# Evidence-Based Software Engineering: Systematic Literature Review Process based on Visual Text Mining

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CNPq

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2 SLR-VTM

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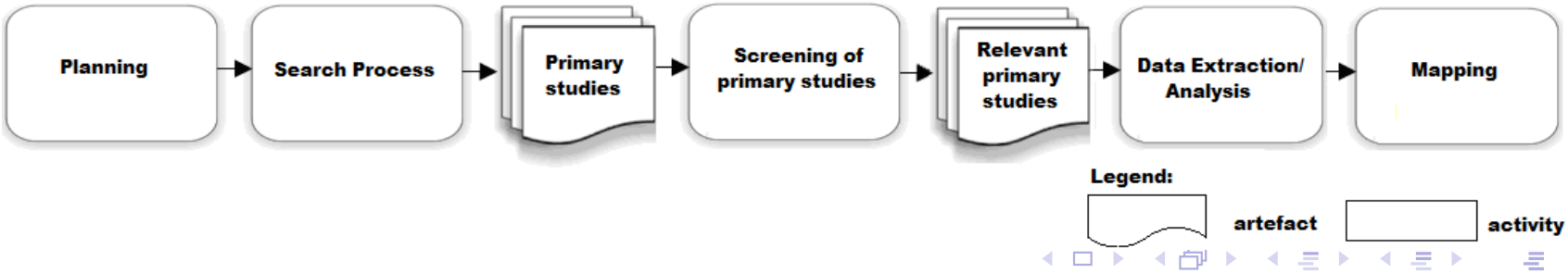
## Systematic Literature Review (SLR)

**SLR** is a structured, well-organized, and step-by-step comprehensive method of conducting a review of the body of literature relevant to a particular research question [Kitchenham and Charters, 2007].

## Systematic Mapping (SM)

**SM** is a more open form of **SLR**, providing an overview of a research area to assess the quantity of evidence existing on a topic of interest [Kitchenham and Charters, 2007].



## Problem Statement and Research Motivation

- Despite its relevance,the **SLR process** is difficult, time-consuming and manually conducted;
- The **selection of primary studies** involves a **large** number of primary studies to be read, analysed and summarized;
- Uncertainties about inclusion or exclusion should be investigated by **sensitivity analysis**, which implies an additional effort to **re-read** the studies;
- The representation of **results of SLRs** are generally based on complicated tables, wich are difficult for readers to understand;
- The definition of consistent **categories** and correct **classification** of the primary studies into these categories is a **non-trivial** task during the data extraction and analysis in SM process
[Afzal et al., 2008, Budgen et al., 2008].

## Visual Text Mining (VTM)

– **VTM** is an interdisciplinary field of research supported by the combination of:

1. visualization techniques;
2. human factors (e.g., interaction, cognition and perception) and;
3. data mining algorithms [Keim et al., 2006, Thomas and Cook, 2005].

– **Visualization** enables users to **"see"** and navigate through the data in multiple ways, with their optical abilities enhancing the knowledge acquisition process [de Oliveira and Levkowitz, 2003].
– VTM can help to deal with the vast volumes of data [Keim, 2002].

Humans present strong visual processing abilities; therefore visual-based techniques make use of these abilities, by using the human system to support knowledge discovery [Keim, 2002], i.e., in the SLR and SM context, to discover the relevant primary studies.

## Objectives

- We propose the use of **VTM** to support different phases and activities of the **SLR** and **SM** processes:
  1. Use of VTM to support the primary studies selection;
  2. Use of VTM to review the primary studies selection;
  3. Analysis of the use of graphs to represent the results of SLR;
  4. Use of VTM to support categorization and classification in SM.

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– Our SM revealed that in the SE domain only one study [Malheiros et al., 2007] supporting the **selection of primary studies** activity was found. This finding suggests that the remaining phases and activities of the SLR process in SE are generally conducted **manually**.

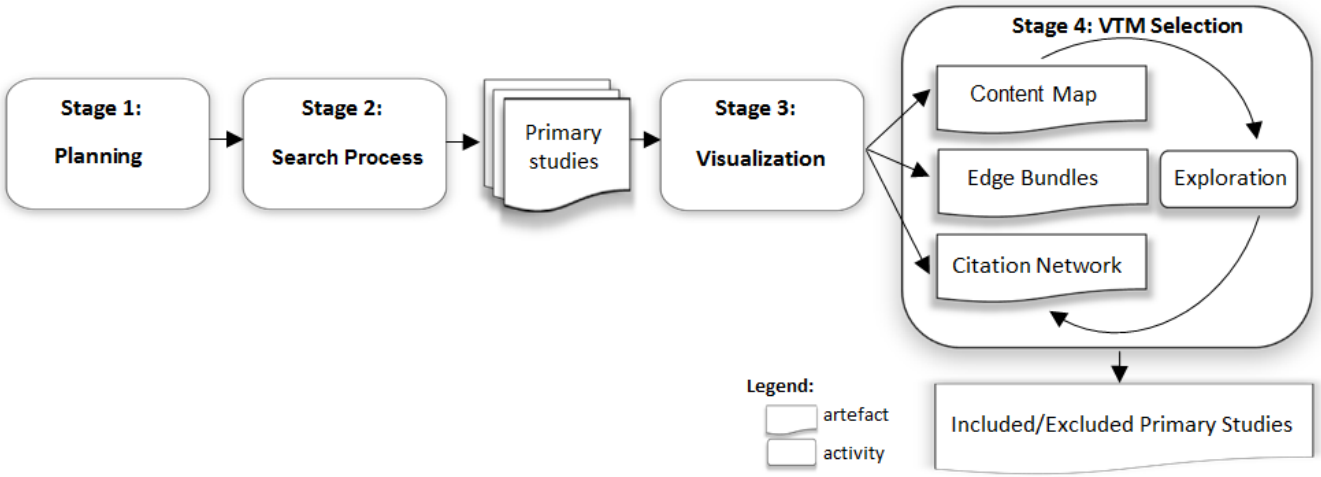
## SLR and VTM – Malheiros et al. (2007) [Malheiros et al., 2007]

- They compared the **performance** of reviewers in selecting primary studies using two different methods:
  1. reading abstracts; and
  2. using a VTM approach.
- Their results were **promising**, showing that the use of VTM can both **reduce** the **time** required and **improve** the **effectiveness** of the selection of primary studies.

## SLR-VTM

An approach based on **VTM**, SLR-VTM – Systematic Literature Review based on Visual Text Mining, to support the selection of primary studies, offering **different perspectives** to those considered in Malheiros et al.'s work, i.e.:

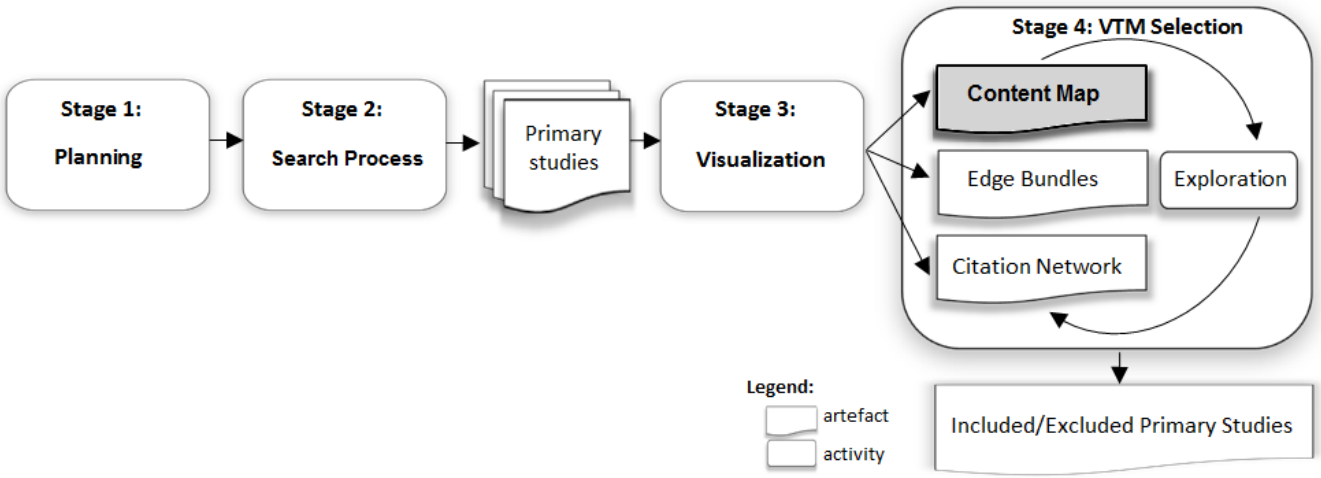
1. visualizations based on the content of the studies (content map) and
2. using **meta-data analysis**, via representations such as **edge bundles** and **citation networks**.



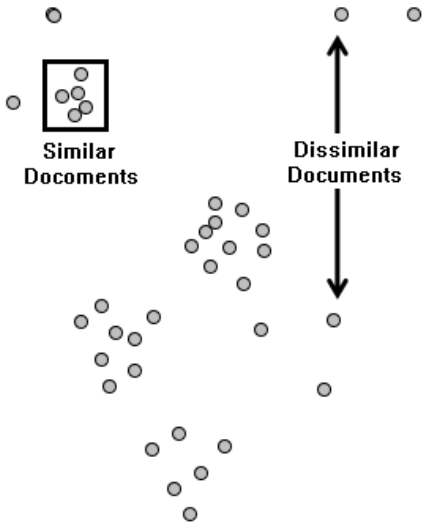

## Systematic Literature Review based on VTM – SLR-VTM

Four stages:

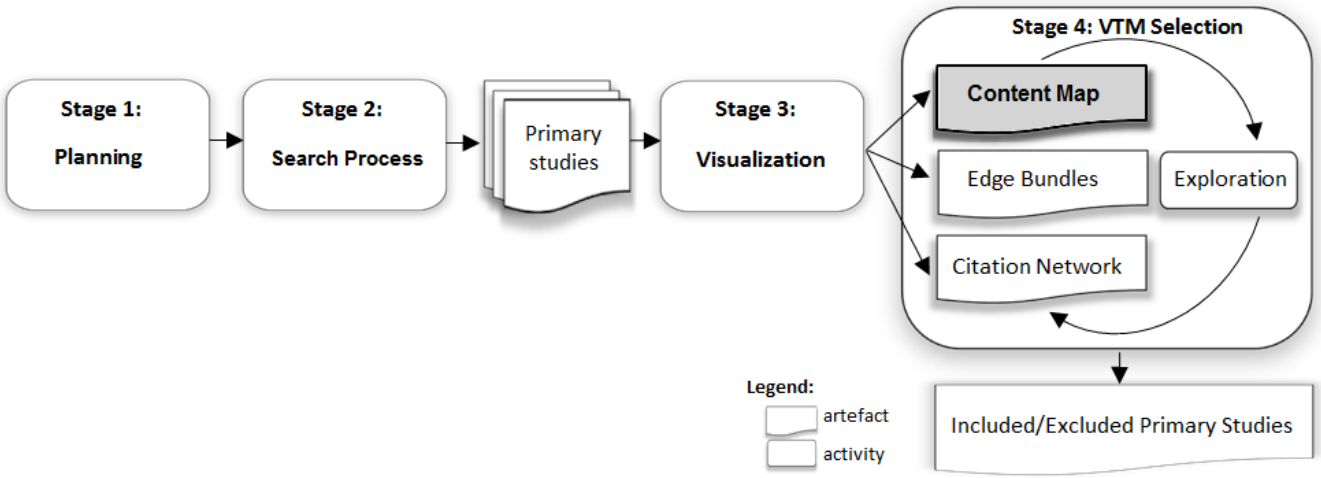
1. planning;
2. search process;
3. visualization and;
4. VTM selection.




## Content Map




- A **content map** is a 2D visual representation of the primary studies, and enables users to investigate content and similarity relationships between these studies.

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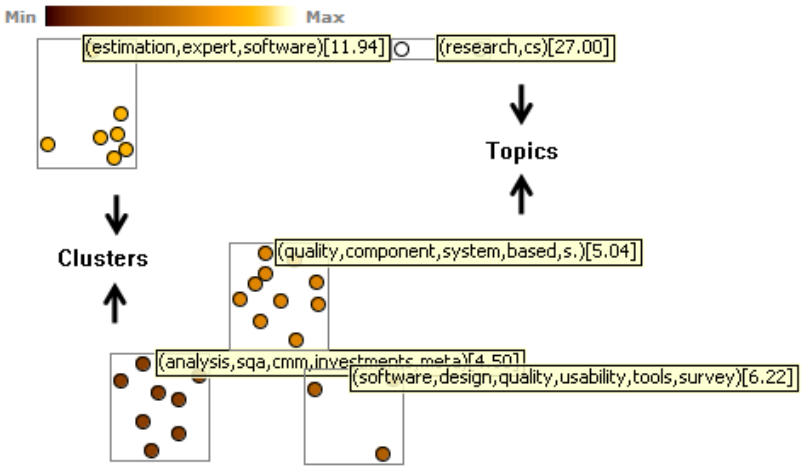
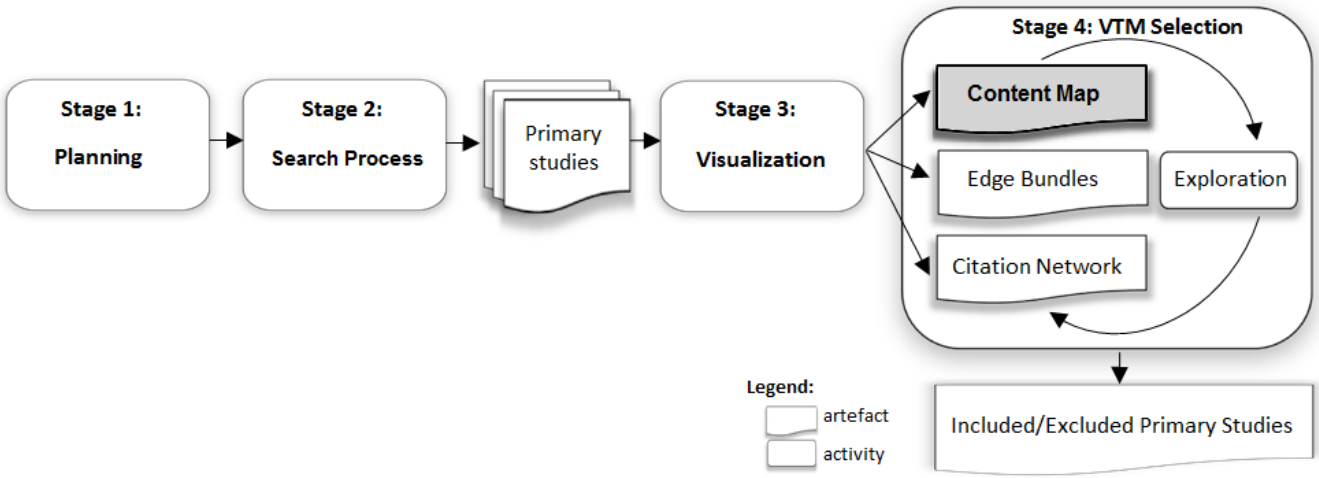



## Clusters and Topics

- to include: concentrate the reading on documents that belong to the clusters labeled with topics that most closely match the SLR's research questions;
- to exclude: review (perhaps less thoroughly) the documents belonging to clusters labeled with topics that do not match their SLR's research questions.

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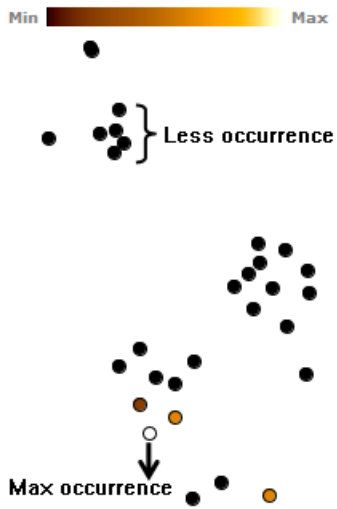
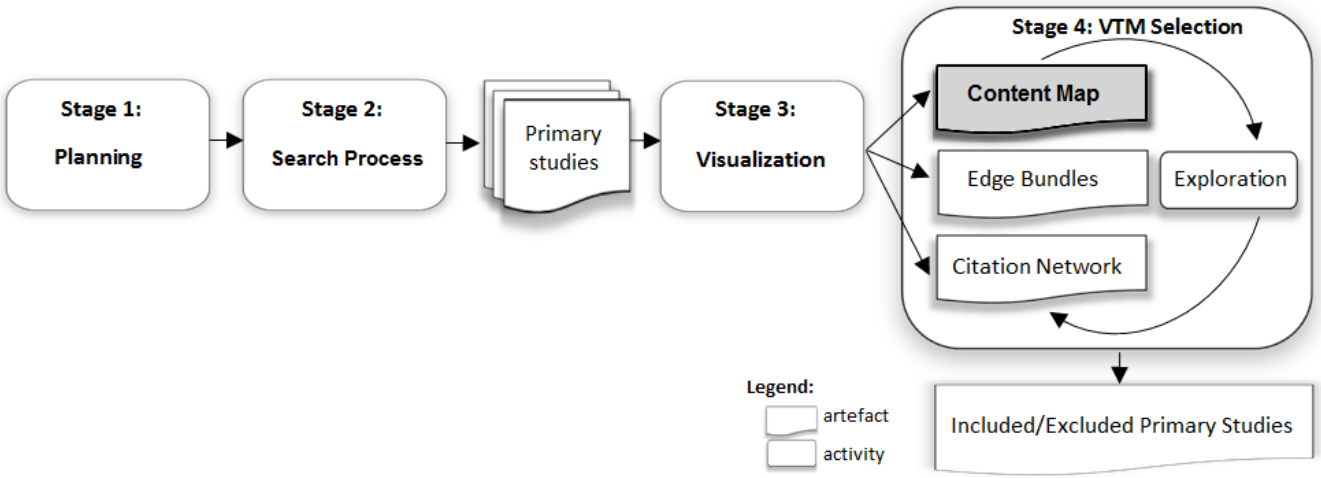



## Expression Occurrence

The colour represents the frequency of occurrence of specific user-defined expressions in the primary studies.

- to include: prioritize the reading towards documents coloured in white (or closer to white – i.e., many occurrences);
- to exclude: read the documents coloured in black (or closer to this colour).

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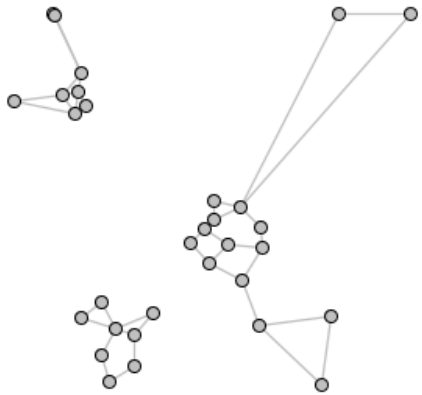
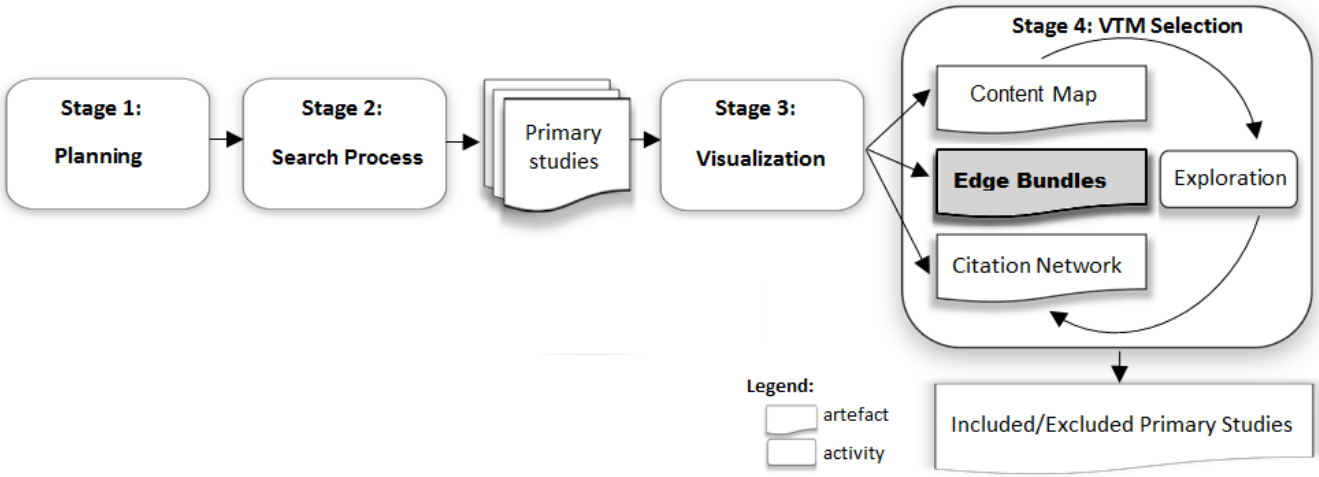


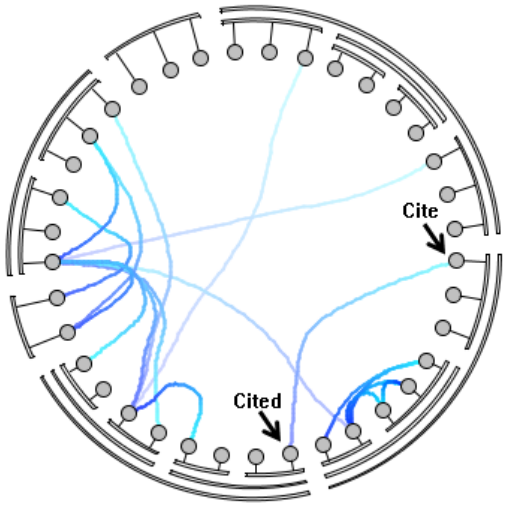
## KNN Connection

This technique connects primary studies with their neighbors to support study inclusion by association.

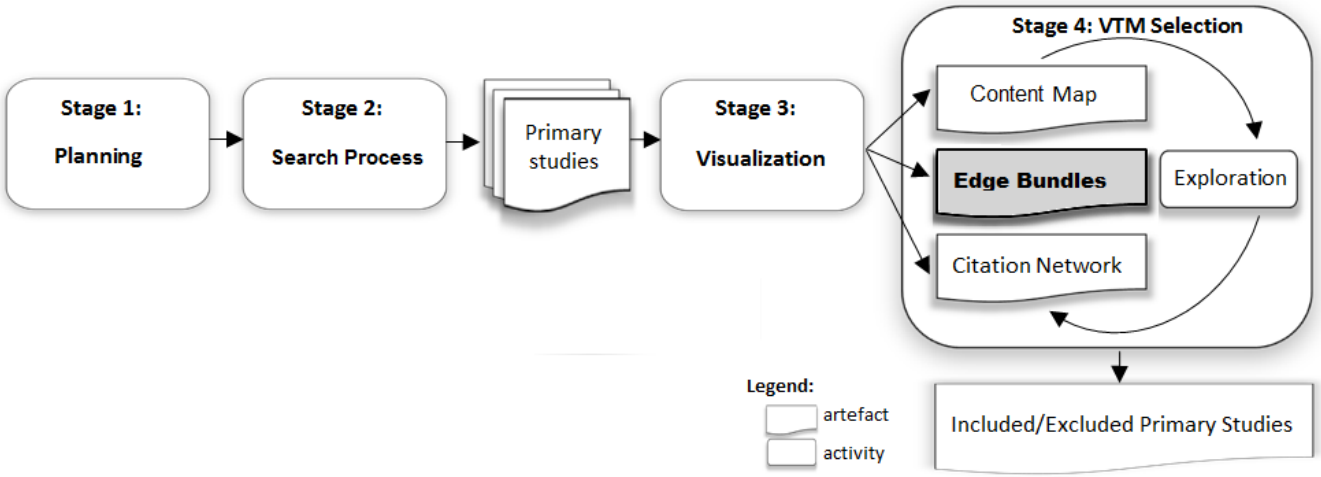
- to include: neighbors of an included study are the more likely they are to be also relevant to the SLR.
- to exclude: neighbors of an excluded study are more likely to be irrelevant and so should not be included.




## Edge Bundles




- A **edge bundle** is a hierarchical tree visualization technique that shows both nodes and node-links (relationships between nodes) at the same time.

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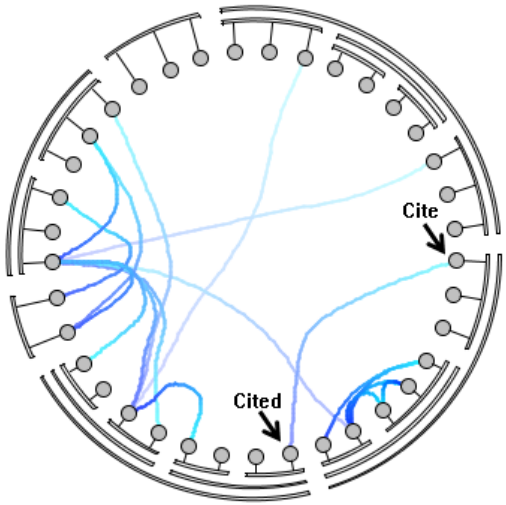
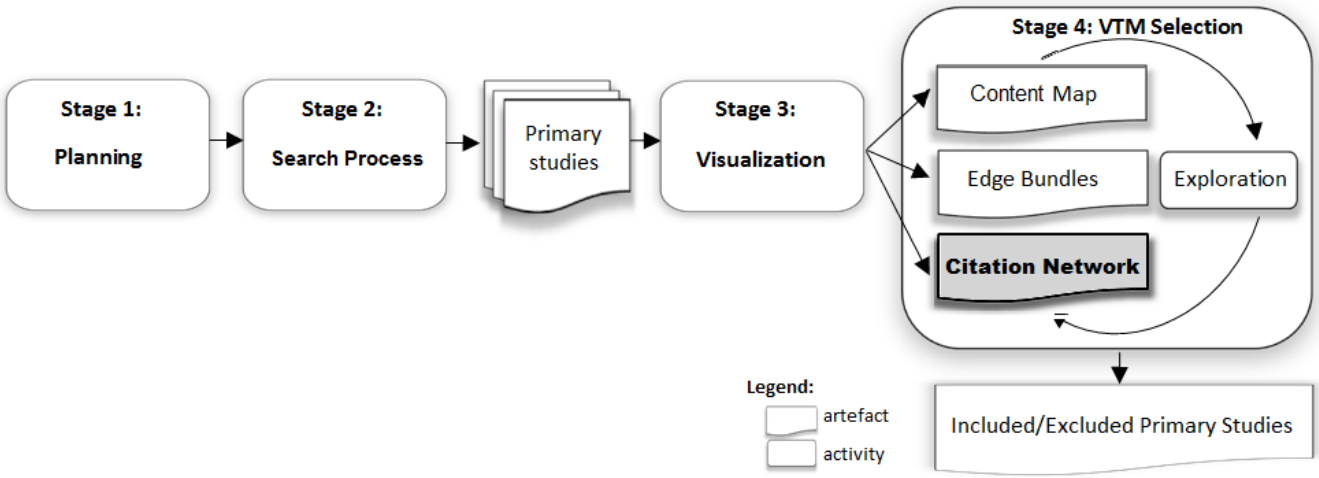
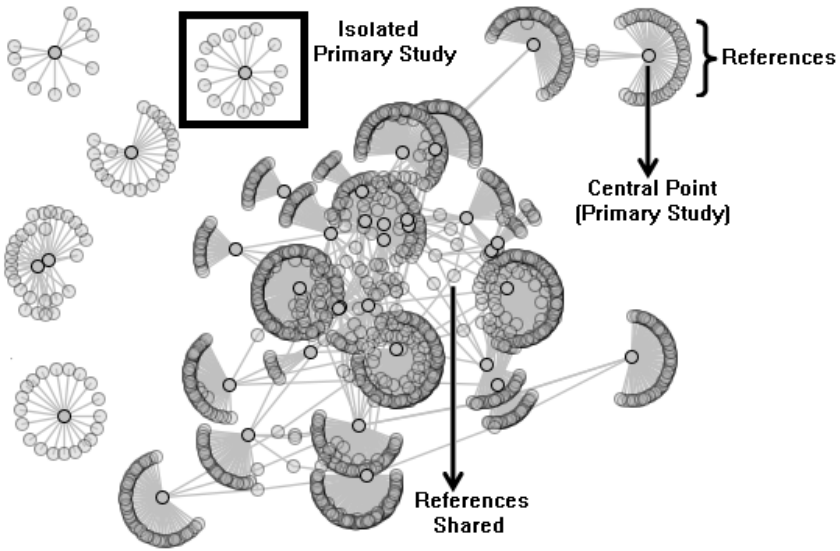


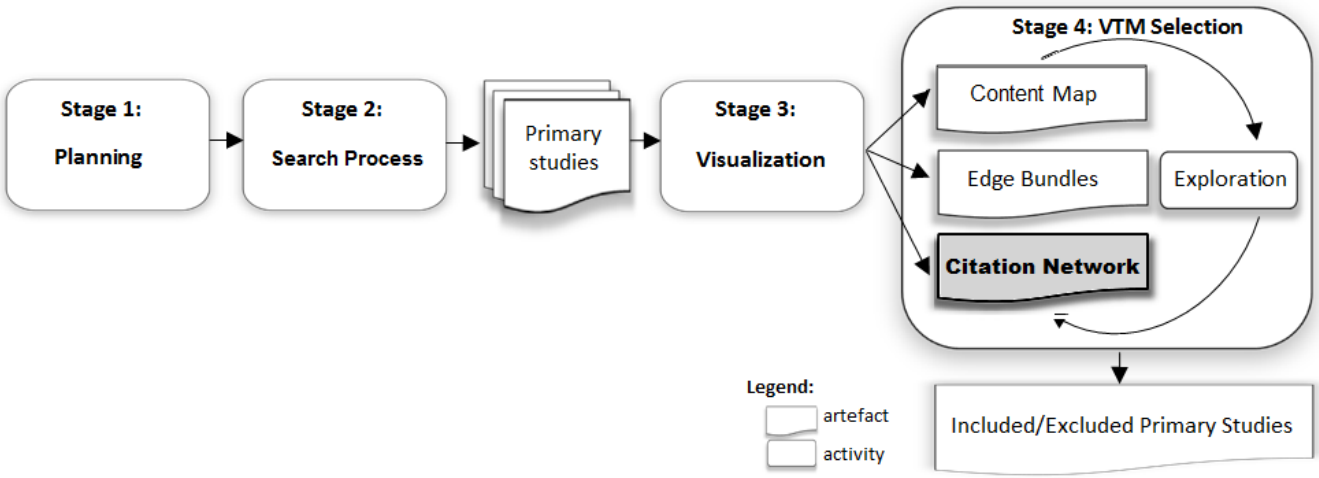

- to include: a relevant paper is usually cited by other papers.
- to exclude: papers that are not cited, or cited very little, may be indicative of studies that should not be included in the SLR.




## Citation Network




- The **citation network** shows the primary studies (central point - circle) with their cited references (circles around the central point, connected by edges).

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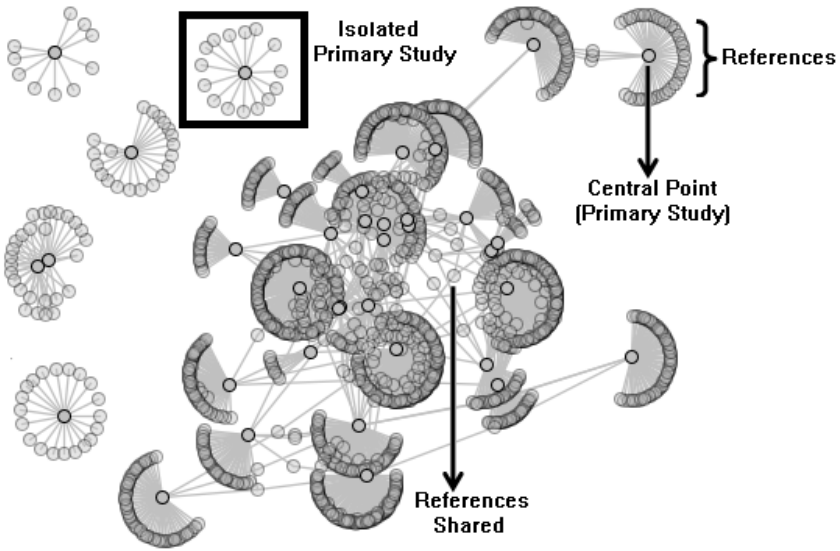
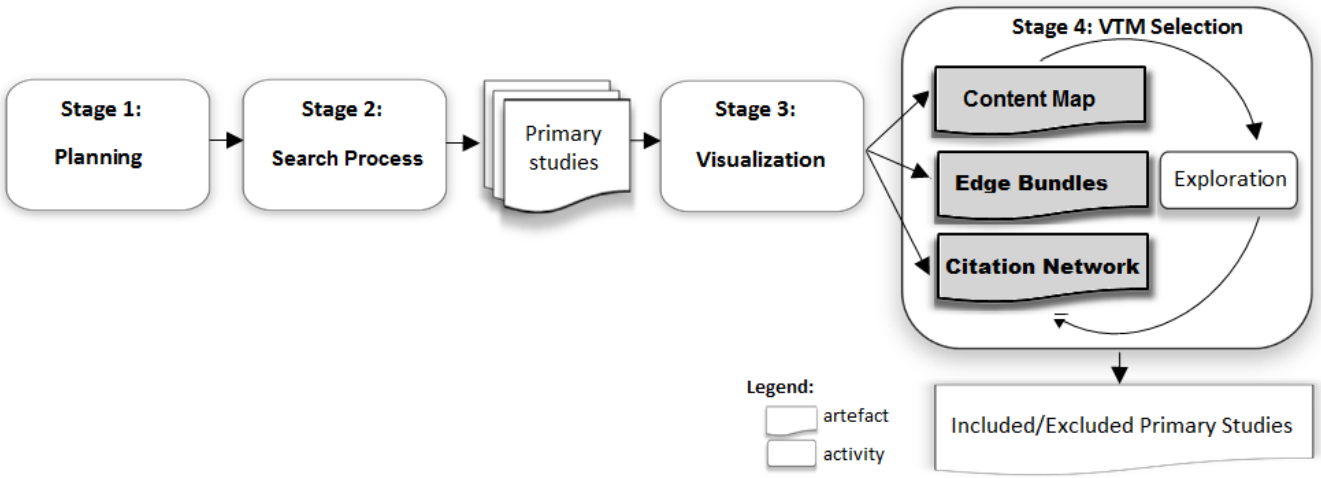
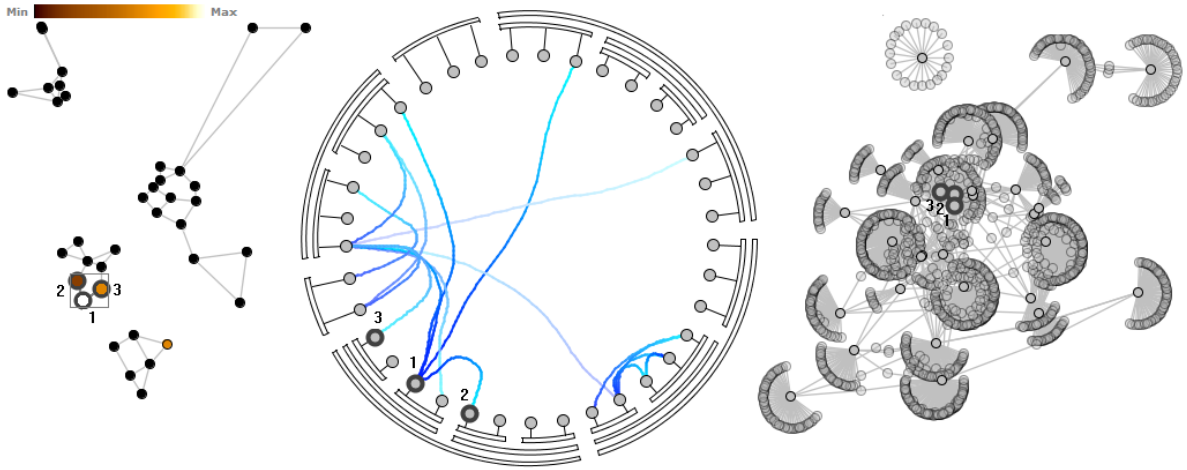


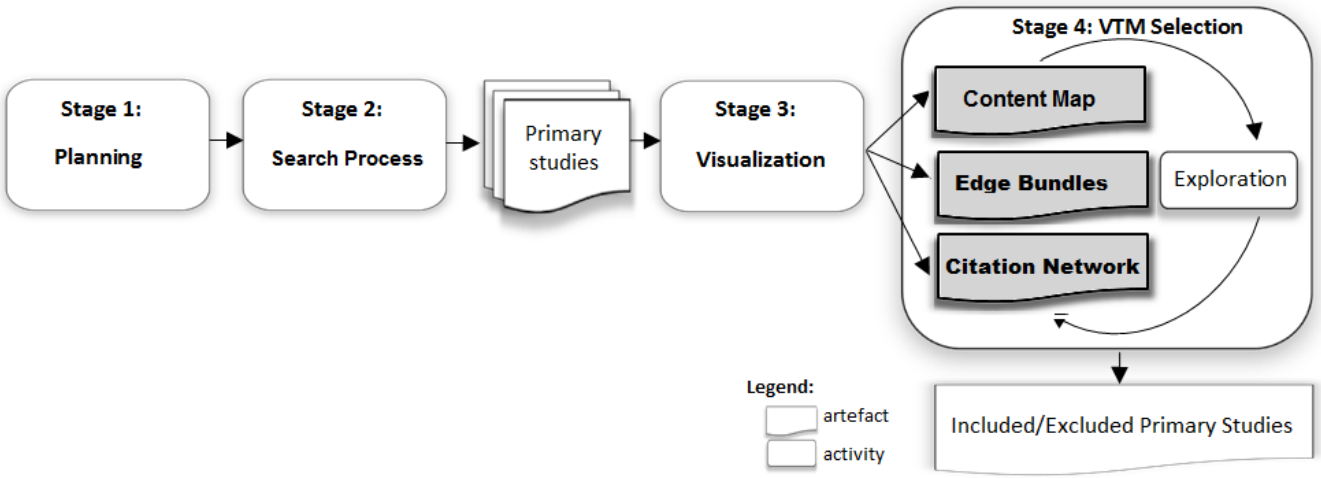

- to include: papers that share references with a relevant paper could be more appropriate for inclusion in the SLR
- to exclude: primary studies that are not connected to any other studies (i.e., do not share citations or references), are more likely to be irrelevant documents.




## Coordination




The user can **combine** the techniques using coordination, which represents an **interaction** among the different views.

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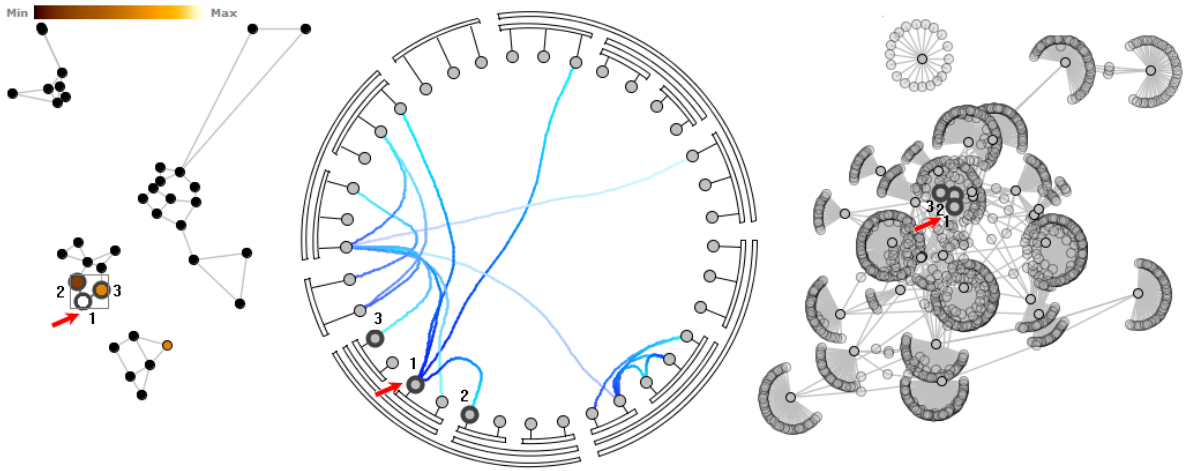
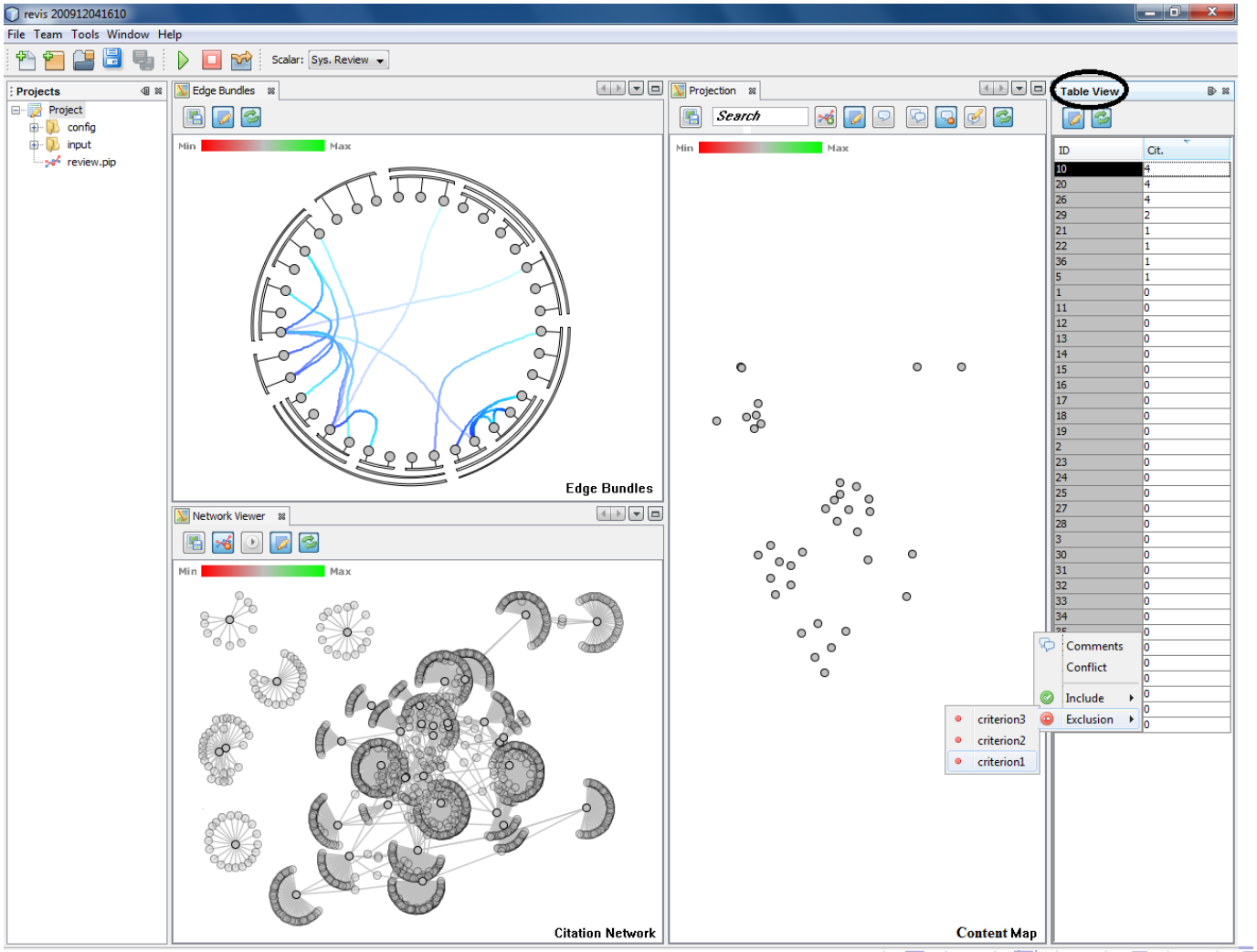



Once a point or a group of documents in a view is selected, the corresponding point (or points) is then **highlighted** in the other **views**.

# REVIS - Systematic Literature Review Supported by Visual Analytics



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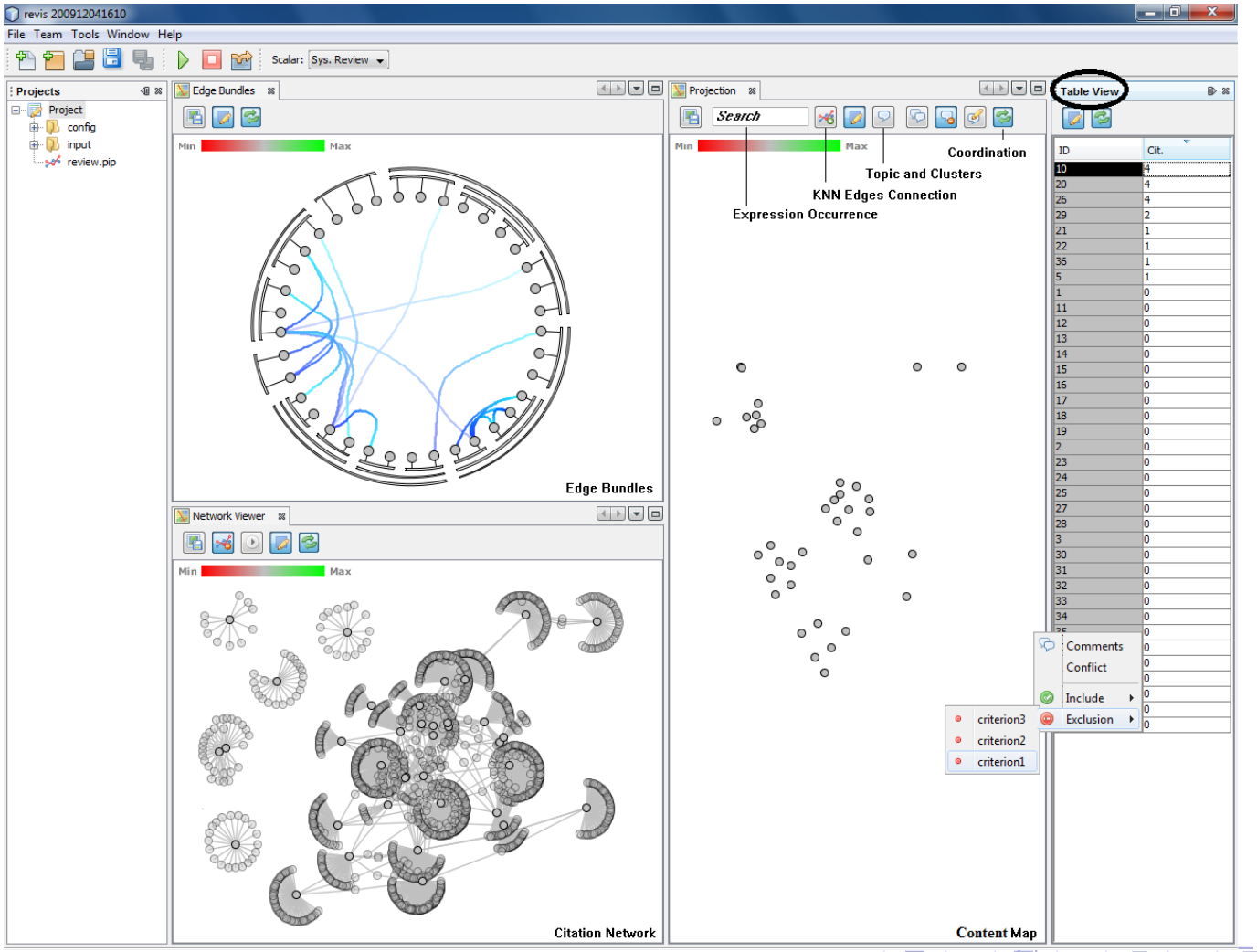

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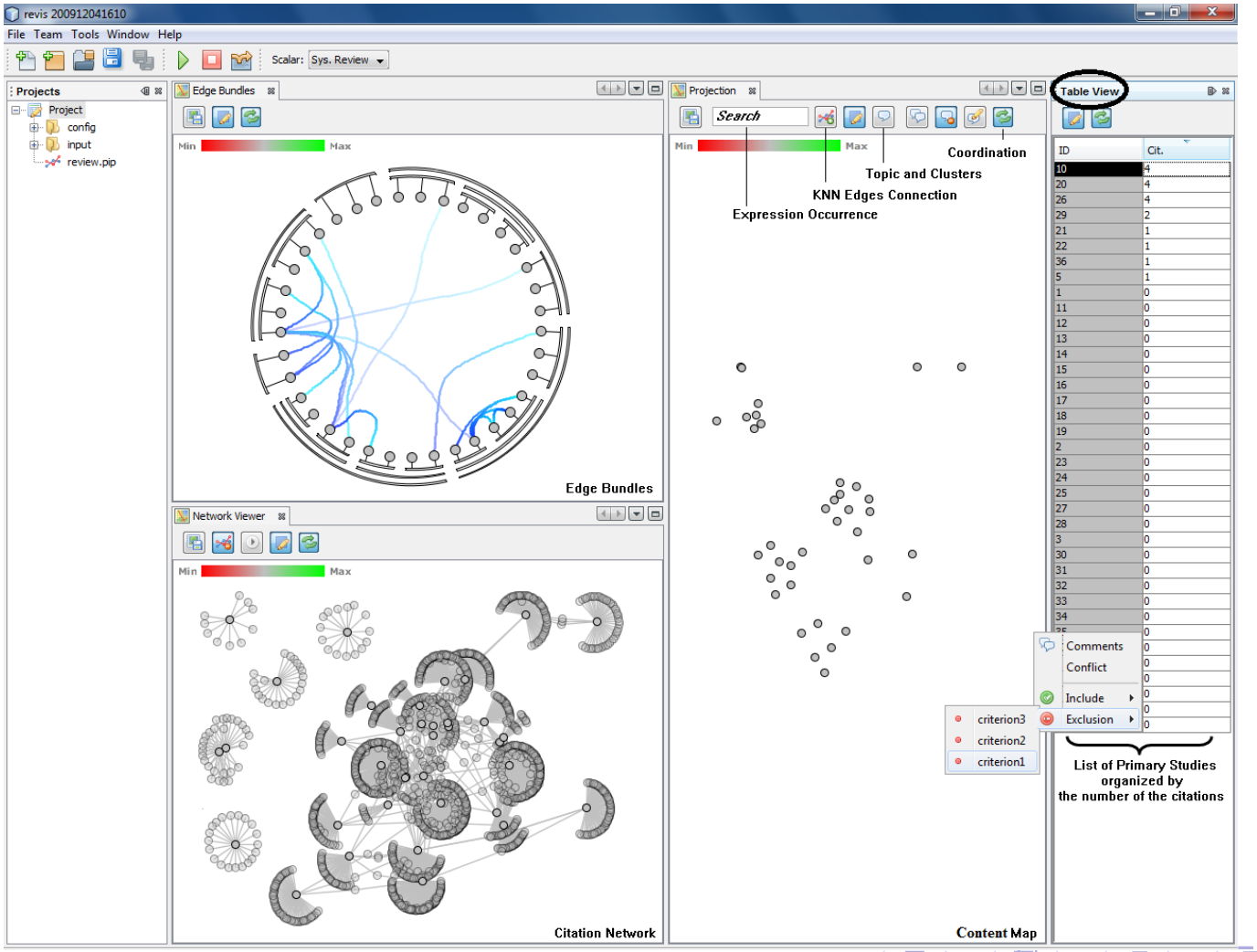

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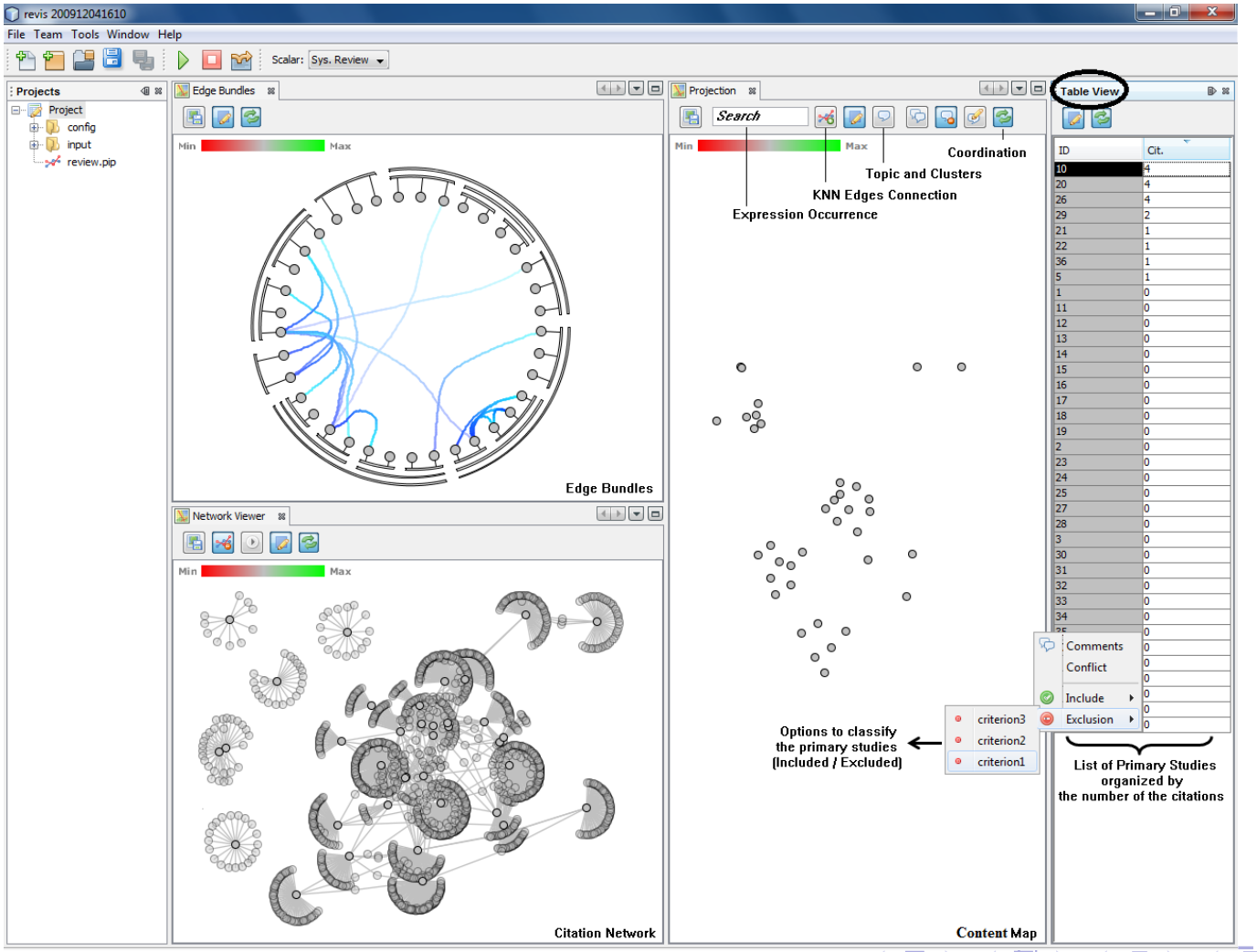

## Pilot Case Study: Our empirical research questions (RQ) are:

1. **RQ1:** Do VTM techniques improve the **performance** (time taken) of the study selection activity in the SLR process?
2. **RQ2:** Do VTM techniques improve the **effectiveness** (correctness of the inclusion/exclusion) of the study selection activity in the SLR process?

## Instrumentation and Procedure

– Two stages:

1. training (set 1) and;
2. execution (set 2).

– Two groups:

1. **group 1** – conduct the study selection activity manually (reading the abstracts) and;
2. **group 2** – conduct the study selection activity using the VTM approach (Revis tool).

## Results

| Approach | Student | Performance | Correctness | |
|---|---|---|---|---|
| | | | Included and Excluded Correctly | Included and Excluded Incorrectly |
| Reading Abstract | 1 | 85 min | 25 | 12 |
| Reading Abstract | 2 | 54 min | 22 | 15 |
| VTM Strategies | 3 | 30 min | 27 | 10 |
| VTM Strategies | 4 | 58 min | 28 | 9 |

- Our results show that incorporating VTM in the SLR study selection activity **reduced** the time spent in this activity and also **increased** the number of studies correctly included.
- Our pilot case study presents promising results suggesting that the use of VTM may indeed be **beneficial** during the study selection activity when performing an SLR.

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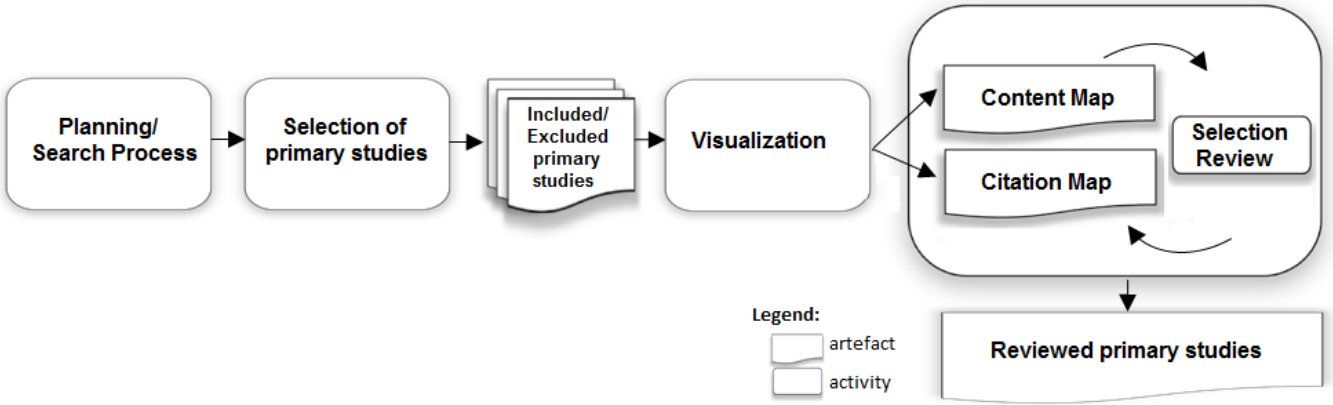
# Approach to use VTM in the Selection Review Activity



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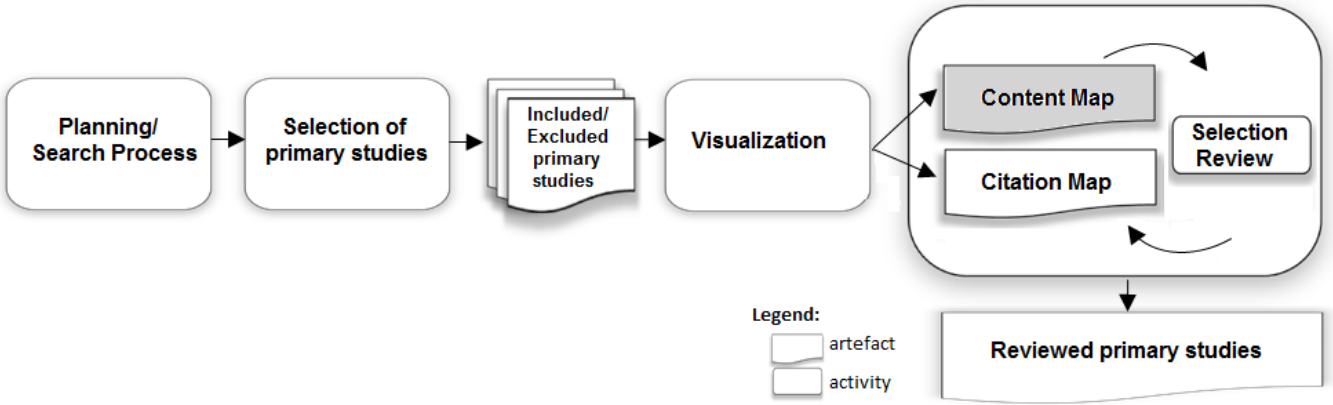
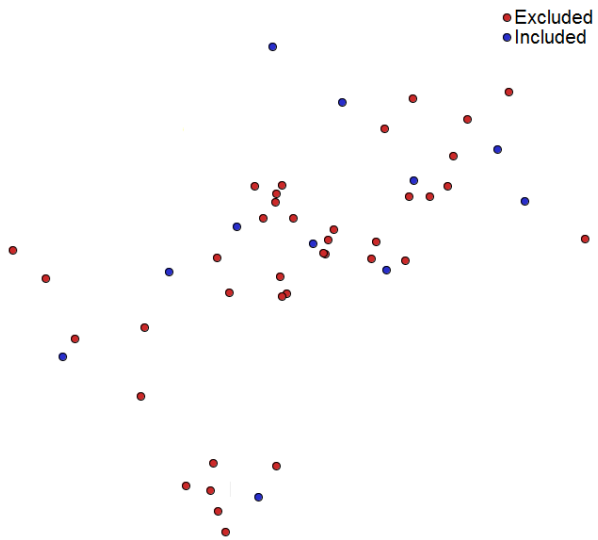



## Content Map Strategies to review the studies selection




### Content Map

- Apply a clustering algorithm to the content map to create groups of highly related (similar) documents;
- Analyse the clusters in terms of included and excluded documents in order to find inconsistencies. In this analysis, the possible situations are:

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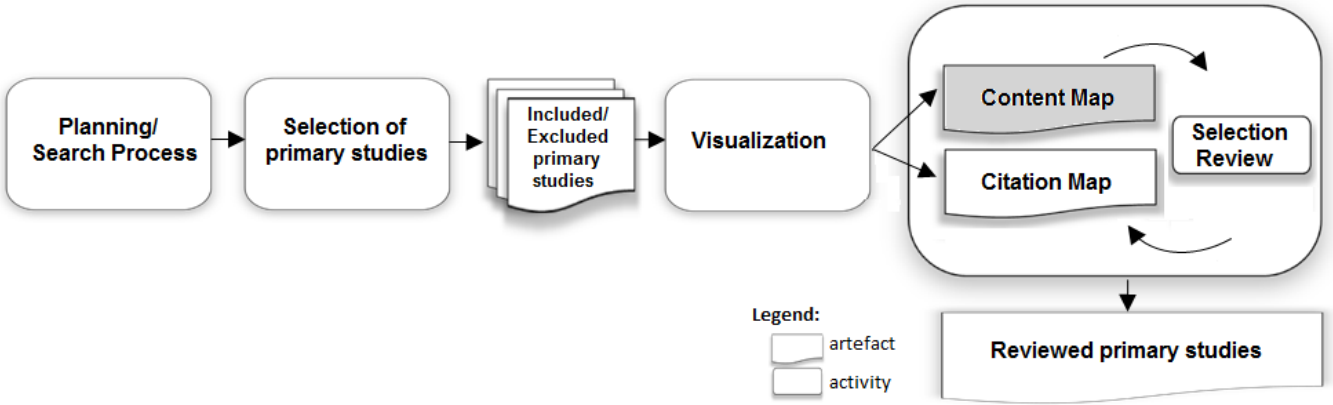


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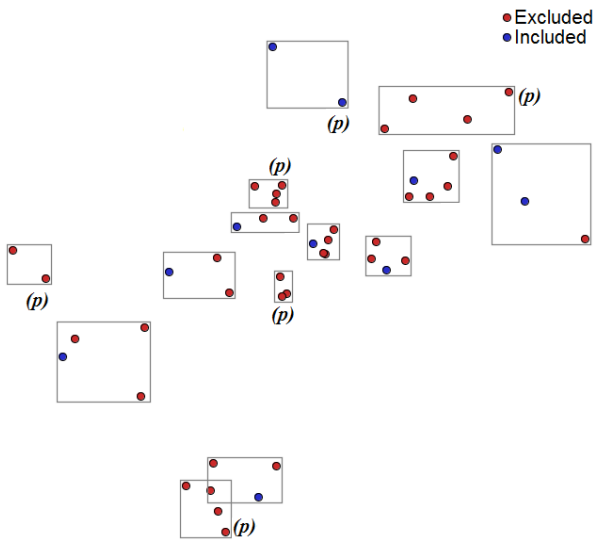


### Pure Clusters

- Pure Clusters *(p)* – all documents belonging to a cluster have the same classification (all included or excluded). Normally, such cases do not need to be reviewed;

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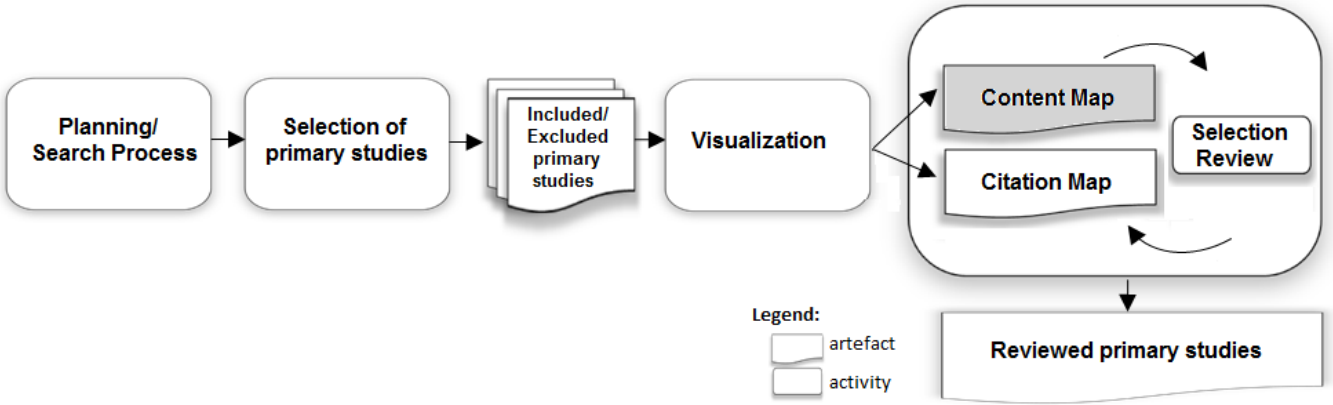


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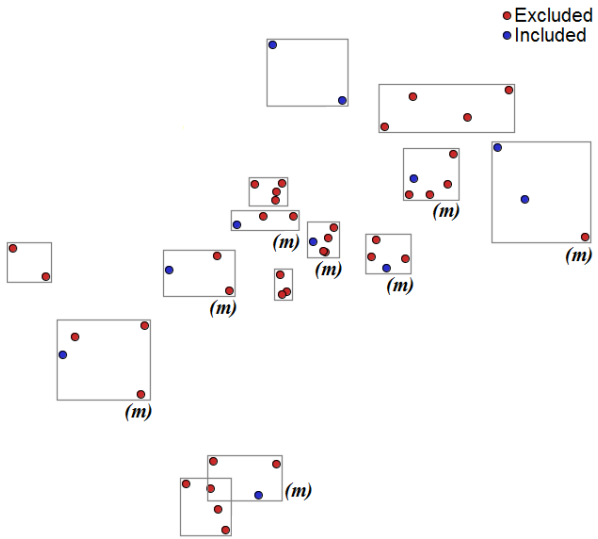


### Mixed Clusters

- Mixed Clusters *m* – there are documents with different classifications in the same cluster. The studies grouped there **should be reviewed** following the traditional method;
- The evaluation of the mixed clusters can be refined with the help of **content-based strategies**.

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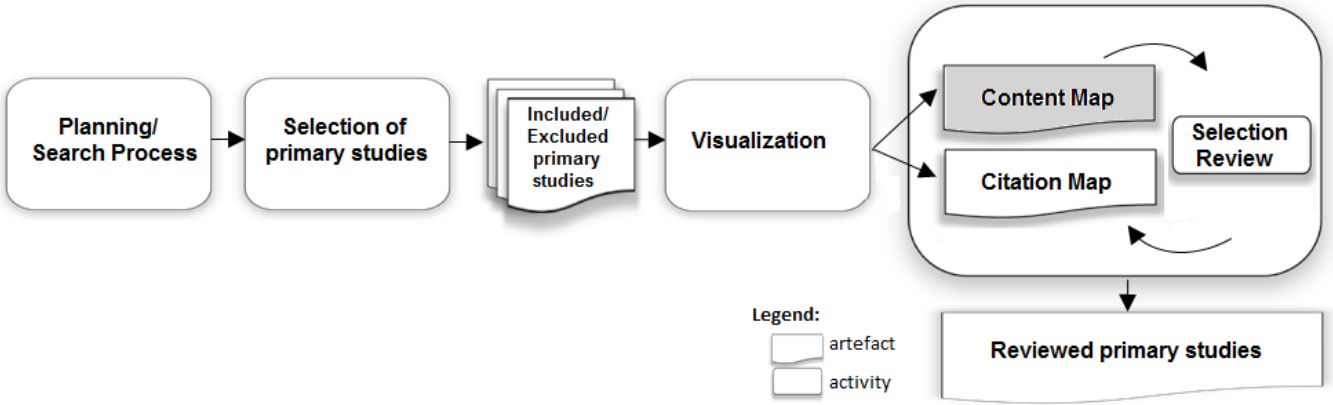
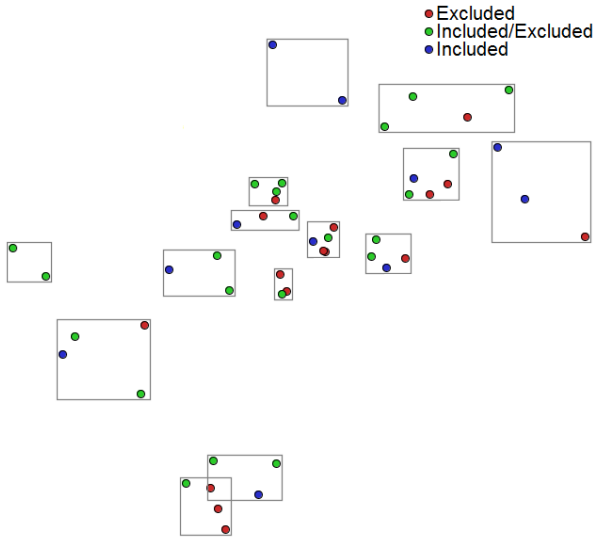


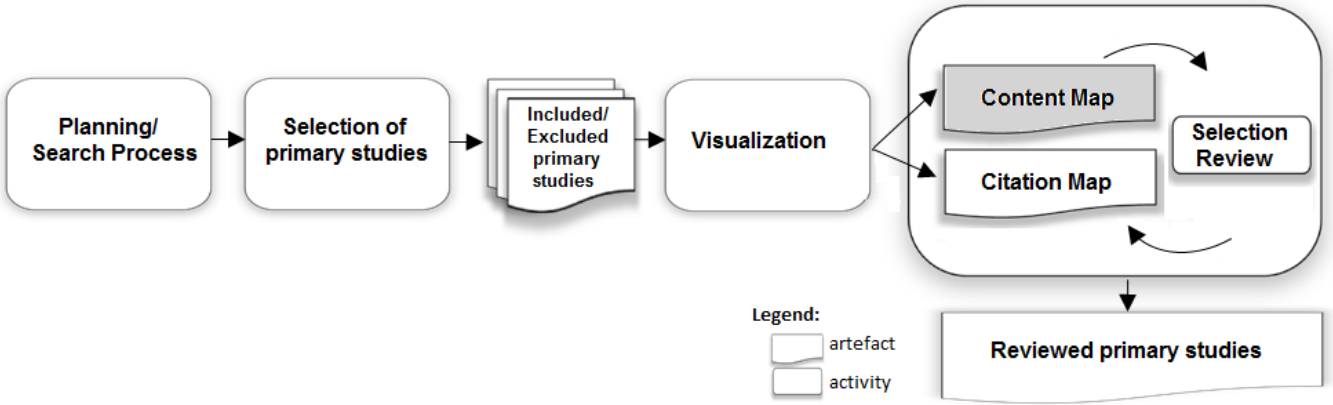

## Content-based Strategies




## Exclusion History

- Use different colours to differentiate in which of the first two steps of the selection activity (i.e., reading abstract or full article) a study was removed from the review;
- Four distinct possibilites for mixed clusters: (i) green and red; (ii) blue and green; (iii) blue and red; and (iv) blue, green and red.

## Approach to use VTM in the Selection Review Activity

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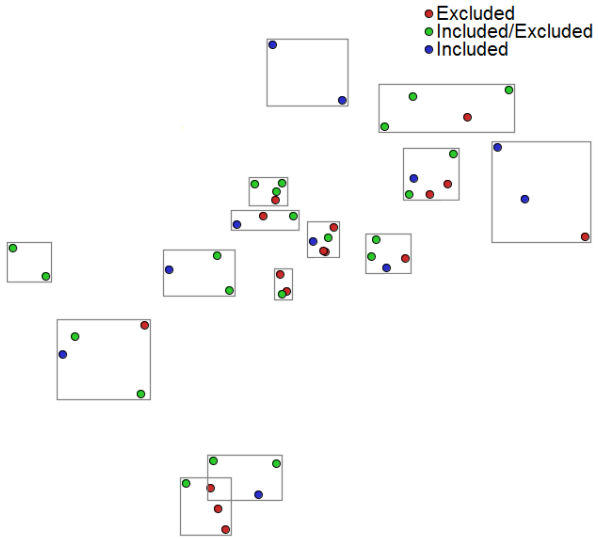


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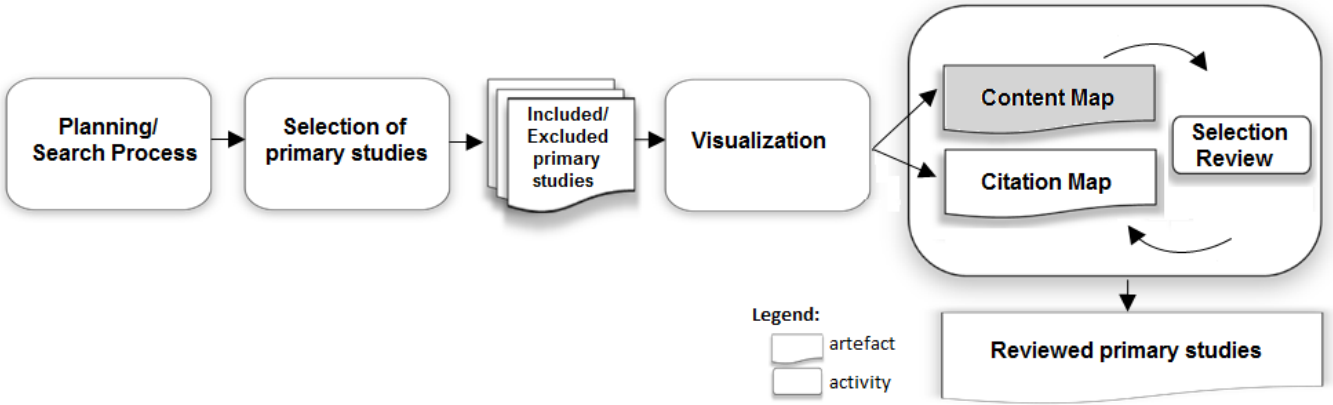


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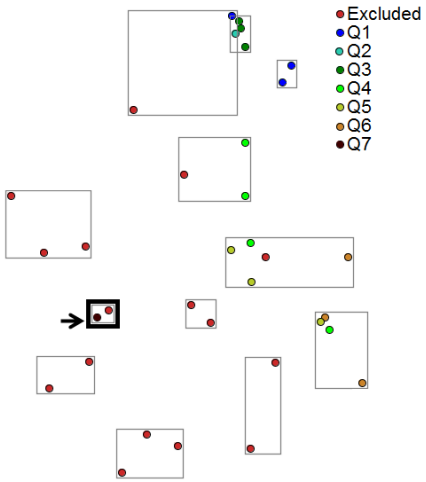
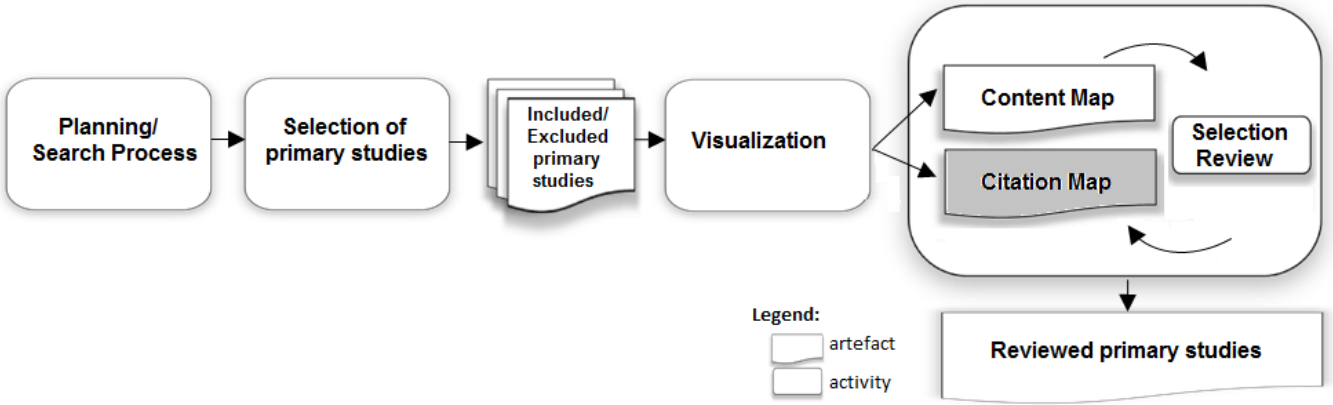


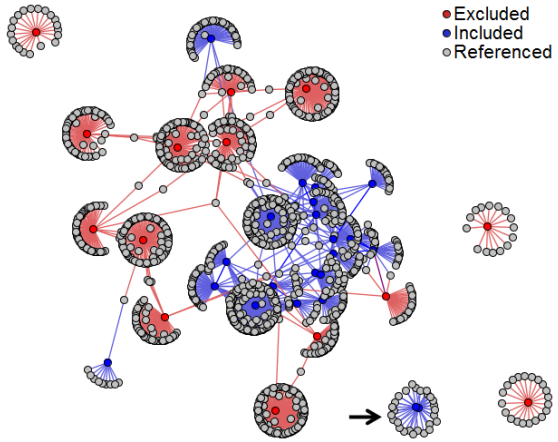

## Classification of Study Quality

- The studies are coloured according to the quality defined and assigned by the reviewers;
- Interesting situation: an excluded paper (red point) is similar to an included paper of low quality *(Q7 - brown point)*.

# Approach to use VTM in the Selection Review Activity



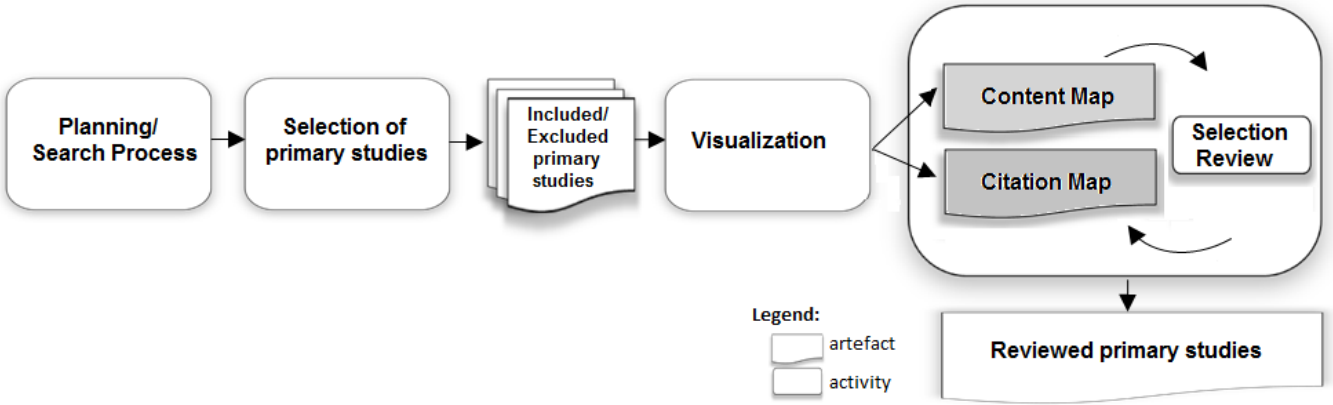

## Citation Map Strategy



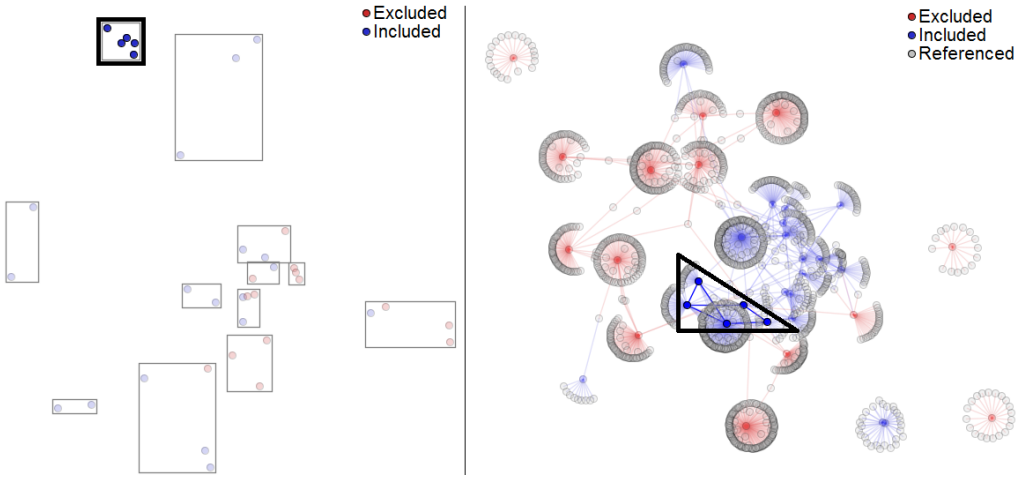

## Classification of Study Quality

- **Deserve attention** from experts (reviewers):
  1. studies that are not connected to any other, that is, studies **isolated** in terms of references and;
  2. **excluded** studies that **share** citations with **included** studies.

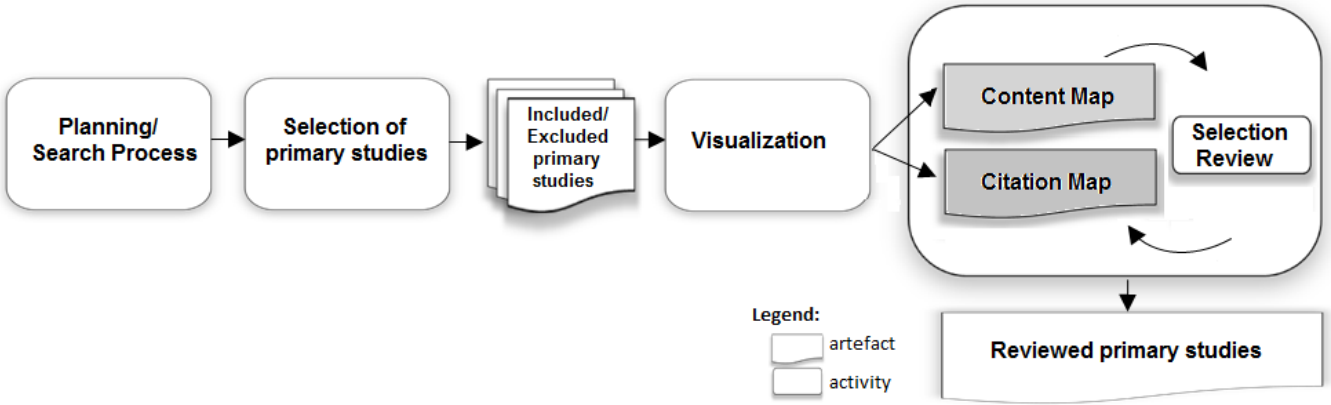
## Approach to use VTM in the Selection Review Activity




## Identity Coordination Strategy



## Approach to use VTM in the Selection Review Activity

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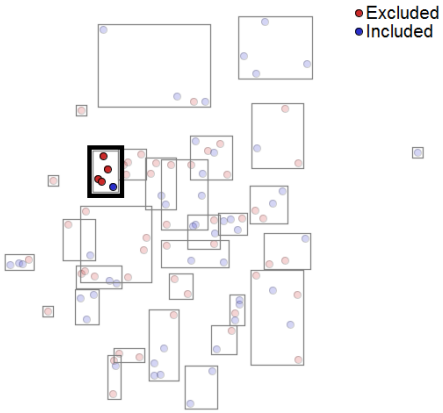
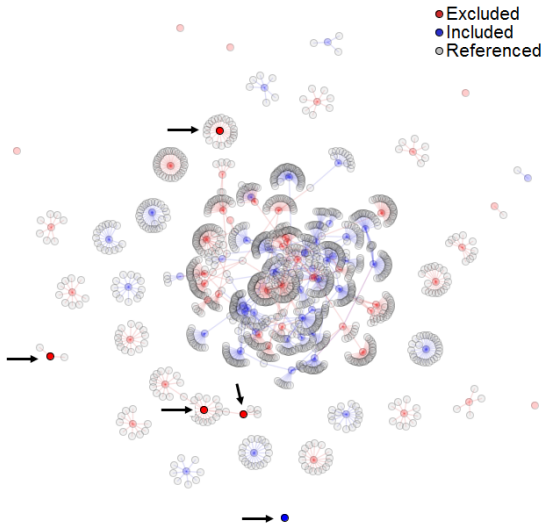


## Notable points

- Different VTM techniques to evaluate the **decisions** of **including** or **excluding** primary studies from an SLR;
- The approach **eliminates** the need for **random choices** of papers to be **re-evaluated**;
- The visual representations can give solid **clues** about which studies should be checked, **reducing** the amount of documents that need to be re-evaluated and the time spent in the whole process.

1 Introduction

2 SLR-VTM

3 SLR-VTM Review

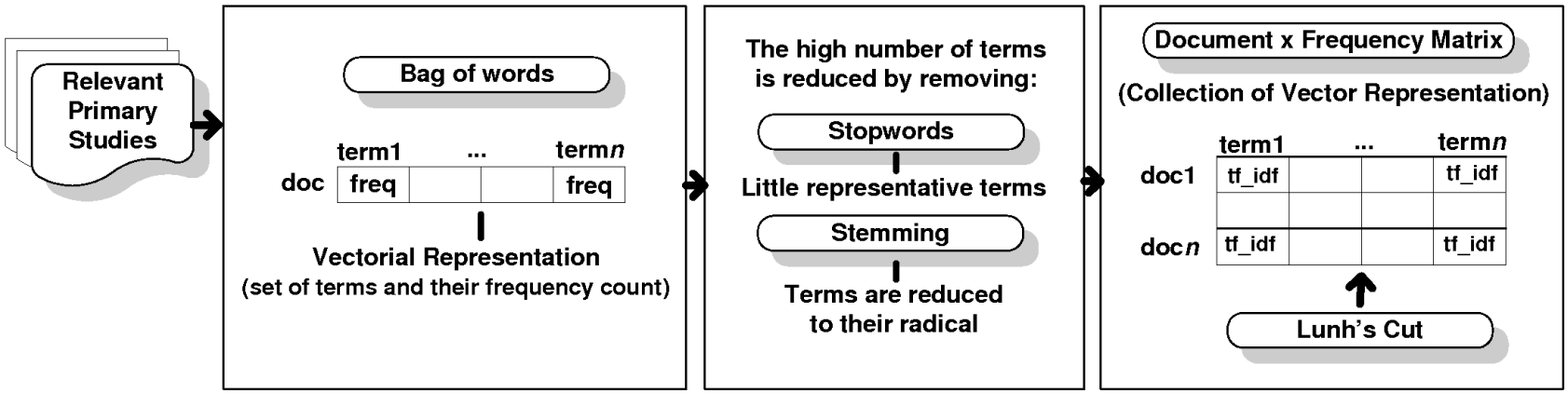
4 Ontology

5 Graphs

6 SM-VTM

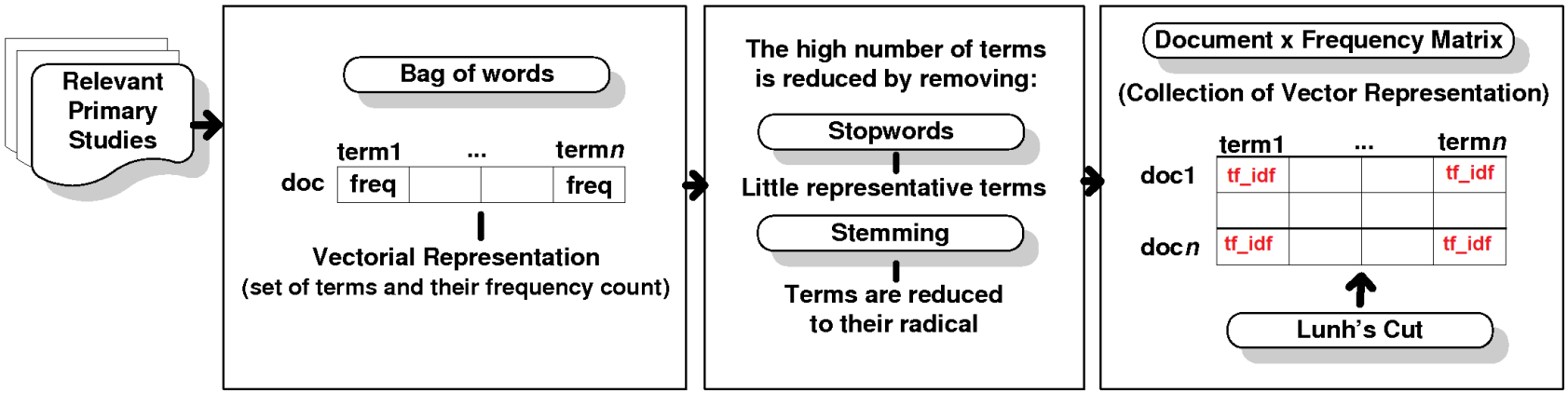
7 Conclusions

# VTM Process: Preprocessing




- The **Preprocessing** activity is responsible for **structuring** and **clearing** data.

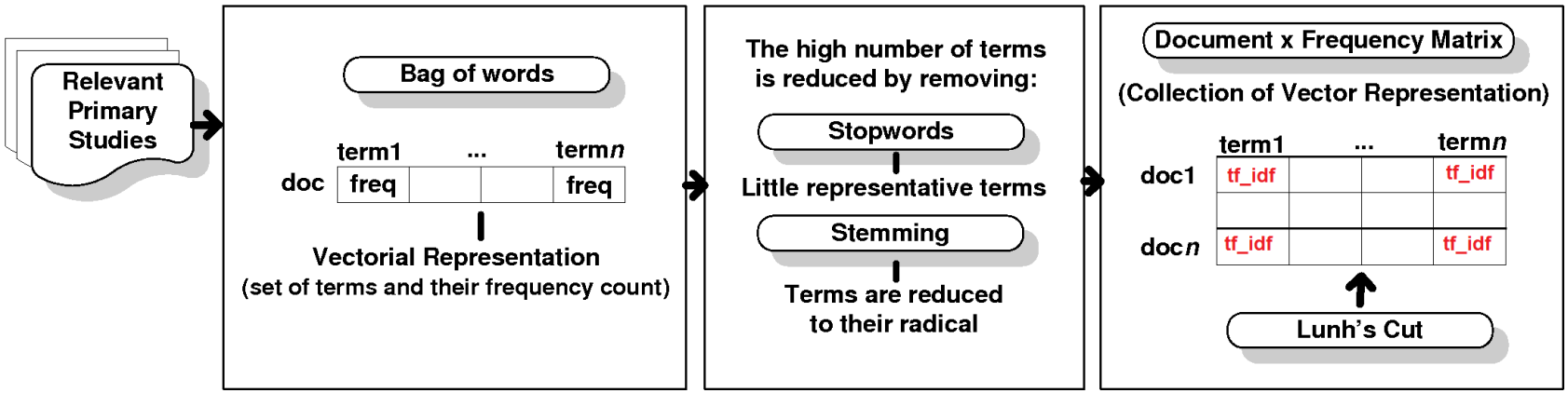
# VTM Process: Preprocessing




**Term Frequency-Inverse Document Frequency(TF-IDF)**

In this model, the importance of terms is **directly** proportional to the **frequency** of their occurrence **in each document**, and **inversely** proportional to the **frequency** of the term in the **collection** [Gennari et al., 1989].

# VTM Process: Preprocessing




**Term Frequency–Inverse Document Frequency**

$$tf - idf\ (t_i, d_i) = freq\ (t_i, d_i) \times \log\left(\frac{n}{dfreq\ (t_i)}\right)$$

- $freq(t_i, d_i)$ → number of times that the term $t_i$ appears in $d_i$
- $n$ → total of documents
- $dfreq\ (t_i)$ → number of documents where the term $t_i$ appears

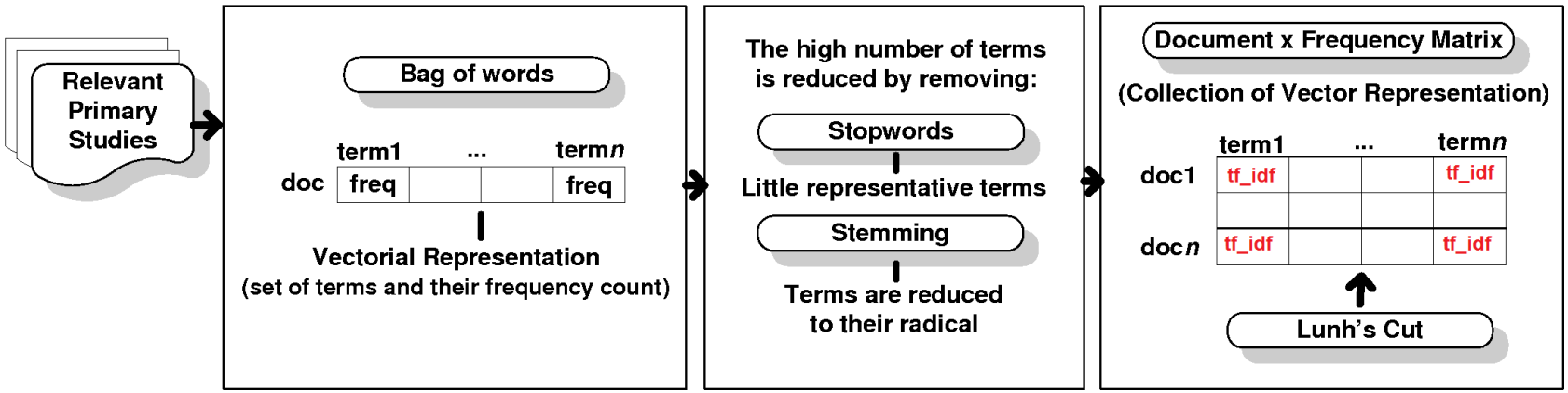
**Example:**

| | term1 | term2 | term3 |
|---|---|---|---|
| doc 1 | 4 | 8 | 10 |

- $freq\ (t_1, d_1)$ → 4
- $freq\ (t_2, d_1)$ → 8
- $freq\ (t_3, d_1)$ → 10
- $n$ → 2048
- $dfreq\ (t_1)$ → 128
- $dfreq\ (t_2)$ → 16
- $dfreq\ (t_3)$ → 1024

- t1 → $4 \times \log\left(2048/128\right) = 4 \times 1.2 = 4.81$
- t2 → $8 \times \log\left(2048/16\right) = 8 \times 2.1 = 16.86$
- t3 → $10 \times \log\left(2048/1024\right) = 10 \times 0.3 = 3.01$

# VTM Process: Preprocessing

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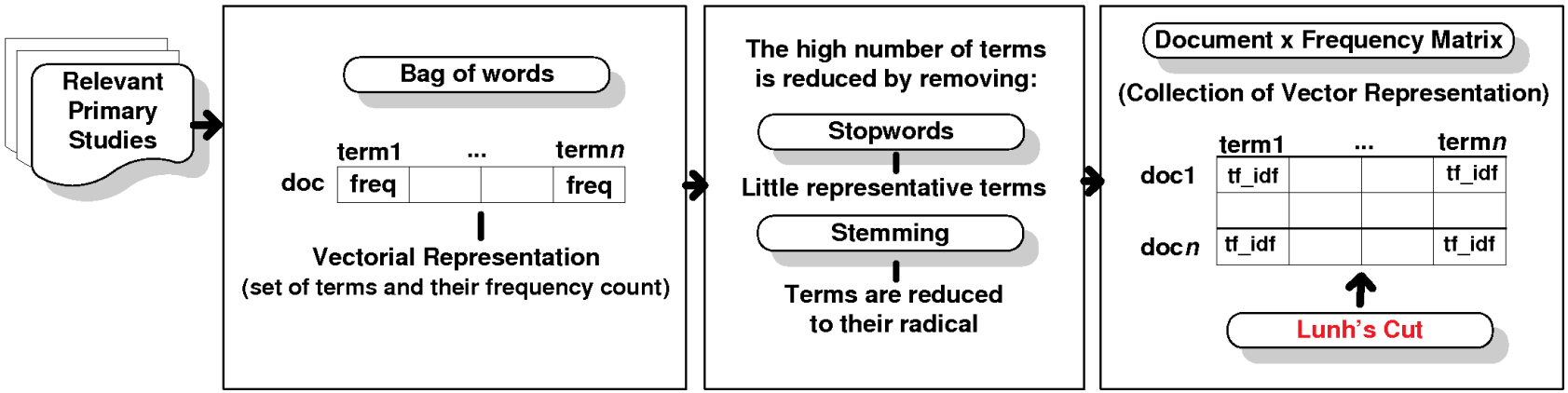
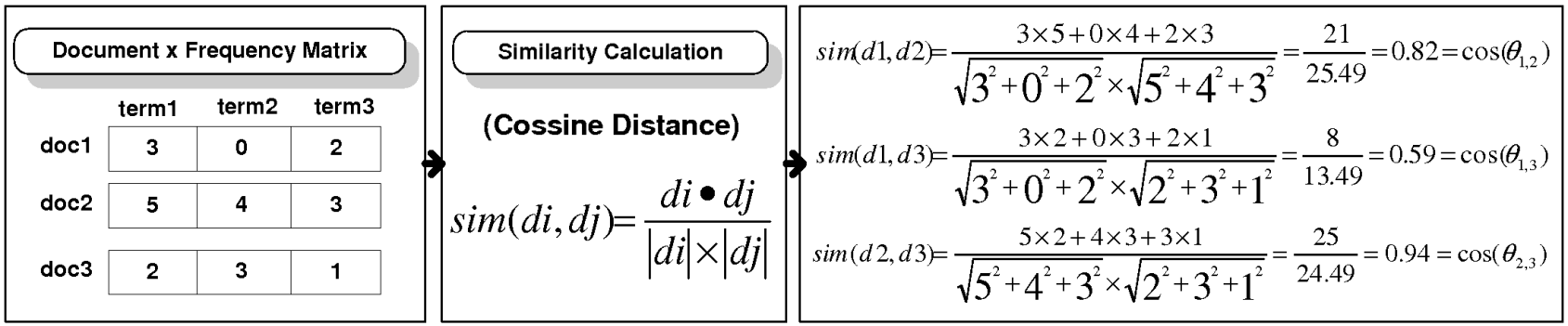
# VTM Process: Preprocessing




- This cut aims at the **elimination** of terms that occur [Luhn, 1958]:
  1. **less** than $n$ times **(Luhn's lower cut)**
     **rare** terms – which do not discriminate documents
  2. **more** than $m$ times **(Luhn's upper cut)**
     too **frequent** terms – which are also not representative

# VTM Process: Similarity Calculation



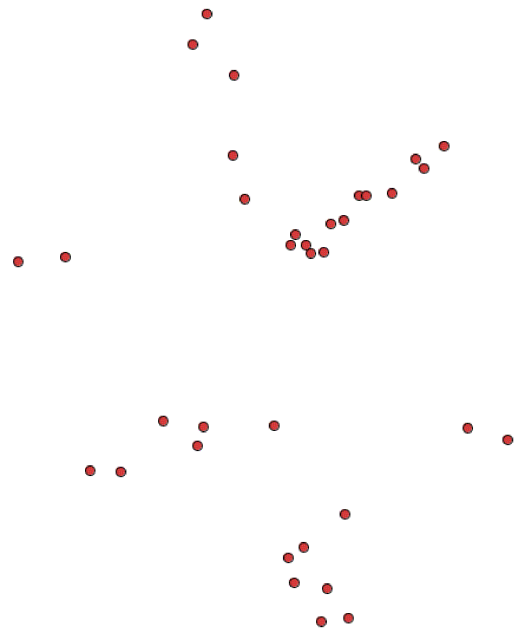

- The **Similarity Calculation** activity is responsible for measuring the similarity degree among the primary studies.
- Result: **0.0** (entirely dissimilar); **1.0** (entirely similar).

# VTM Process: Projection

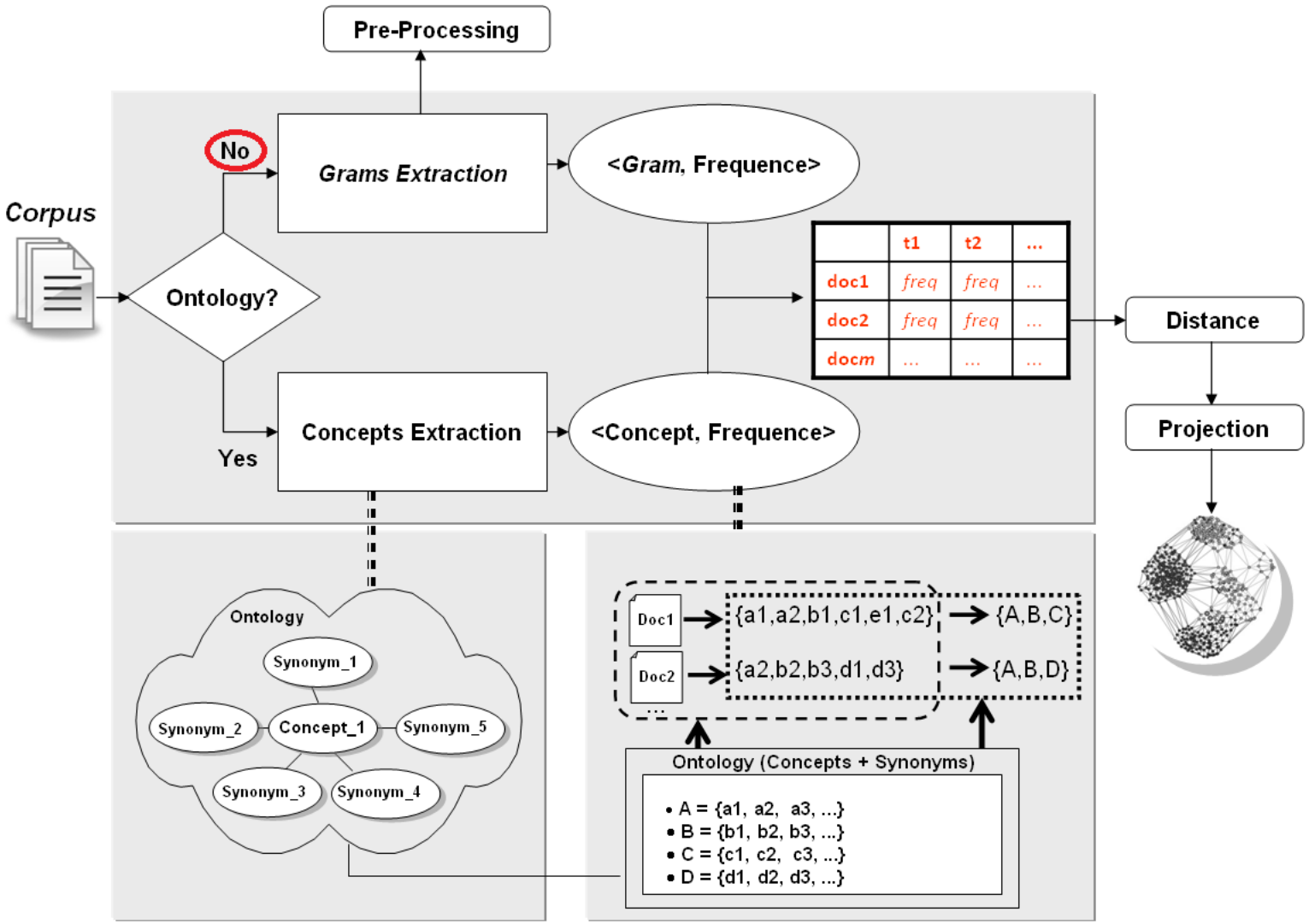
## Projection

- This activity is responsible for placing the primary studies onto a plane (2D) based on their similarity.
- **Result: Content map.**

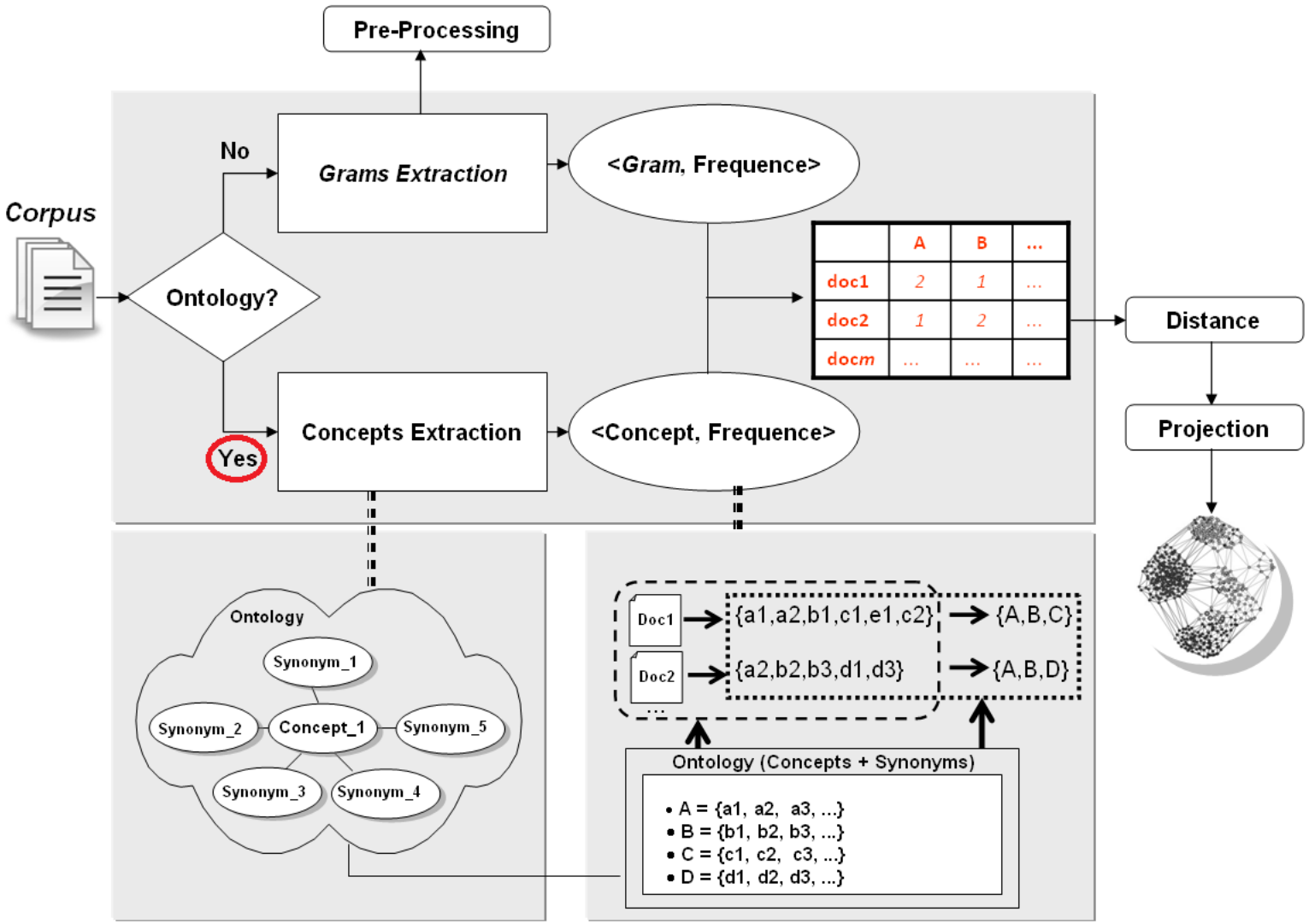
## Content Map



# VTM Process using Ontology



# VTM Process using Ontology

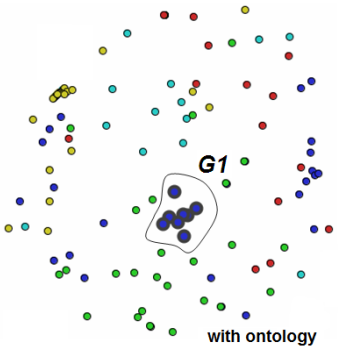


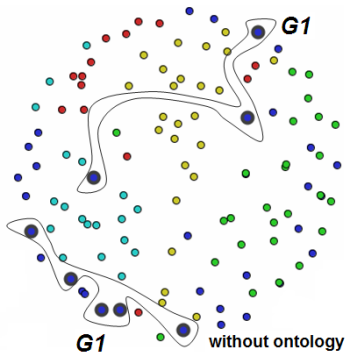
## Case Study

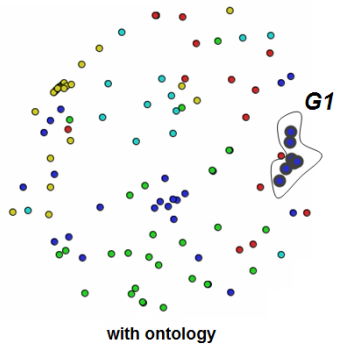
- **Objective:** Evaluate the use of ontology on VSM construction;
- **Data Set** – 118 articles, originated from 5 SLRs:

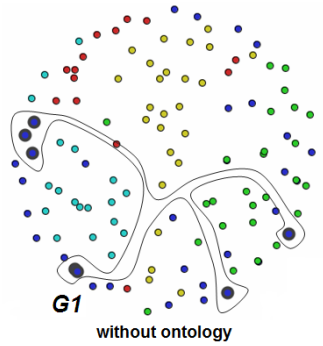
  **G1** – Integration Testing of Aspect-Oriented Programs;
  **G2** – Verification, Validation and Testing (VV&T) of Web-Services Composition;
  **G3** – Mutation Testing of Aspect-Oriented Programs;
  **G4** – Software Testing on Agile Methods;
  **G5** – Quality of Component-Based Software Development Processes;
- **Ontology:** OntoTest [Barbosa et al., 2007];
- **Evaluation:** Visual Analysis using **coordination** of two projections of the same data, **with** and **without** ontologies.

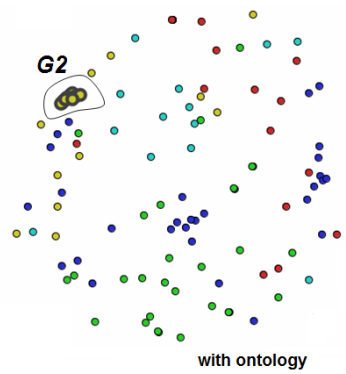
## Ontology

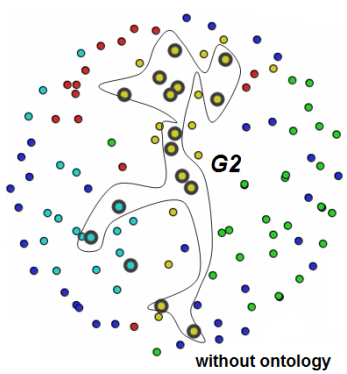


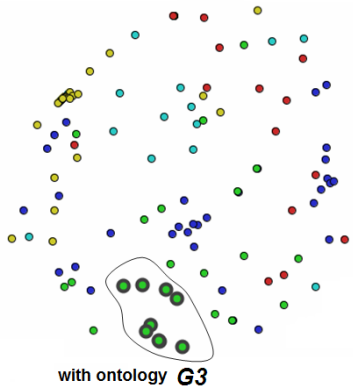



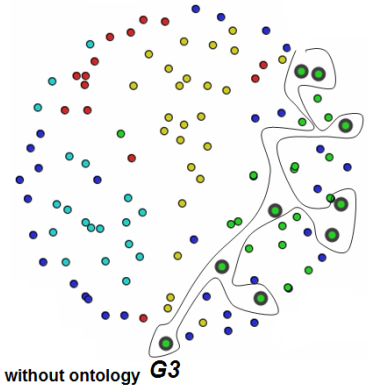



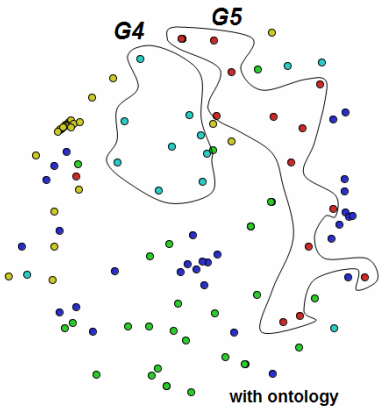



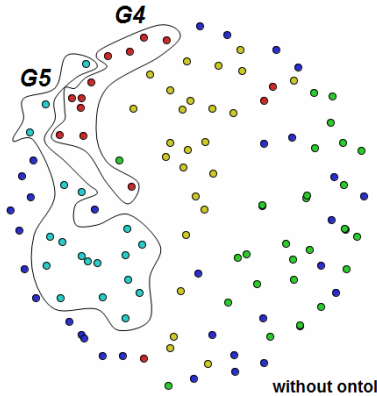




- *G1- Integration Testing of Aspect-Oriented Programs*
- *G2- Verification, Validation and Testing of Web-Services Composition*
- *G3- Mutation Testing of Aspect-Oriented Programs*
- *G4- Software Testing in Agile Methods*
- *G5- Quality of Component-Based Software Development Processes*

## Notable points

- G4 – "Software Testing on Agile Methods" showed the **worst** results;
- **Cause:** OntoTest did not include concepts from the "Agile Development" domain;
- Improvement on the case study: New concepts (and synonyms) added to OntoTest.

**Conclusions after other interactions**

- An ontology can **quickly** become outdated or limited, depending on the rate of development of its research area;
- The **absence** of some concepts makes document representation difficult and affects the final projection;
- Documents' authors do not necessarily follow domain writing conventions;
- The use of ontologies to improve visualization of document sets is **promising**, **however**, the domain has to be effectively represented, with many variations of concepts.

1 Introduction

2 SLR-VTM

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## Aims of this Study

- to investigate whether graph representations (particular type of graphical representation, i.e., graphs) result is better **comprehensibility** than tables when presenting SLR results;
- to investigate whether interpretation using graphs impacts on **performance** (i.e., the time consumed to analyse and understand the data).

## Our contention

**Graphical** representations should **increase** the comprehensibility of SLR outcomes and **decrease** the time required to analyse those outcomes.

According to Kitchenham et al. [Kitchenham and Charters, 2007] graphical representations of results are often easier for readers to understand than complicated tables.

## Preparation of the Experimental Instrument

We selected an SLR published in the literature [Kitchenham et al., 2009] and used two different formats (i.e. tables and graphs) to represent its results in three different combinations:

1. table format only;
2. graph format only and
3. a mixture of tables and graphs.

– 24 participants with varying levels of experience with research and SLRs - eight participants for each type of form.
– 13 questions.

# Table and Graph Format

## Original Format [Kitchenham et al., 2009]

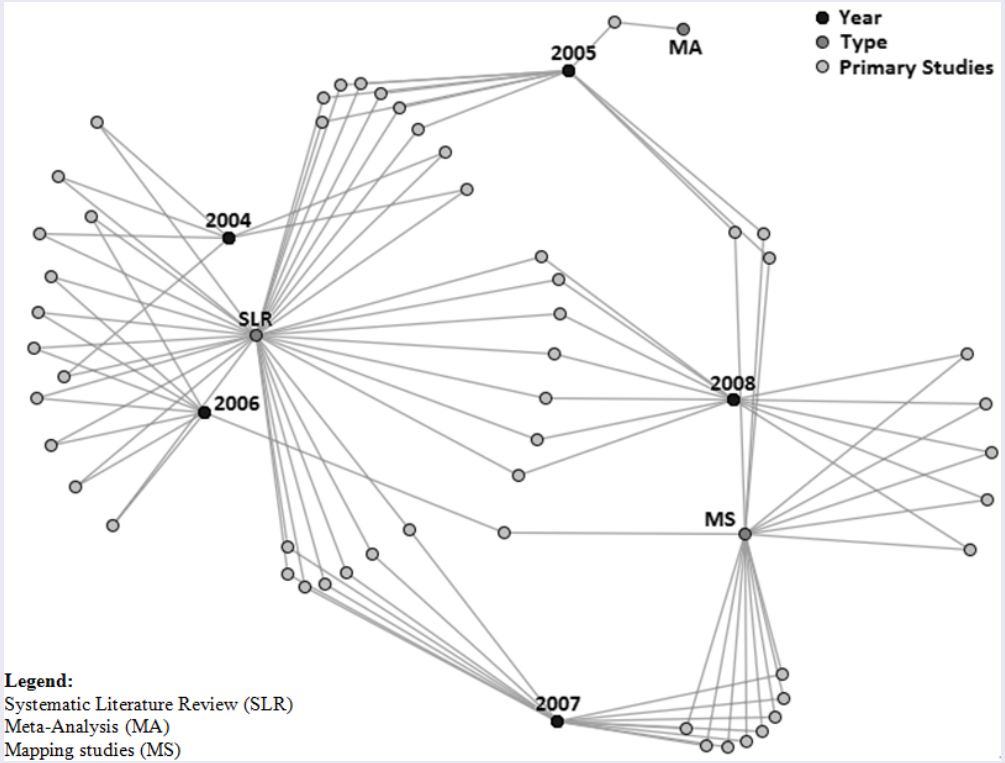
| Primary Study | Type | Year |
|---|---|---|
| p_1 | MS | 2006 |
| p_2 | MS | 2007 |
| p_3 | MS | 2007 |
| p_4 | SLR | 2004 |
| p_5 | MS | 2007 |
| p_6 | SLR | 2005 |
| p_7 | SLR | 2005 |
| p_8 | MS | 2008 |
| p_9 | SLR | 2006 |
| p_10 | SLR | 2007 |
| p_11 | SLR | 2007 |
| p_12 | SLR | 2006 |
| p_13 | SLR | 2007 |
| p_14 | SLR | 2005 |
| p_15 | SLR | 2004 |
| p_16 | SLR | 2004 |
| p_17 | MS | 2008 |
| p_18 | SLR | 2007 |

...

| Primary Study | Type | Year |
|---|---|---|
| p_37 | SLR | 2004 |
| p_38 | SLR | 2004 |
| p_39 | SLR | 2006 |
| p_40 | SLR | 2008 |
| p_41 | MS | 2007 |
| p_42 | MS | 2007 |
| p_43 | SLR | 2008 |
| p_44 | SLR | 2005 |
| p_45 | SLR | 2007 |
| p_46 | MS | 2007 |
| p_47 | SLR | 2005 |
| p_48 | MS | 2005 |
| p_49 | SLR | 2006 |
| p_50 | MS | 2008 |
| p_51 | MS | 2005 |
| p_52 | SLR | 2006 |
| p_53 | SLR | 2008 |

**Legend:**
Systematic Literature Review (SLR)
Meta-Analysis (MA)
Mapping studies (MS)

## Modified Format




Example of the conversion from a table to a graph using PEx-Graph tool [Andery et al., 2009].

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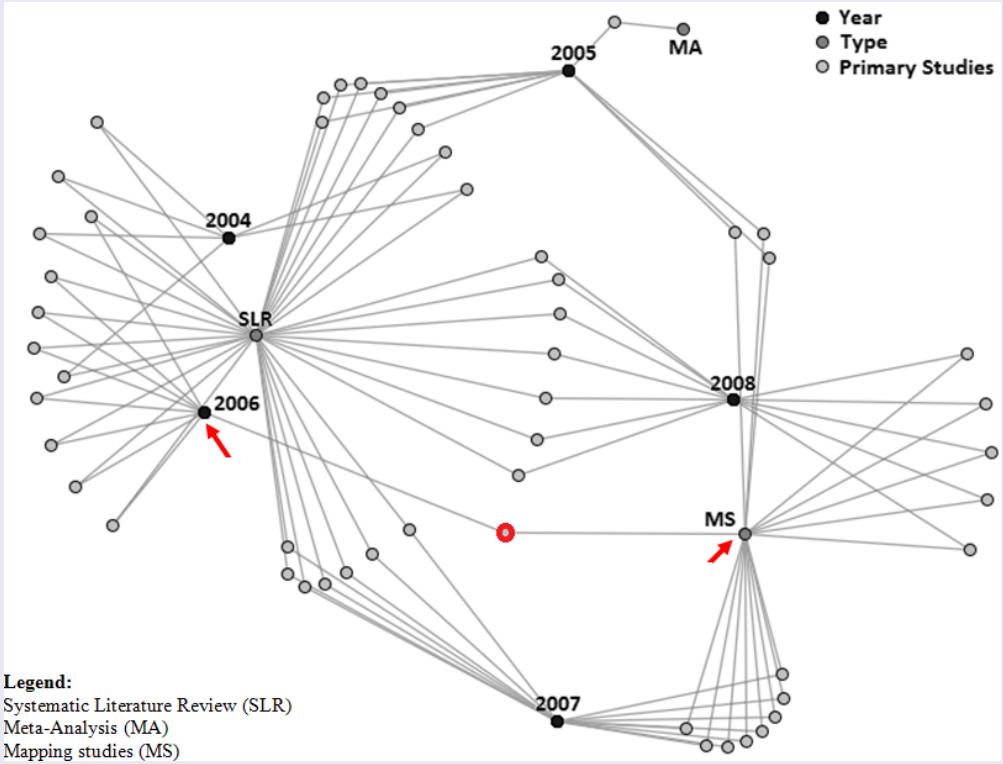


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**Legend:**
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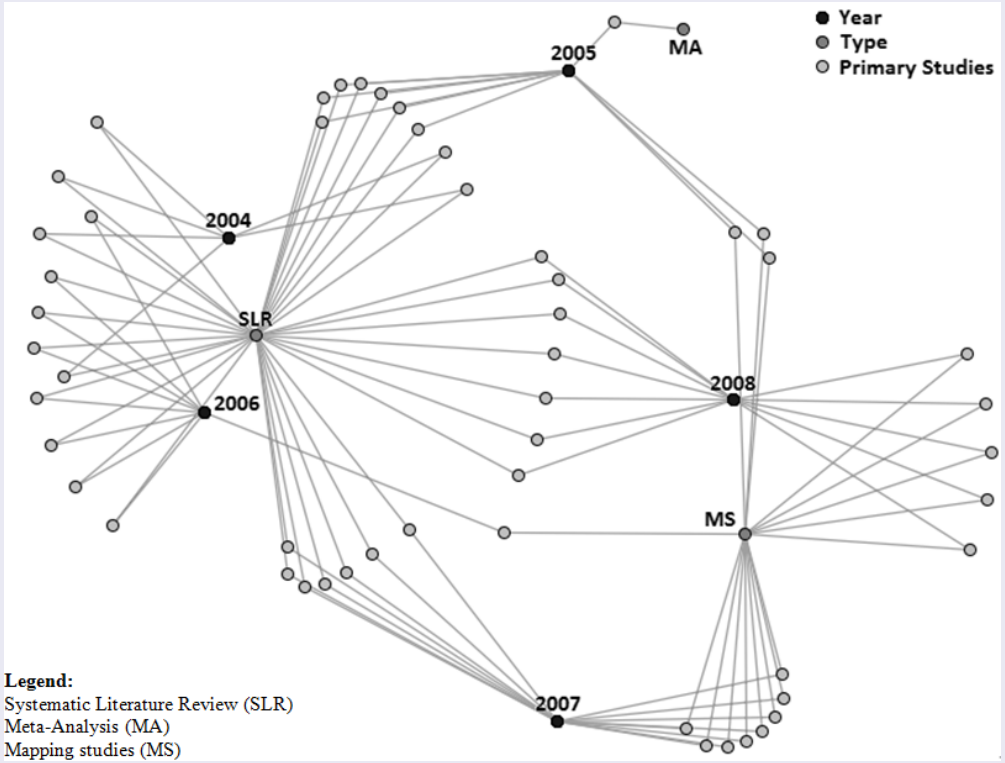
Meta-Analysis (MA)
Mapping studies (MS)

## Modified Format




Example of question: Is SLR the majority type of publication? Yes ( ) No ( )

# Table and Graph Format

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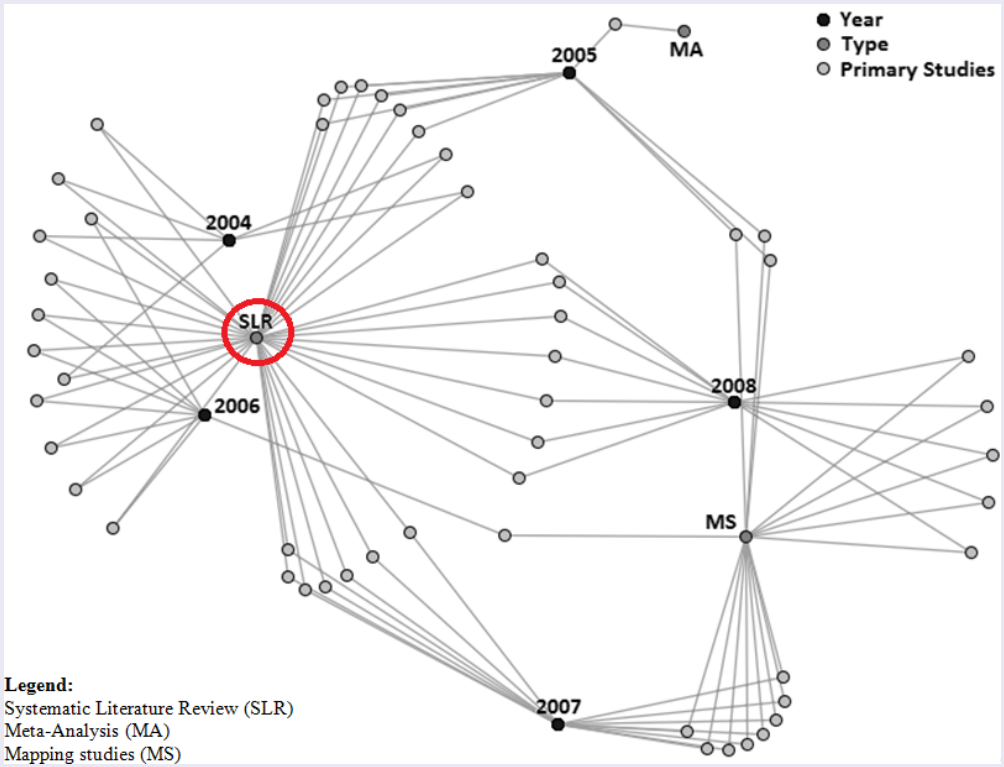
| p_49 | SLR | 2006 |
| p_50 | MS | 2008 |
| p_51 | MS | 2005 |
| p_52 | SLR | 2006 |
| p_53 | SLR | 2008 |

**Legend:**
Systematic Literature Review (SLR)
Meta-Analysis (MA)
Mapping studies (MS)

## Modified Format




Example of question: Is SLR the majority type of publication? Yes ( x ) No ( )

# Summary of Results

Graph

| Experience | Score | % Score | Time |
|---|---|---|---|
| Master 1 | 12/13 | 92.3 | 12'00" |
| Master 2 | 12/13 | 92.3 | 07'00" |
| PhD 1 | 12/13 | 92.3 | 10'23" |
| PhD 2 | 13/13 | 100 | 11'00" |
| PhD 3 | 12/13 | 92.3 | 11'00" |
| PhD 4 | 12/13 | 92.3 | 12'00" |
| Expert 1 | 13/13 | 100 | 05'00" |
| Expert 2 | 11/13 | 84.62 | 04'00" |
| | **Average:** | **93.3** | **09'15"** |

# Summary of Results

Table

| Experience | Score | % Score | Time |
|---|---|---|---|
| Master 3 | 11/13 | 84.62 | 52'00" |
| Master 4 | 12/13 | 92.3 | 45'00" |
| PhD 5 | 11/13 | 84.62 | 13'50" |
| PhD 6 | 13/13 | 100 | 47'00" |
| PhD 7 | 11/13 | 84.62 | 34'00" |
| PhD 8 | 12/13 | 92.3 | 21'00" |
| Expert 3 | 12/13 | 92.3 | 31'00" |
| Expert 4 | 11/13 | 84.62 | 09'00" |
| | **Average:** | **89.4** | **31'56"** |

# Summary of Results

## Mixed (Graphs and Tables)

| Experience | Score | % Score | Time |
|---|---|---|---|
| Master 5 | 12/13 | 92.3 | 22'00" |
| Master 6 | 11/13 | 84.62 | 26'00" |
| PhD 9 | 11/13 | 84.62 | 10'50" |
| PhD 10 | 12/13 | 92.3 | 08'00" |
| PhD 11 | 12/13 | 92.3 | 17'00" |
| PhD 12 | 11/13 | 84.62 | 22'00" |
| Expert 5 | 08/13 | 61.54 | 11'00" |
| Expert 6 | 13/13 | 100 | 22'00" |
| | **Average:** | **86.5** | **17'25"** |

# Summary of Results

## Summary – Comprehensibility

| | |
|---|---|
| **Graph Average:** | **93.3** |
| **Table Average:** | **89.4** |
| **Mixed (Graphs and Tables) Average:** | **86.5** |

- The graph representation was greater than that of the tables and the tables and graphs combined. **However**, ANOVA testing showed that the difference between the average scores of the participants using the three forms was not statistically significant.
- We conclude that the accuracy in **comprehending** results presented in tables is **no** different to that of graphs.

# Summary of Results

## Summary – Time

| | |
|---|---|
| **Graph Average:** | **09'15"** |
| **Table Average:** | **31'56"** |
| **Mixed (Graphs and Tables) Average:** | **17'25"** |

- Graphs, overall, have been observed as the **least** time-consuming format for understanding the data presented in the SLR.
- On the other hand, tables have been observed as the **higher** time-consuming format.
- **ANOVA** testing confirms that the difference between the average **time** taken by the participants to understand the data presented in each of the three forms **is significant**.

## Experiment's Results

- the **graphical representation** of SLR data led to a **reduction** in the **time** taken for its analysis, without any loss in data comprehensibility;
- the analysis of **graphical** data proved to be **faster** than the analysis of tabular data;
- there is **no** difference in **comprehensibility** whether using tables, graphical format or a combination.

## Conclusion

**Graphs** are a suitable alternative to tables when it comes to representing the results of an SLR.

1 Introduction

2 SLR-VTM

3 SLR-VTM Review

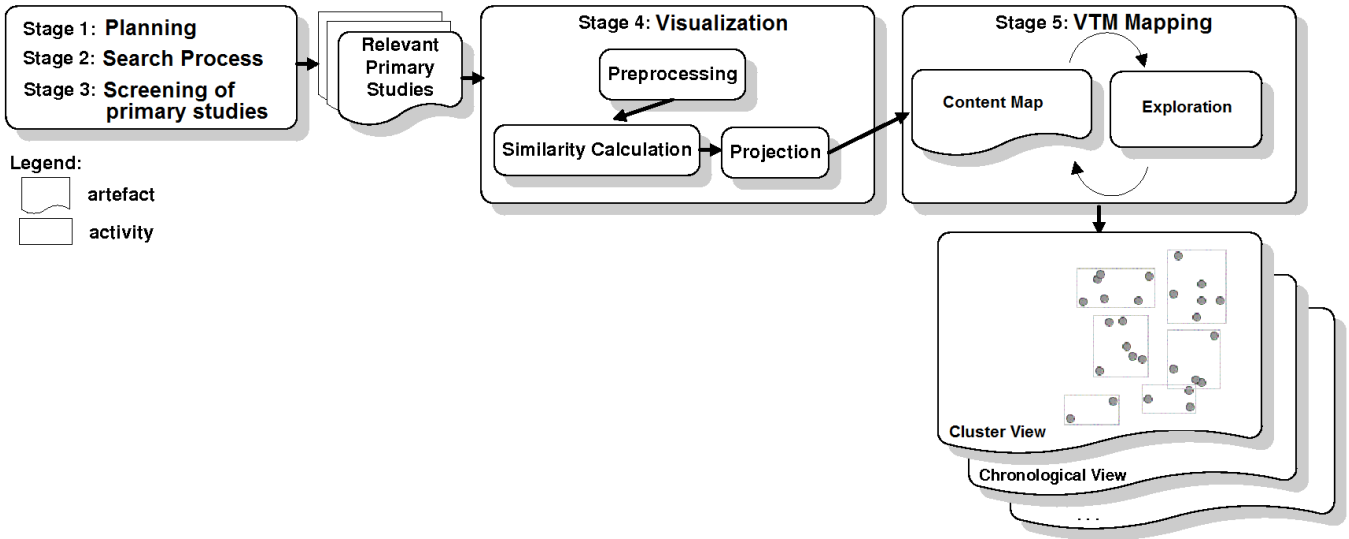
4 Ontology

5 Graphs

6 SM-VTM

7 Conclusions

Systematic Mapping based on Visual Text Mining **(SM-VTM)** applies VTM to support the **categorization** and **classification** in the SM.



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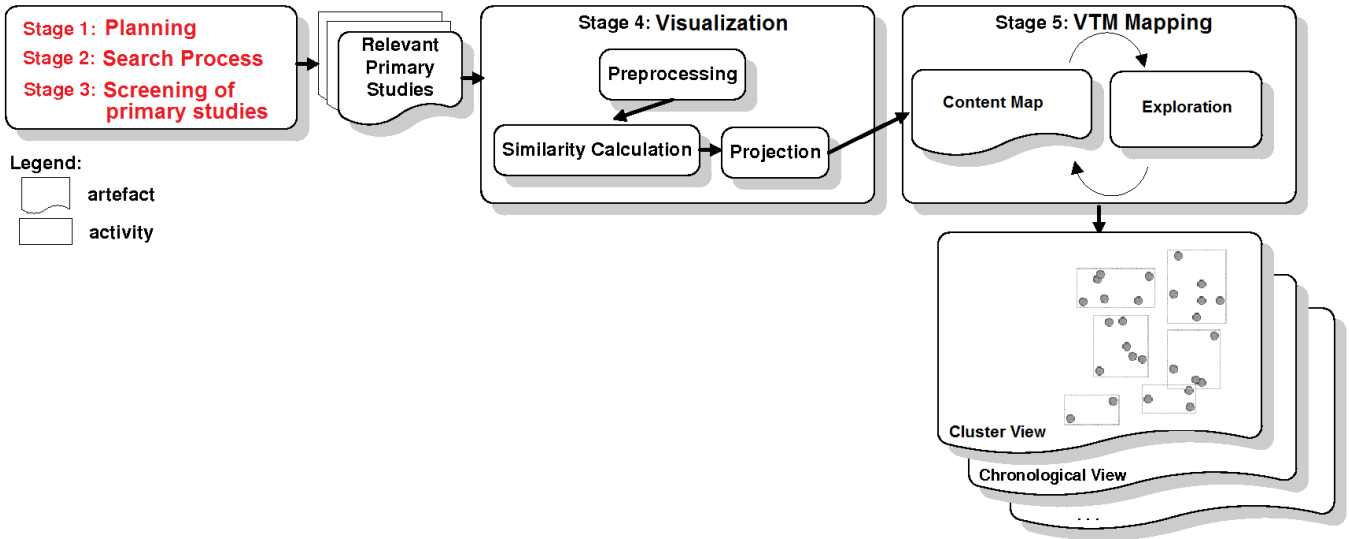
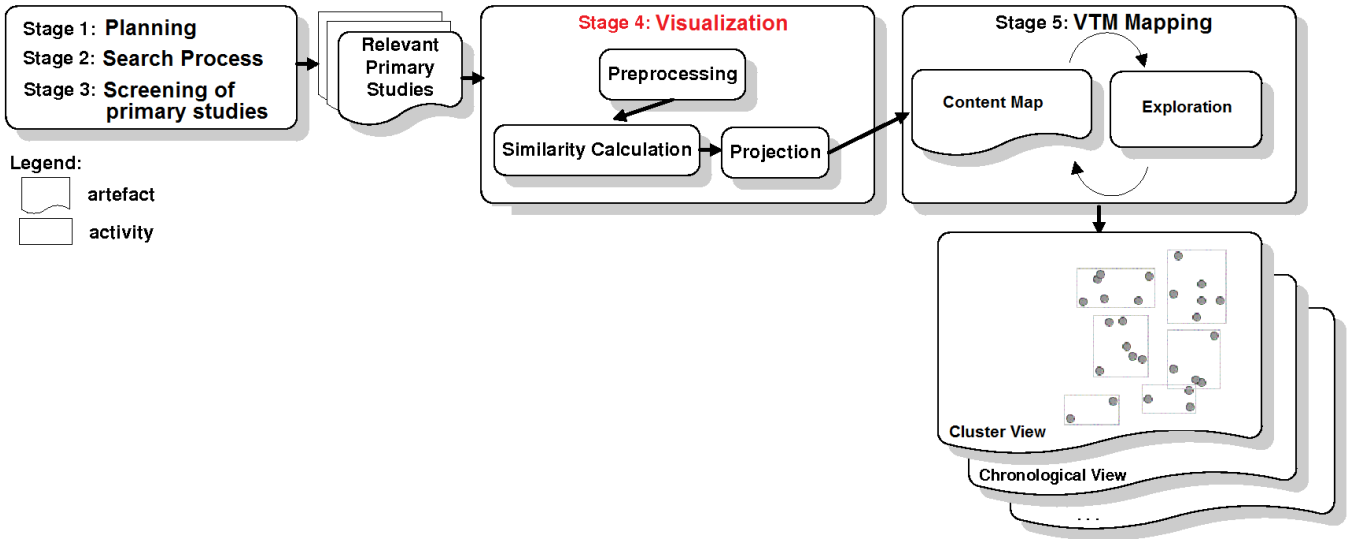


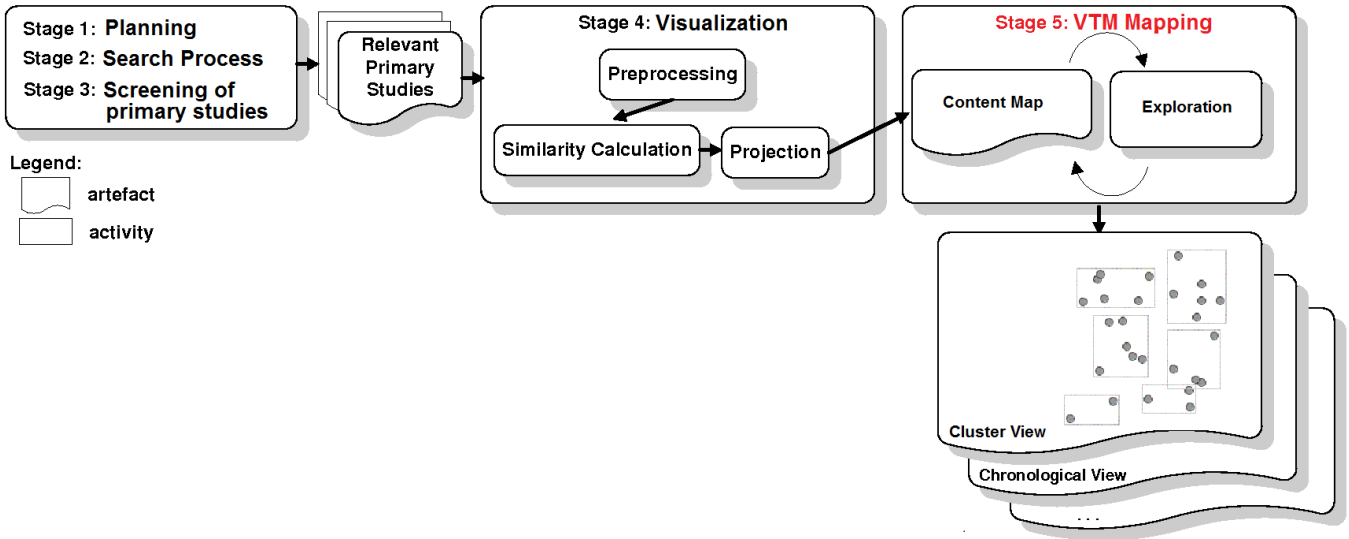

The **first three stages** of our approach (planning, search process and screening of primary studies) are **identical** to the **traditional** SM approach.

Systematic Mapping based on Visual Text Mining **(SM-VTM)** applies VTM to support the **categorization** and **classification** in the SM.




**Stage 4** aims at the generation of a visual representation of the primary studies **(content map)**.

Systematic Mapping based on Visual Text Mining **(SM-VTM)** applies VTM to support the **categorization** and **classification** in the SM.




In **Stage 5**, **categorization** – Topic Establishment – and **classification** – Clustering – activities are conducted.

# Case Study using SM-VTM

- In order to demonstrate the **use** of our approach, we compared results of **two** systematic mappings:
  1. one performed **manually** - Study 1
  2. another using the **SM-VTM** - Study 2

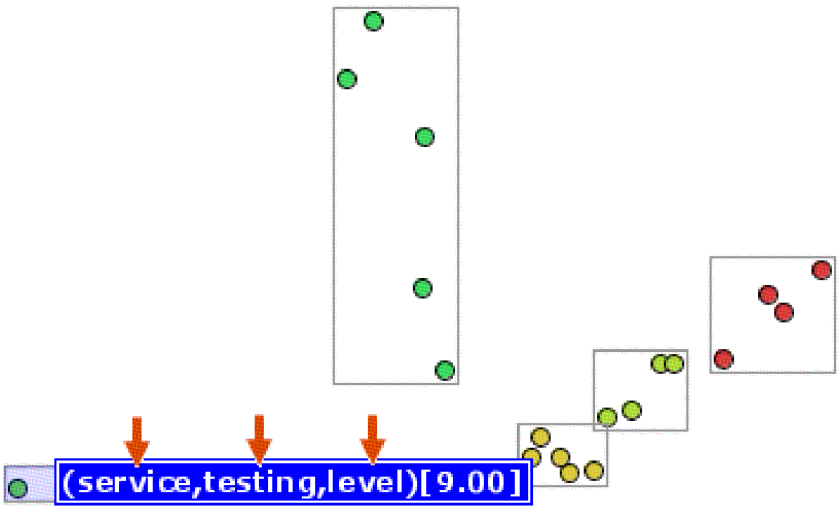
# Study 1

## Systematic Mapping conducted by [Afzal et al., 2008]

- Area: Search-Based Software Testing (SBST);
- **Categories** established:
  1. **non-functional properties**
     (safety, usability, buffer overflow, quality of service (**qos**) and execution time)
- The primary studies (**35**) are distributed between 1996 and 2007.

# Study 2 - Stage 5: Topics

## Topics

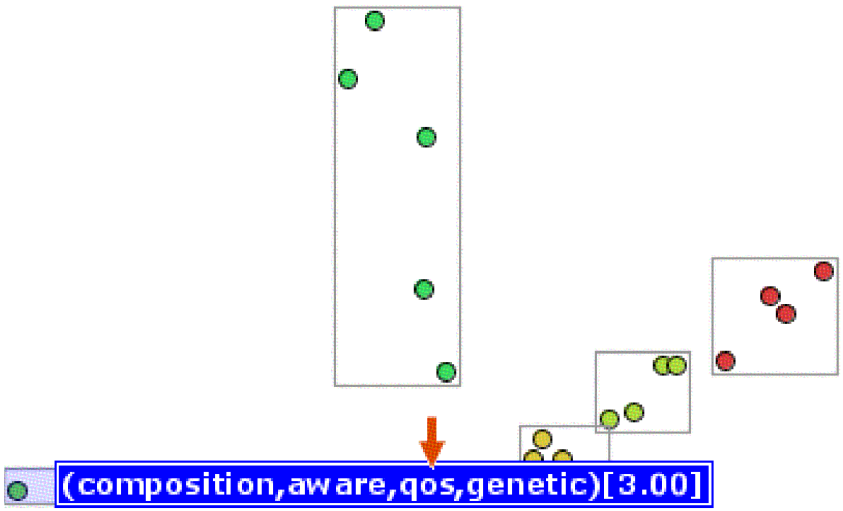



## Description: First Interaction

- The topics (created by Revis) were **little** representative.
- Aiming at the generation of **more representative** topics, a number of generic terms was inserted in the list of **stopwords**.
- **4** other interactions: **22** terms were manually inserted in the list of **stopwords**.
- **Results:** Cluster View and Chronological View

# Study 2 - Stage 5: Topics

## Topics

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- **4** other interactions: **22** terms were manually inserted in the list of **stopwords**.
- **Results:** Cluster View and Chronological View

# Views

## Cluster View

- This **view** presents a set of **clusters** and related **topics**.
- The **topics** represent the **categories** of the systematic mapping.

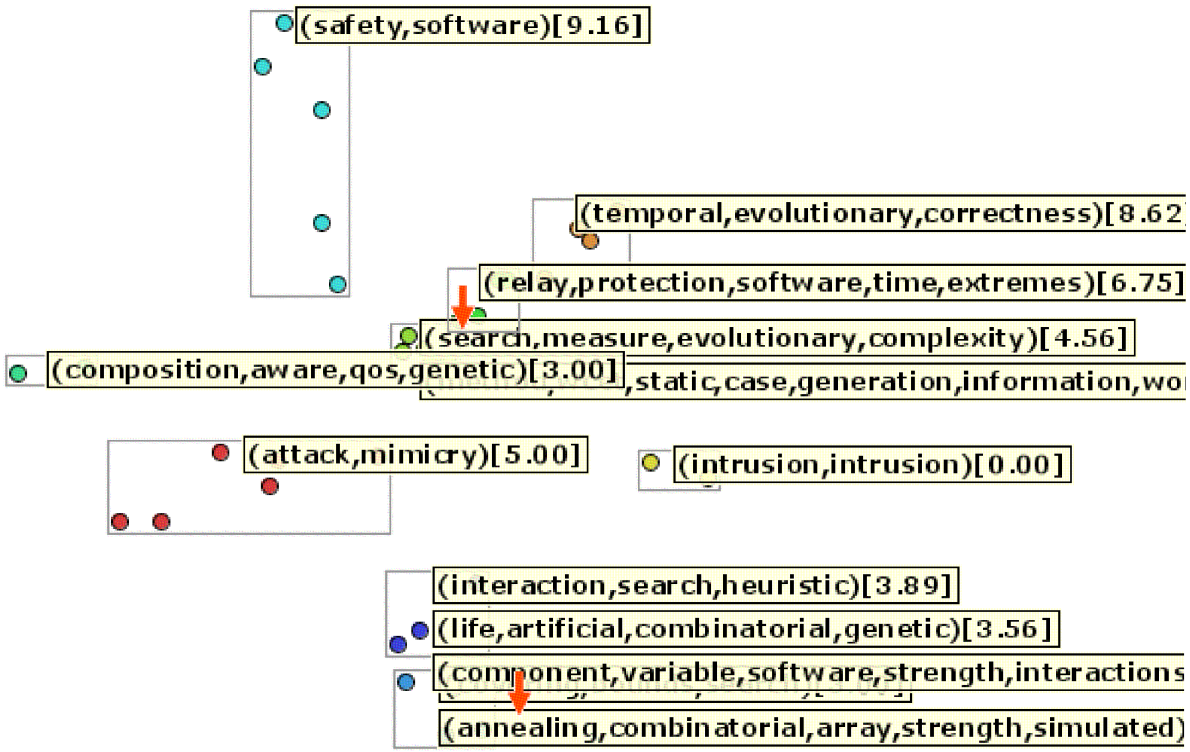
## Chronological View

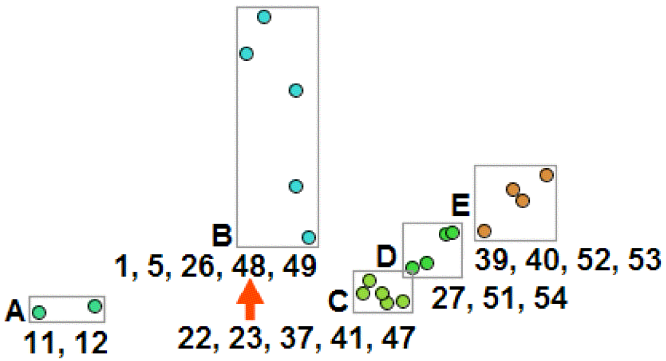
- This view provides a visual representation of the primary studies indicating their **year** of **publication**.

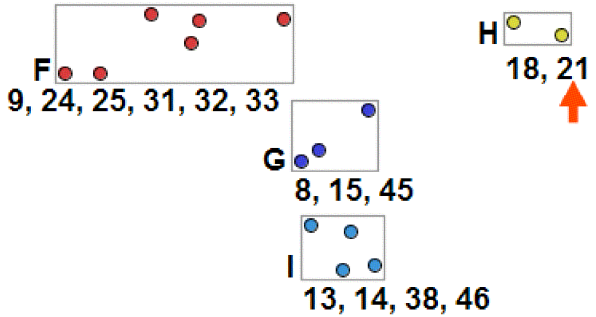
**Based on these two views, the mapping can be built.**

## Cluster View

- The **cluster view** is the content map containing the **clusters** and their respective **topics**.

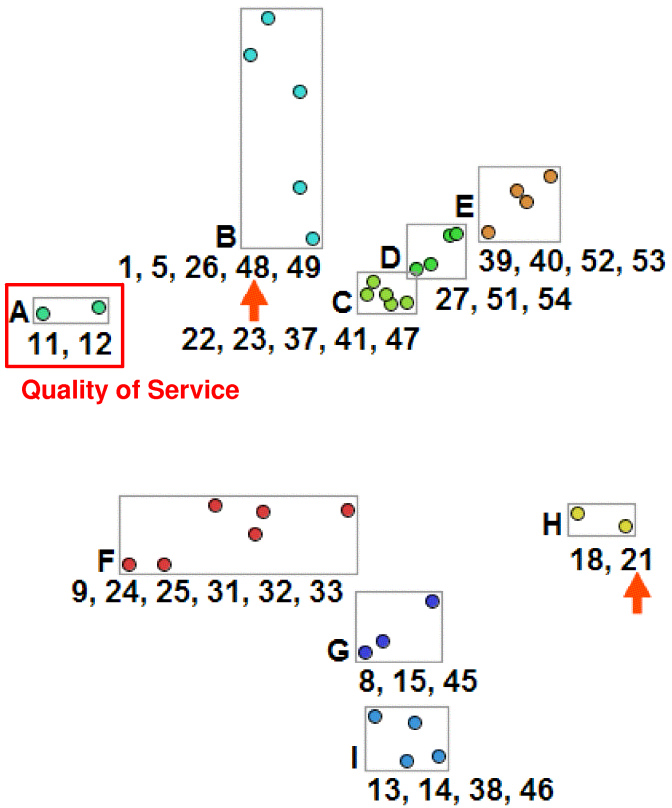




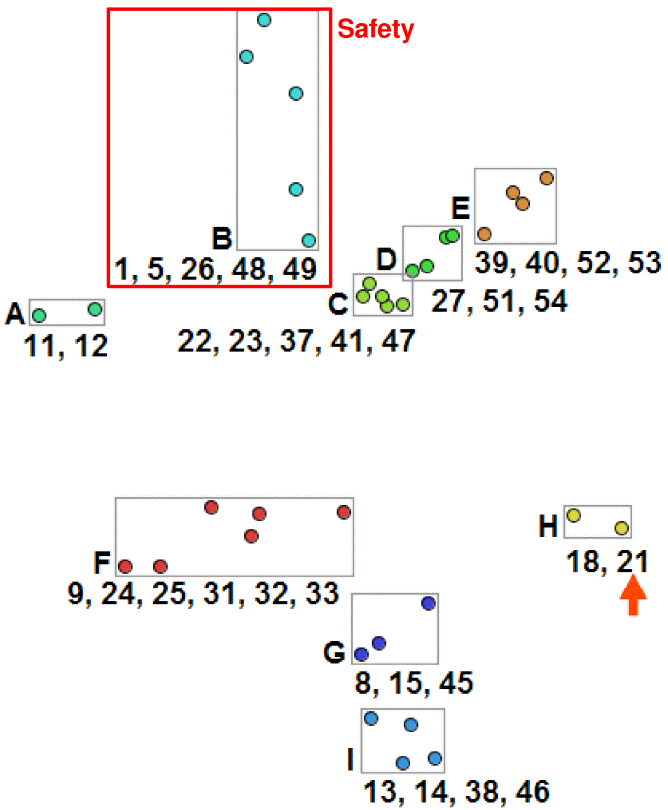

## Comparative

- Only the studies numbered as **21** and **48** were not classified in the same way as in Studies 1 and 2.




## Comparative

- Only the studies numbered as **21** and **48** were not classified in the same way as in Studies 1 and 2.
- Cluster **A** grouped the primary studies classified in Study 1 as **Quality of Service**

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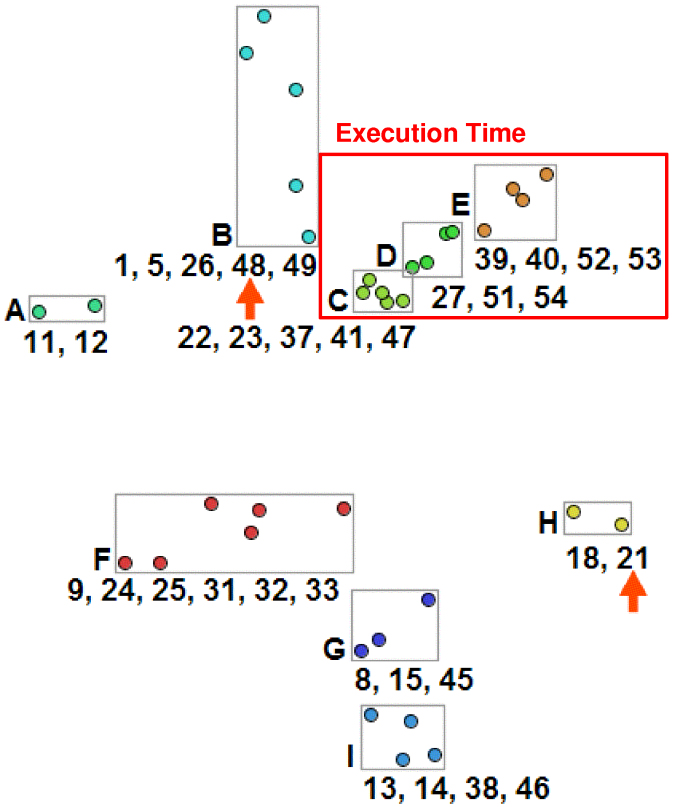


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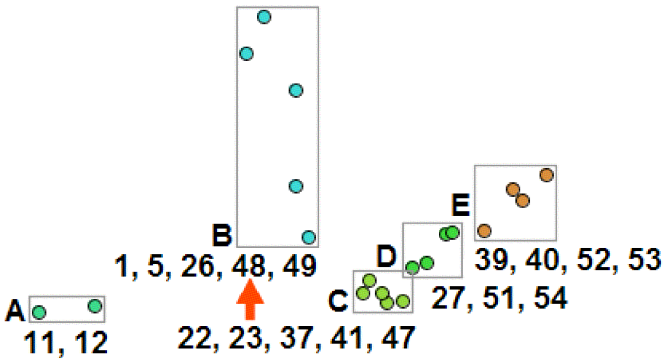


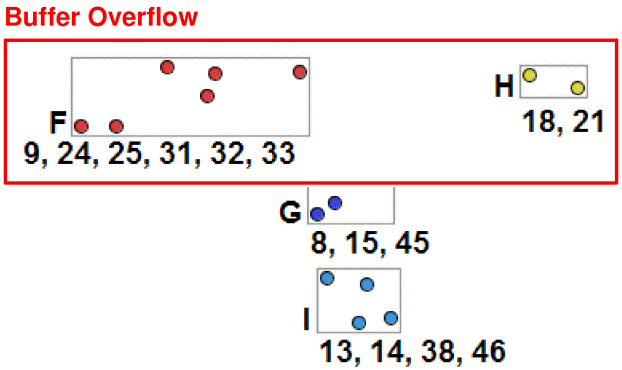


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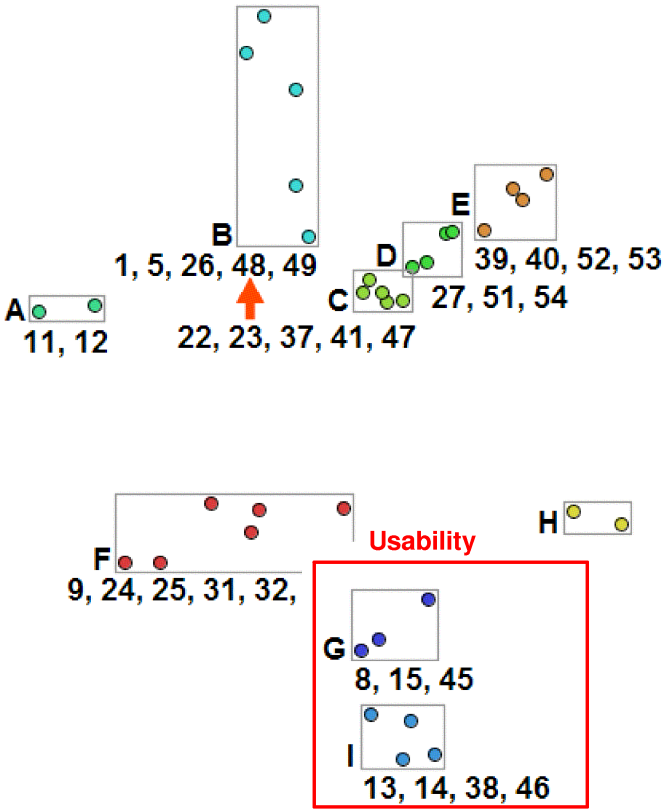


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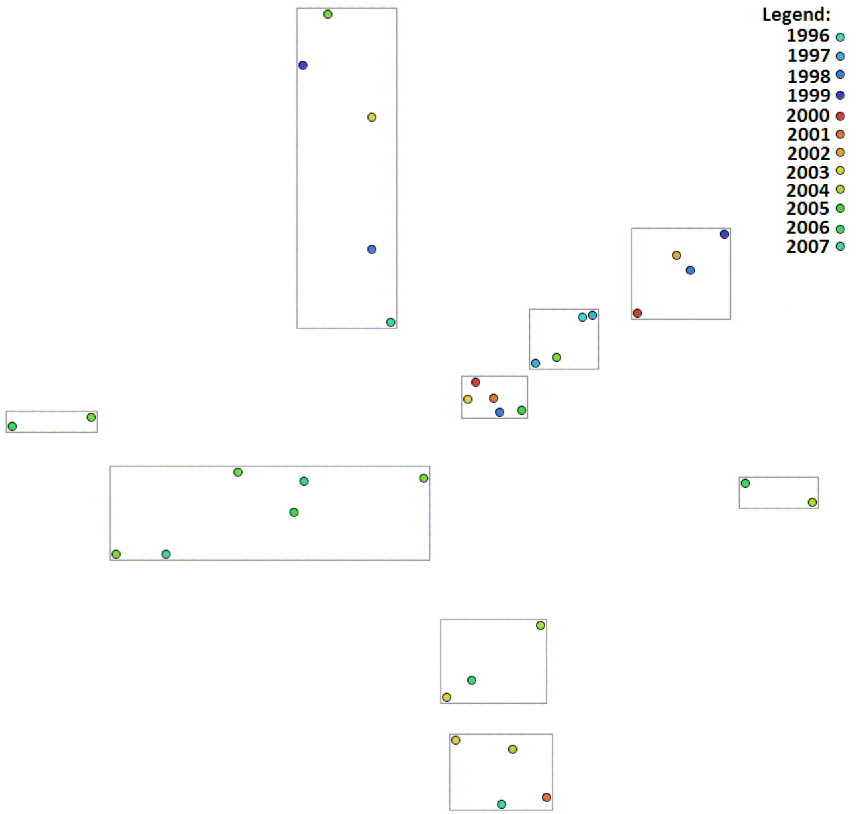
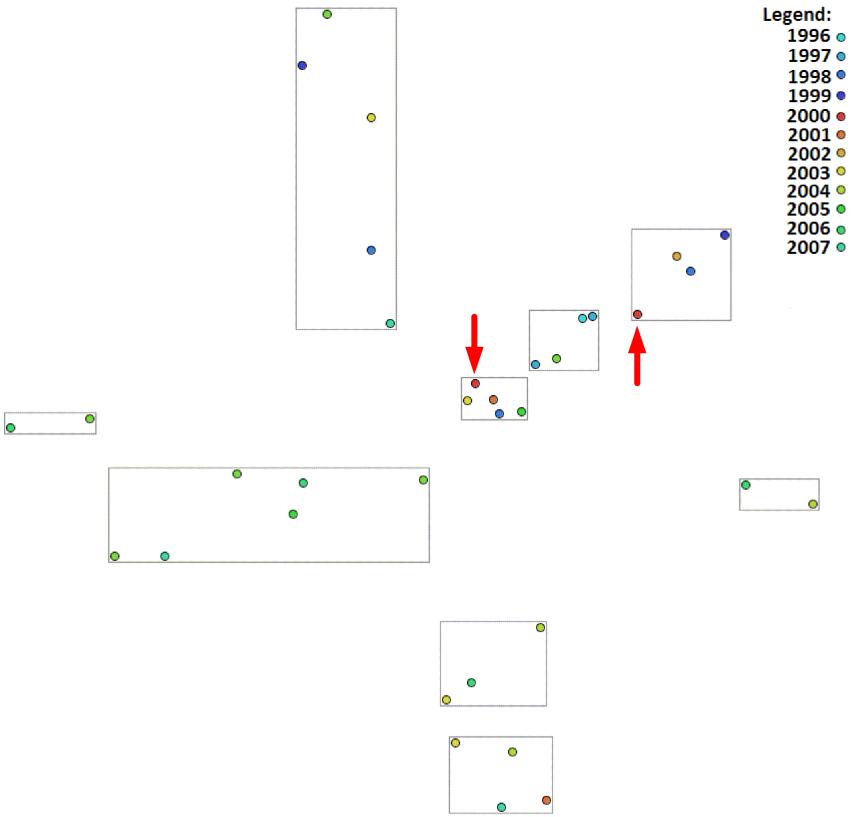
- Clusters **F** and **H** – **Buffer Overflow**
- Clusters **G** and **I** – **Usability**

## SM-VTM




### Chronological View

- The points contained in the Cluster View were coloured automatically by Revis to represent the publication **year** of each primary study.
- This view is very **useful** to identify concentration of primary studies throughout the **years**.
- **2000**: Lowest number of primary studies (red points).

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## Results

- The use of **VTM** in systematic mapping has shown to be very useful.
- We have proposed a different **point of view** to represent a systematic map:
  1. **Cluster View** and
  2. **Chronological View**
- Users can explore these views, obtaining **information** to build other visual representations of a systematic map.
- Our approach provides an initial **categorization** (**Topics**) and **classification** of the papers (**Clusters**).
- Our approach is automated using a supporting tool (**Revis**).

1 Introduction

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## Contributions of our work

- one **SM** to collect evidences of the use of VDM to support the SLR process;
- a new approach based on **VTM** containing different visualizations and strategies to support the **selection** of primary studies in an SLR;
- a new approach based on **VTM** containing different visualizations and strategies to support the **review** of selection of primary studies in an SLR;
- a new approach based on **VTM** to support the **categorization** and **classification** stages of **SM**;
- an automated **tool** to support the selection and review selection activity in SLRs;
- **empirical evidence** regarding the effects of the use of **VTM** in an **EBSE** context;
- one case study to evaluate the use of **ontologies** in the construction of visual representations;
- one case study to evaluate the use of **graphs** to represent the SLR results.

## Limitations

- the relatively **small sample** size used in the **case studies**, limiting the use of the data for more advanced statistical analysis;
- to load the primary studies into the VTM tool (Revis), the studies should be in ***bibtext*** format, and for any other format, for example, PDF, it is necessary to **convert** them prior to the analysis;
- the effect of changing **different parameters** of the **clustering** technique (i.e., number of clusters chosen by the users) was **not explored**.

## Possible Research Directions

**Use of VTM to support the selection of primary studies**

- explore **other types** of **VTM techniques** to be incorporated in the SLR-VTM approach to support the selection activity;
- **replicate** the case study involving **more** students as well as SLR experts;
- test the **individual effectiveness** of the various **visual representations** in the SLR-VTM approach, analysing the **trade-off** between the **number of visualizations** and the incremental benefit to be gained from each one in terms of performance and effectiveness in selecting primary studies;

## Possible Research Directions

**Use of VTM to review the selection of primary studies**

- design and implment a **tool** to **convert**, as automatically as possible, PDF documents into text format (input format of VTM tool – Revis).

## Possible Research Directions

**Visualization of document collections using ontologies**

- explore other **types** of ontology-based vector space construction **strategies**;
- **replicate** the case study involving **other** information **domains** represented in the ontologies (i.e., medicine, social sciences, information systems, among others).

## Possible Research Directions

**Analysis of the use of graphs to represent the results of SLR**

- carry out similar experiments with a **larger sample** size involving **other types of graphs** and using results from other SLRs.

## Possible Research Directions

**Use of VTM to support categorization and classification in SM**

- **apply** the SM-VTM approach to **different** topics and domains of interest;
- explore the effects of using **different** **clustering** techniques;

- **Thank you for your attention!**
- **Any question?**

**First slide**

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A systematic mapping study on non-functional search-based software testing.
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