the summarization process by using abstractive summarization methods as an alternative to the existing extractive summarization method. The tool can be extended to include these features to get a better summary.

A. Appendix

A.1 Search Results of the SLR

Title	Year
Text Mining to Understand the Influence of Social Media Applications on Smartphone Supply Chain	2018
Towards Accurate Detection of Offensive Language in Online Communication in Arabic	2018
Automatic Construction of E-Government Services Ontology from Arabic Webpages	2018
Performance evaluation of density-based clustering methods	2009
A Rich Arabic WordNet Resource for Al-Hadith Al-Shareef	2017
Vision for SLR tooling infrastructure: Prioritizing value-added requirements	2017
Using Ensemble StackingC Method and Base Classifiers to Ameliorate Prediction Accuracy of Pedagogical Data	2018
Discovering implicit intention-level knowledge from natural-language texts	2009
From Business Intelligence to semantic data stream management	2016
Improving Performance of Text Summarization	2015
Feature extraction approaches from natural language requirements for reuse in software product lines: A systematic literature review	2015
GraphSum: Discovering correlations among multiple terms for graph-based summarization	2013
Data mining and integration for predicting significant meteorological phenomena	2010
Hardcore Gamer Profiling: Results from an unsupervised learning approach to playing behavior on the Steam platform	2018
Detecting discussion communities on vaccination in twitter	2017
ATSSI: Abstractive Text Summarization Using Sentiment Infusion	2016
A systematic mapping study on text analysis techniques in software architecture	2018
Noun retrieval effect on text summarization and delivery of personalized news articles to the users desktop	2010
Ranking Sentences for Keyphrase Extraction: A Relational Data Mining Approach	2014
Temporal Data Mining and Visualization for Treatment Outcome Prediction in HIV Patients	2012
SCIFNET: Stance community identification of topic persons using friendship network analysis	2016
Topic knowledge map and knowledge structure constructions with genetic algorithm, information retrieval, and multi-dimension scaling method	2014
An Enhanced Fuzzy Clustering and Expectation Maximization Framework based Matching Semantically Similar Sentences	2015
Automating the Extraction of Static Content and Dynamic Behaviour from e-Commerce Websites	2017
Topic identification based on document coherence and spectral analysis	2011
Graph-based Arabic NLP Techniques: A Survey	2018
Usability evaluation methods for the web: A systematic mapping study	2011
Web data extraction, applications and techniques: A survey	2014
Investigating the relationship between price, rating, and popularity in the Blackberry World App Store	2017
Data stream mining for predicting software build outcomes using source code metrics	2014
Performance Analysis of Graph based Keyphrase Extraction metrics for uncertain User-generated data	2018
Challenges and Techniques for Testing of Big Data	2016
Testing embedded software: A survey of the literature	2018
A systematic literature review: Opinion mining studies from mobile app store user reviews	2017
Big Data and forensics: An innovative approach for a predictable jurisprudence	2018
Automated discovery of multi-faceted ontologies for accurate query answering and future semantic reasoning	2013
A comparison of automated training-by-example selection algorithms for Evidence Based Software Engineering	2018

Approximation of COSMIC functional size to support early effort estimation in Agile	2013
A Histogram Method for Summarizing Multi-dimensional Probabilistic Data	2013
A systematic literature review of software requirements reuse approaches	2018
Adaptive affinity propagation method based on improved cuckoo search	2016
Warning system for online market research-Identifying critical situations in online opinion formation	2011
An improved methodology on information distillation by mining program source code	2007
Aspect based Summarization of Context Dependent Opinion Words	2014
Identifying the Effective Parameters for Vertical Handover in Cellular Networks Using Data Mining Techniques	2016
Towards Extended Data Mining: An Examination of Technical Aspects	2018
Information Inference in Scholarly Communication Infrastructures: The OpenAIREplus Project Experience	2014
A Systematic Mapping Study driven by the margin of error	2018
ClowdFlows: Online workflows for distributed big data mining	2017
Greedy Algorithms for Granular Computing Problems in Spatial Granulation Technique	2017
A survey of the applications of text mining in financial domain	2016
Optimistic Multi-granulation Rough Set Based Classification for Medical Diagnosis	2015
Summarizing User Opinions: A Method for Labeled-data Scarce Product Domains	2015
Business Intelligence Model to Analyze Social Media Information	2018
Learning to Predict the Need of Summarization on News Articles	2013
A Binary-based MapReduce Analysis for Cloud Logs	2016
A multi-disciplinary review of knowledge acquisition methods: From human to autonomous eliciting agents	2016
Static analysis of android apps: A systematic literature review	2017
Data analytics of urban fabric metrics for smart cities	2018
A Method of Extracting The Semi-structured Data Implication Rules	2018
SwiftRank: An Unsupervised Statistical Approach of Keyword and Salient Sentence Extraction for Individual Documents	2017
Application of clustering methods for detecting critical acute coronary syndrome patients	2018
A systematic literature review on methods that handle multiple quality attributes in architecture-based self-adaptive systems	2017
Knowledge Based Summarization and Document Generation using Bayesian Network	2016
Pattern-based Mining in Electronic Health Records for Complex Clinical Process Analysis	2017
A Study on Ontology Based Abstractive Summarization	2016
Automated browsing in AJAX websites	2011
Ant colony heuristic for user-contributed comments summarization	2017
Mining the Czech Insolvency Proceedings Data	2014
Long range dependence in texts: A method for quantifying coherence of text	2017
A grid-based approach for enterprise-scale data mining	2007
Finding association rules in semantic web data	2012
Machine learning based heterogeneous web advertisements detection using a diverse feature set	2018
Social context summarization using user-generated content and third-party sources	2018
SyMSS: A syntax-based measure for short-text semantic similarity	2011
Prediction of Online Lectures Popularity: A Text Mining Approach	2016
Software requirements selection and prioritization using SBSE approaches: A systematic review and mapping of the literature	2015
Multi-document summarization using closed patterns	2016
A Flexible Keyphrase Extraction Technique for Academic Literature	2018
Topic Detection Approaches in Identifying Topics and Events from Arabic Corpora	2018
Dependable large scale behavioral patterns mining from sensor data using Hadoop platform	2017
A survey on opinion mining and sentiment analysis: Tasks, approaches and applications	2015
Extractive multi-document text summarization using a multi-objective artificial bee colony optimization approach	2018
Social networking data analysis tools & challenges	2018
Performance Evaluation of Distributed Association Rule Mining Algorithms	2016
Data mining agent conversations: A qualitative approach to multiagent systems analysis	2013
Extracting reusable design decisions for UML-based domain-specific languages: A multi-method study	2016
Grid-enabling data mining applications with DataMiningGrid: An architectural perspective	2008
A discretization algorithm based on Class-Attribute Contingency Coefficient	2008
A data mining approach to knowledge discovery from multidimensional cube structures	2013
Requirements monitoring frameworks: A systematic review	2016
An automated Psychometric Analyzer based on Sentiment Analysis and Emotion Recognition for healthcare	2018
Requirements traceability technologies and technology transfer decision support: A systematic review	2018
A short text modeling method combining semantic and statistical information	2010
Traffic big data prediction and visualization using Fast Incremental Model Trees-Drift Detection (FIMT-DD)	2016
Integrating statistical and lexical information for recognizing textual entailments in text	2013
Summarizing data using a similarity based mountain method	2008
A framework for automated construction of resource space based on background knowledge	2014
A noun-based approach to feature location using time-aware term-weighting	2014
Re-discover Values of Data Using Data Jackets by Combining Cluster with Text Analysis	2017
Optimization for Automatic Personality Recognition on Twitter in Bahasa Indonesia	2018
Effectiveness of template detection on noise reduction and websites summarization	2013
A two phased service oriented Broker for replica selection in data grids	2013
A new hybrid semi-supervised algorithm for text classification with class-based semantics	2016
Extracting lists of data records from semi-structured web pages	2008

Semi-supervised Aspect Based Sentiment Analysis for Movies Using Review Filtering	2016
Development of a human error taxonomy for software requirements: A systematic literature review	2018
Big Data Analytics for Behavior Monitoring of Students	2016
New research directions for data and knowledge engineering: A philosophy of language approach	2008
A Service-oriented Framework for Integration of Domain-specific Data Models in Scientific Workflows	2013
Extending the SOA paradigm to e-Science environments	2011
Enhancing diversity and coverage of document summaries through subspace clustering and clustering-based optimization	2014
Multimodal latent topic analysis for image collection summarization	2016
A periodicity-based parallel time series prediction algorithm in cloud computing environments	2018
A multiview approach for intelligent data analysis based on data operators	2008
Generating automatic linguistic descriptions with big data	2017
Advanced knowledge-based systems	2010
Ensemble Classifier for Mining Data Streams	2014
Identifying streaming frequent items in ad hoc time windows	2013
Prognosis of Dementia Employing Machine Learning and Microsimulation Techniques: A Systematic Literature Review	2016
A Framework to Formulate Customer Taste from Unstructured Review Data	2016
Linguistic Resumes in Software Engineering: The Case of Trend Summarization in Mobile Crash Reporting Systems	2016
COWB: A cloud-based framework supporting collaborative knowledge management within biomedical communities	2016
Social information discovery enhanced by sentiment analysis techniques	2018
Software reliability modeling based on ISO/IEC SQuaRE	2016
Potential and limitations of the ISBSG dataset in enhancing software engineering research: A mapping review	2014
A tool for design pattern detection and software architecture reconstruction	2011
Open source software ecosystems: A Systematic mapping	2017
DSS from an RE Perspective: A systematic mapping	2016
Common motifs in scientific workflows: An empirical analysis	2014
Highly-cited papers in software engineering: The top-100	2016
Big Data for Internet of Things: A Survey	2018
Modeling and Management of Big Data: Challenges and opportunities	2016
A Data Cube Model for Analysis of High Volumes of Ambient Data	2012
Automatic text categorization based on content analysis with cognitive situation models	2010
Identification of SLR tool needs – results of a community workshop	2016
Applying Deep Learning for Arabic Keyphrase Extraction	2018
Evaluation of E-Commerce Product Reviews Based on Structural, Metadata, and Readability Characteristics	2017
Information extraction for search engines using fast heuristic techniques	2010
A local variance-controlled reversible data hiding method using prediction and histogram-shifting	2010
Systematic literature review of ensemble effort estimation	2016
DAWQAS: A Dataset for Arabic Why Question Answering System	2018
Knowledge Acquisition for Electronic Health Records on cloud	2017
Chunked N-Grams for Sentence Validation	2015
Pattern graph tracking-based stock price prediction using big data	2018
A Systematic Literature Review Comparing Primary and Community Health Care Indicators and Measurement Frameworks	2017
Multi-modal sliding window-based support vector regression for predicting plant water stress	2017
A systematic review of systematic review process research in software engineering	2013
Multiple criteria mathematical programming for multi-class classification and application in network intrusion detection	2009
Complex Data-driven Predictive Modeling in Personalized Clinical Decision Support for Acute Coronary Syndrome Episodes	2016
A systematic review on security in Process-Aware Information Systems – Constitution, challenges, and future directions	2014
Communication and personality profiles of global software developers	2015
Business Intelligence and Analytics in Small and Medium-sized Enterprises: A Systematic Literature Review	2017
Reproducibility and replicability of software defect prediction studies	2018
An overview of the Applications of Natural Language to Information Systems	2013
On the value of a prioritization scheme for resolving Self-admitted technical debt	2018
A systematic literature review of software visualization evaluation	2018
Identification of Pathophysiological Subclinical Variances During Complex Treatment Process of Cardiovascular Patients	2018
LoCo CoCo: Automatically constructing coordination and communication networks from model-based systems engineering data	2017
Image steganography using uncorrelated color space and its application for security of visual contents in online social networks	2018
SparseHC: A Memory-efficient Online Hierarchical Clustering Algorithm	2014
Search-based software library recommendation using multi-objective optimization	2017
Early software defect prediction: A systematic map and review	2018
Automatically maintaining navigation sequences for querying semi-structured web sources	2007
A Study of Process Mining-based Business Process Innovation	2016
An Improved SRL Based Plagiarism Detection Technique Using Sentence Ranking	2015

Social media metrics and sentiment analysis to evaluate the effectiveness of social media posts	2018
A recommender system of reviewers and experts in reviewing problems	2016
Opinion Ensembling for Improving Economic Growth through Tourism	2017
Automatic Chinese Multiple-Choice Question Generation for Human Resource Performance Appraisal	2018
Document Clustering Using Hybrid XOR Similarity Function for Efficient Software Component Reuse	2013
Automatically maintaining wrappers for semi-structured web sources	2007
Performance Comparison and Optimization of Text Document Classification using k-NN and Naïve Bayes Classification Techniques	2017
Past and future of software architectures for context-aware systems: A systematic mapping study	2018
Automatic validation of requirements to support multidimensional design	2010
On Continent and Script-Wise Divisions-Based Statistical Measures for Stop-words Lists of International Languages	2016
An Overview of Software Functionality Service: A Systematic Literature Review	2017
Outcomes from Indexing Initiatives of Medical Imaging DICOM Metadata Repositories. A Secondary Analysis	2018
Why good data analysts need to be critical synthesists. Determining the role of semantics in data analysis	2017
Synchronization-based clustering on evolving data stream	2018
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Domain Transfer Learning for MCI Conversion Prediction	2015
Decay Rate Estimators and Their Performance for Blind Reverberation Time Estimation	2014
A review of applications of search based software engineering techniques in last decade	2016
A Study of Computing Undergraduates Undertaking a Systematic Literature Review	2011
Data Mining Techniques in Intrusion Detection Systems: A Systematic Literature Review	2018
Spoken Language Recognition With Prosodic Features	2013
A Low-Cost Real-Time Research Platform for EMG Pattern Recognition-Based Prosthetic Hand	2015
A Sign-Component-Based Framework for Chinese Sign Language Recognition Using Accelerometer and sEMG Data	2012
A Novel Chinese Sign Language Recognition Method Based on Keyframe-Centered Clips	2018
Software project management approaches for global software development: a systematic mapping study	2018
SLR: Semi-Coupled Locality Constrained Representation for Very Low Resolution Face Recognition and Super Resolution	2018
An empirical investigation of the software integration success factors in GSD environment	2017
Systematic Mapping of Process Mining Studies in Healthcare	2018
Success Factors for Software Outsourcing Partnership Management: An Exploratory Study Using Systematic Literature Review	2017
Iterated Posterior Linearization Smoother	2017
Study of Senone-Based Deep Neural Network Approaches for Spoken Language Recognition	2016
Decision Support System for Risk Assessment and Management Strategies in Distributed Software Development	2017
Quantitative Determination of Cyfluthrin in N-Hexane by Terahertz Time-Domain Spectroscopy With Chemometrics Methods	2010
Posterior Linearization Filter: Principles and Implementation Using Sigma Points	2015
Antenna Placement Optimization for Distributed Antenna Systems	2012
Optimizing the Performance of Spoken Language Recognition With Discriminative Training	2008
High accuracy gene signature for chemosensitivity prediction in breast cancer	2015
Review of Statistical and Analytical Degradation Models for Photovoltaic Modules and Systems as Well as Related Improvements	2018
Euler Elastica Regularized Logistic Regression for Whole-Brain Decoding of fMRI Data	2018
Cooperative Localization Using Posterior Linearization Belief Propagation	2018
Grid integration of wind generation considering remote wind farms: hybrid markovian and interval unit commitment	2017
Genetic Improvement of Software: A Comprehensive Survey	2018
A Survey of App Store Analysis for Software Engineering	2017
Frequency-Hopping Signal Parameters Estimation Based on Orthogonal Matching Pursuit and Sparse Linear Regression	2018
Dynamic MR Image Reconstruction Separation From Undersampled	2014
A Brain-Computer Interface Based on a Few-Channel EEG-fNIRS Bimodal System	2017
A Deep Cascade of Convolutional Neural Networks for Dynamic MR Image Reconstruction	2018
A fast image matching technique for the panoramic-based localization	2016
A Size Estimation Model for Board-Based Desktop Games	2017
Semi-supervised Domain Adaptation on Manifolds	2014
On the Correlation of Sensor Location and Human Activity Recognition in Body Area Networks (BANs)	2018
Optimal Transport for Domain Adaptation	2017
Sticky Projections-A Model-Based Approach to Interactive Shader Lamps Tracking	2016
Regression Methods for Virtual Metrology of Layer Thickness in Chemical Vapor Deposition	2014
A Wearable System for Recognizing American Sign Language in Real-Time Using IMU and Surface EMG Sensors	2016
Predicting Vertical Acceleration of Railway Wagons Using Regression Algorithms	2010
Exact Feature Extraction Using Finite Rate of Innovation Principles With an Application to Image Super-Resolution	2009
Automatic Prediction of Children's Reading Ability for High-Level Literacy Assessment	2011
Airborne Vehicle Detection in Dense Urban Areas Using HoG Features and Disparity Maps	2013
Texture Classification and Visualization of Time Series of Gait Dynamics in Patients With Neuro-Degenerative Diseases	2018
Regenerator site selection for mixed line rate optical networks	2014
Fast Bayesian JPEG Decompression and Denoising With Tight Frame Priors	2017
Bridging the Gap: From Research to Practical Advice	2018
On the Privacy Risks of Virtual Keyboards: Automatic Reconstruction of Typed Input from Compromising Reflections	2013
Cross-Domain Recognition by Identifying Joint Subspaces of Source Domain and Target Domain	2017
Discriminative Structured Feature Engineering for Macroscale Brain Connectomes	2015
Robust LSTM-Autoencoders for Face De-Occlusion in the Wild	2018

Domain Invariant Transfer Kernel Learning	2015
Weakly Supervised Photo Cropping	2014
Spatial Logistic Regression for Support-Vector Classification of Hyperspectral Imagery	2017
Scatter Component Analysis: A Unified Framework for Domain Adaptation and Domain Generalization	2017
A Systematic Literature Review on Fault Prediction Performance in Software Engineering	2012
Motionlets Matching With Adaptive Kernels for 3-D Indian Sign Language Recognition	2018
On Dynamic Effects Influencing IGBT Losses in Soft-Switching Converters	2011
Image reconstruction from highly undersampled space data with joint partial separability and sparsity constraints	2012
Constrained Manifold Learning for Hyperspectral Imagery Visualization	2018
Linear Disentangled Representation Learning for Facial Actions	2018
Dictionary Learning-Based Feature-Level Domain Adaptation for Cross-Scene Hyperspectral Image Classification	2017
Classifying Discriminative Features for Blur Detection	2016
Magnetic Resonance RF Pulse Design by Optimal Control With Physical Constraints	2018
An Exemplar-Based Multi-View Domain Generalization Framework for Visual Recognition	2018
Empirical Evaluation of the Impact of Object-Oriented Code Refactoring on Quality Attributes: A Systematic Literature Review	2018
Brain-Wide Genome-Wide Association Study for Alzheimer's Disease via Joint Projection Learning and Sparse Regression Model	2019
Optimized relay placement to federate segments in wireless sensor networks	2010
Deep Learning of Transferable Representation for Scalable Domain Adaptation	2016
A Classification and Comparison Framework for Cloud Service Brokerage Architectures	2018
OInduced: An Efficient Algorithm for Mining Induced Patterns From Rooted Ordered Trees	2011
Integrated Low-Rank-Based Discriminative Feature Learning for Recognition	2016
Robust Single-Shot Fringe Projection Profilometry Based on Morphological Component Analysis	2018
Probabilistic Real-Time Thermal Rating Forecasting for Overhead Lines by Conditionally Heteroscedastic Auto-Regressive Models	2017
Stacked Sparse Autoencoder Modeling Using the Synergy of Airborne LiDAR and Satellite Optical and SAR Data to Map Forest Above-Ground Biomass	2017
Discriminant Correlation Analysis: Real-Time Feature Level Fusion for Multimodal Biometric Recognition	2016
Robust Visual Knowledge Transfer via Extreme Learning Machine-Based Domain Adaptation	2016
Multilevel and Session Variability Compensated Language Recognition: ATVS-UAM Systems at NIST LRE 2009	2010
Generating Query Facets Using Knowledge Bases	2017
Clustering-Based Ensembles as an Alternative to Stacking	2014
Structured Domain Adaptation	2017
Gait Rhythm Fluctuation Analysis for Neurodegenerative Diseases by Empirical Mode Decomposition	2017
Dynamic Programming for Instance Annotation in Multi-Instance Multi-Label Learning	2017
An efficient error concealment algorithm for H.264/AVC using regression modeling-based prediction	2010
Improved Modeling of Cross-Decoder Phone Co-Occurrences in SVM-Based Phonotactic Language Recognition	2011
Deep Domain Generalization With Structured Low-Rank Constraint	2018
A Dynamic Discretization Approach for Constructing Decision Trees with a Continuous Label	2009
Learning the LMP-Load Coupling From Data: A Support Vector Machine Based Approach	2017
Domain Generalization and Adaptation Using Low Rank Exemplar SVMs	2018
No-Reference Quality Assessment of Tone-Mapped HDR Pictures	2017
A Knowledge-Based Approach to Arterial Stiffness Estimation Using the Digital Volume Pulse	2012
Blind Domain Adaptation With Augmented Extreme Learning Machine Features	2017
Hybrid CS-DMRI: Periodic Time-Variant Subsampling and Omnidirectional Total Variation Based Reconstruction	2017
Multi-Modal Sensing Techniques for Interfacing Hand Prostheses: A Review	2015
Damped Posterior Linearization Filter	2018
Dual Low-Rank Pursuit: Learning Salient Features for Saliency Detection	2016
EQAR: Effective QoS-Aware Relay Node Placement Algorithm for Connecting Disjoint Wireless Sensor Subnetworks	2011
Machine Learning Methods for Attack Detection in the Smart Grid	2016
Transmission Contingency-Constrained Unit Commitment With High Penetration of Renewables via Interval Optimization	2017
Impact From Dynamic Line Rating on Wind Power Integration	2015
Local Minimax Learning of Functions With Best Finite Sample Estimation Error Bounds: Applications to Ridge and Lasso Regression, Boosting, Tree Learning, Kernel Machines, and Inverse Problems	2009
Attributed Social Network Embedding	2018
Domain Invariant and Class Discriminative Feature Learning for Visual Domain Adaptation	2018
Resource Allocation in SWIPT Networks Under a Nonlinear Energy Harvesting Model: Power Efficiency, User Fairness, and Channel Nonreciprocity	2018
Sparse Spatio-Spectral LapSVM With Semisupervised Kernel Propagation for Hyperspectral Image Classification	2017
Face Spoof Detection With Image Distortion Analysis	2015
S3DRGF: Spatial 3-D Relational Geometric Features for 3-D Sign Language Representation and Recognition	2019
Score-Independent Audio Features for Description of Music Expression	2008
Training CNNs for 3-D Sign Language Recognition With Color Texture Coded Joint Angular Displacement Maps	2018

Convolutional Recurrent Neural Networks for Dynamic MR Image Reconstruction	2019
Robust Fringe Projection Profilometry via Sparse Representation	2016
Time-Aware Multivariate Nearest Neighbor Regression Methods for Traffic Flow Prediction	2015
A New Feature Selection Scheme Using a Data Distribution Factor for Unsupervised Nominal Data	2008
Domain-Specific Image Analysis for Cervical Neoplasia Detection Based on Conditional Random Fields	2011
Online Handwritten Shape Recognition Using Segmental Hidden Markov Models	2007
Upstream Ultrasonic Level Based Soft Sensing of Volumetric Flow of Non-Newtonian Fluids in Open Venturi Channels	2018
A Generative Data Augmentation Model for Enhancing Chinese Dialect Pronunciation Prediction	2012
Adaptive Greedy Dictionary Selection for Web Media Summarization	2017
HPCMP CREATE-AV Quality Assurance: Lessons Learned by Validating and Supporting Computation-Based Engineering Software	2016
Robust Frequency-Hopping Spectrum Estimation Based on Sparse Bayesian Method	2015
Push-Pull: Deterministic Search-Based DAG Scheduling for Heterogeneous Cluster Systems	2007
Applications of Deep Learning and Reinforcement Learning to Biological Data	2018
A Sparse Plus Low-Rank Exponential Language Model for Limited Resource Scenarios	2015
Joint Denoising/Compression of Image Contours via Shape Prior and Context Tree	2018
Learning With Augmented Features for Supervised and Semi-Supervised Heterogeneous Domain Adaptation	2014
Inter-Swarm Content Distribution Among Private BitTorrent Networks	2013
Incomplete Multisource Transfer Learning	2018
Multi-Camera Saliency	2015
Spectrally Constrained Unimodular Sequence Design Without Spectral Level Mask	2018
System Monitoring with Metric-Correlation Models	2011
Salient Object Detection via Structured Matrix Decomposition	2017
On the Projection of PLLRs for Unbounded Feature Distributions in Spoken Language Recognition	2014
Spatio-Temporal Feature-Extraction Techniques for Isolated Gesture Recognition in Arabic Sign Language	2007
Domain Transfer Learning for MCI Conversion Prediction	2015
Decay Rate Estimators and Their Performance for Blind Reverberation Time Estimation	2014
A review of applications of search based software engineering techniques in last decade	2016

A.2 Results of the Tool

A.2.1 Results of Meta-data Extraction

ID: 1

Title: Problem-Based Learning for Engineering Students: An Evidence-Based Comparative Study

Author: Cynthia Hsieh; Lorrie Knight

Creation Year: 2009

Creator: Elsevier

Keywords:

Producer: None

ID: 2

Title: None

Author: None

Creation Year: 2015

Creator: Adobe InDesign CS6 (Windows)

Keywords:

Producer: Adobe PDF Library 10.0.1

ID:3

Title: Applying Systematic Reviews to Diverse Study Types: An Experience Report

Author: Tore Dybå

Creation Year: 2007

Creator: PScript5.dll Version 5.2.2

Keywords:

Producer: Acrobat Distiller 8.1.0 (Windows)

ID: 4

Title: ESELAW-ISBN-978-9974-8379-3-5.pdf

Author: FamiliaDias

Creation Year: 2013

Creator: PDFCreator Version 1.4.1

Keywords:

Producer: GPL Ghostscript 9.05

ID: 5

Title: BNOSA: A Bayesian network and ontology based semantic annotation framework

Author: Quratulain Rajput

Creation Year: 2011

Creator: Elsevier

Keywords:

Producer: Acrobat Distiller 8.1.0 (Windows)

A.2.2 Extraction of Specific Sections

Specific paragraphs: Introduction

1: prepare students to understand the role of engineers and their activities in society. The library workshop introduces students to the library and its resources for research. Traditionally, a small group of librarians divide the instructional responsibilities over a series of comparable sessions. The students are given a library

assignment to be completed during the class.Over the last few years, the librarians have observed a decrease in student attention and less competence among students in the successful completion of their library assignments. The librarian decided to take a proactive approach to change the downward trend. They felt, based on their observations and review of the literature, a more active learning environment would enhance the students' library classroom experience. They proposed the use of a type of problem-based learning (PBL) in the classes. However,the engineering professors were concerned that a changed process might not help students reach their desired learning outcomes.Therefore, the librarians designed a study to compare the students' mastery of the learning outcomes using the lecture-based vs. the problem-based method. The goal was to develop empirical evidence to convince the engineering professors that the new approach would result in positive outcomes.LITERATURE REVIEW a review of the literature suggests that many librarians are aware of the potential positive outcomes of employing problem-basedJanuary 2008 25mailto:chsieh@pacific.edumailto:lknight@pacific.edulearning in bibliographic instruction. This active, participatory teaching style is consistent with the goals of information literacy in several ways. As an inquiry-based form of instruction, PBLclosely parallels the Association of College and ResearchLibraries Information Competency Standards1 for defining and purposefully resolving an information need. Similarly, both PBLand IL share an overarching goal of instilling skills and abilities for lifelong learning. In addition, the theoretical bases that underlie both IL and PBL recognize and address the influence of learning styles on student acquisition and retention of skills and knowledge.A number of studies in the literature of both librarianship and education describe the methods of problem-based learning.Students are given a realistic scenario without a single correct answer. They are guided through a process of analyzing the problem, researching their alternatives, and presenting a recommended solution. Advocates of PBL feel this provides real-world and real-time learning opportunities that replicate the type of problem solving students will use throughout their academic and professional lives.2 Although PBL is not firmly established in library instruction, there are several reports of successful endeavors. Snavely3 reviews several studies about the use ofPBL in library instruction and describes how the lessons learned can lead to ongoing improvement. PBL also fosters collaboration with subject faculty that makes library user education more integral to the course content and therefore more valued by students and professors.4 Pelikan5 notes that PBL is similar to a"reference interview with a twist" in that it allows librarians to partner with students in developing research strategies and selecting databases.There is increasing evidence that supports the belief that active, experiential educational experiences are more transferable than passive, lecture-based instruction.6 This is especially true for today's students, who prefer a self-directed, technological approach to information retrieval. Although faculty and students may believe that technological fluency is equivalent to information competency, librarians recognize the distinction and address it in user education.7 Problem-based learning offers librarians a chance to capitalize on students' pre-existing confidence in theInternet while overlaying it with skills in evaluation and critical thinking.8 Carder, Willingham, and Bibb9 use focused cases to encourage students to identify their own information scenarios and strategies. They conclude that this approach makes information literacy more relevant rather than

"just another hoop to jump." For the current generation of college students,learning is more valid when it builds upon an existing knowledge base and style.10 A literature review in engineering education also revealed an extensive interest in engineering students'learning styles and a general discontent with the conventional lecture-based instructional style."There is increasing evidence that supports the belief that active, experiential educational experiences are more transferable than passive,lecture-based instruction."In an attempt to assess engineering students' preferred learning styles, many studies focus on the role of personality

2: Pearson, 2012), 145–57.

3: The volume of research that needs to be considered by software engineering (SE) practitioners and researchers is constantly expanding. In many areas it has become almost impossible for the individual to read, critically evaluate, and synthesize the state of current knowledge, let alone keep updating this on a regular basis. As a result, reviews have become essential tools for anyone who wants to keep up with the new evidence that is accumulating in his or her field of interest. Reviews are also required to identify areas where the available evidence is insufficient and further studies are required. However, because of the often poor quality of traditional narrative reviews, there has recently been an increasing focus on formal methods of systematically reviewing studies, to produce explicitly formulated, reproducible, and up-to-date summaries of the effects of health care and social science interventions [5], [6], [9], [15], [24], [26]. The recent focus on evidence-based software engineering (EBSE) [8], [19] has resulted in an increased interest in systematic reviews (SRs) within the field of SE as a means of evaluating and interpreting the available research relevant to a particular research question, topic area, or phenomenon of interest [1], [18]. Recent examples of such reviews include [9], [12], [16], [28], EBSE aims to improve decision making related to software development and maintenance by integrating current best evidence from research with practical experience and human values [19]. This is an ambitious aim, particularly because the gap between research and practice can be wide. EBSE seeks to close this gap by encouraging a stronger emphasis on methodological rigor while focusing on relevance for practice. EBSE involves five steps to reach its aim [8]:

A.2.3 Results of Summarization

Results of Extractive Summarization:

Summarization

Summary : 1

1: The Selection Execution is the acquisition and analysis of primary studies and involves three tasks: (i) in the Initial Selection the studies are identified, collected and organized in a list; (ii) in the Studies Evaluation, studies are marked as included

or excluded in two steps, first by reading the title,abstract and conclusions, and then by reading the full text.

2: VTM is the integration of Text Mining, which is the process of extracting patterns and non-trivial knowledge from textual documents [38], and Information Visualization techniques,which enable a user to visually interact in the knowledge acquisition process [31].We believe that the use of VTM can assist the Selection Review of primary studies not only speeding up the SLR process, but also improving the reliability of the results.

3: Felizardo et al. [17] employed VTM to support categorization and classification of studies when carrying out systematic mapping studies; and Malheiros et al. [29] investigated the use of content-based VTM techniques to help with the selection of primary studies, using a feasibility study.

4: There is not any peculiarity of application of the proposed VTM approaches only to SE field.In order to create the content maps we used the Revis,1 which is a visualization and interaction tool that offers a framework of different projection techniques and methods to create data maps in general and document maps in particular based on the similarity between pairs of data points, supporting VTM exploration of document collections.

5: It takes Revis only a few seconds to create and present a map with a few hundred documents.The strategy suggested here to review the studies selection from that map can be summarized into two main steps: (1) first,a clustering algorithm is applied to the content map, creating groups of highly related (similar) documents using the k-means algorithm [28] (the number of clusters is automatically detected based on the number of documents); (2) then, the resulting clusters are analyzed in terms of included and excluded documents in order to find inconsistencies.

6: It can occur if authors write several different papers about the same study (e.g. a conference paper and a journal paper) and decide to include only the most recent ones.Based on this justification, we can assume that similar papers with divergent classifications should be reviewed only if we guarantee that in the content map there is only the most recent versions of papers about each study.

7: Exclusion history The first strategy to review the selection activity considers the creation of content maps containing the studies collected and analyzed in an SLR and highlighting them using different colors in order to differentiate in which of the first two steps of the Evaluation task a study was removed from the review.

8: (a) Each point represents a primary study and the color indicates if a study has been included (blue points) or excluded (red points).

9: The squares represent regions (clusters) where the content of the studies (i.e. title, abstracts and keywords) are similar; (b) the color indicates the history of the selection activity,red points are studies excluded in the first step (reading abstracts), green points are studies excluded in the second step (reading full text) and blue points are included studies.

10: The included study (blue point) is similar in content to other excluded studies and isolated in terms of references, indicating that its inclusion should be reviewed.

11: Case studies: investigating the use of VTM techniques to support the selection review activity.The examples used in Section 3 (i.e. SRLs 1–4) contain a rather small number of primary studies (dozens of articles), however, in real SRLs a large number of candidate studies are considered –hundreds and even thousands.

Results of Keyword based Summarization

Question Game Summary : 1

Question: 1

01: It takes Revis only a few seconds to create and present a map with a few hundred documents.The strategy suggested here to review the studies selection from that map can be summarized into two main steps: (1) first,a clustering algorithm is applied to the content map, creating groups of highly related (similar) documents using the k-means algorithm [28] (the number of clusters is automatically detected based on the number of documents); (2) then, the resulting clusters are analyzed in terms of included and excluded documents in order to find inconsistencies.

02: (a) Each point represents a primary study and the color indicates if a study has been included (blue points) or excluded (red points).

03: The squares represent regions (clusters) where the content of the studies (i.e. title, abstracts and keywords) are similar; (b) the color indicates the history of the selection activity,red points are studies excluded in the first step (reading abstracts), green points are studies excluded in the second step (reading full text) and blue points are included studies.

Question: 2

01: The purpose of EBSE is to inform researchers about empirical evidence that can be used to improve SE practice, however, Kitch-enham et al. [26] found out that relatively few SLRs provided ad-vice oriented to practitioners.The results of an independent assessment study conducted by da Silva et al. [9] showed that the main limitation constraining the use of SLRs in SE is that a large number of SLRs do not assess the quality of the underlying primary studies, confirming the pre-vious findings of Kitchenham et al.

02: This suggests that currently the attention given to research synthesis in SE is limited.K.R.

Question: 3

01: Our proposal focuses on extending that approach to supporting the review of the selection task

Question: 4

01: The Selection Execution is the acquisition and analysis of primary studies and involves three tasks: (i) in the Initial Selection the studies are identified, collected and organized in a list; (ii) in the Studies Evaluation, studies are marked as included

or excluded in two steps, first by reading the title, abstract and conclusions, and then by reading the full text.

02: incorporating two different VTM approaches to supporting the Selection Review task: (i) content map; and (ii) citation map visualizations.

03: Exclusion history: The first strategy to review the selection activity considers the creation of content maps containing the studies collected and analyzed in an SLR and highlighting them using different colors in order to differentiate in which of the first two steps of the Evaluation task a study was removed from the review.

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