ATHABASCA UNIVERSITY

A SYSTEMATIC MAPPING STUDY OF APPROACHES
BRIDGING SOFTWARE PRODUCT LINE AND
SERVICE-ORIENTED ARCHITECTURE

BY

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A comprehensive review essay submitted in partial
fulfillment of the requirements for the degree of

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ATHABASCA UNIVERSITY

The undersigned certify that they have read and recommend for acceptance the master’s essay “A SYSTEMATIC MAPPING STUDY OF APPROACHES BRIDGING SOFTWARE PRODUCT LINE AND SERVICE-ORIENTED ARCHITECTURE” submitted by ESANANTH MURUGESUPILAILAI in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE in INFORMATION SYSTEMS.

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Dragan Gašević, Ph.D.
Supervisor

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Zoran Jeremic, Ph.D.
Examiner

Date: _______________________

Date: ________________________
DEDICATION

I would like to dedicate this work to my father, Arulappah, my mother, Anuratha, and my late grandfather, Anathamyl Singaram, for teaching me the value of education and encouraging me to pursue my interest in Computer Science.
ABSTRACT

Service Oriented Architectures (SOA) and Software Product Lines (SPL) have individually proven to be software engineering concepts that create added value to the development of software systems. Recently, the research community has recognized and investigated potentials for combining these two concepts. However, there have been no literature surveys that systematically map the present research results in combining the two. This paper presents results of a preliminary work on a systematic mapping study of research papers that report on combining SOA and SPL. The work is based on the papers published from 2002 to mid-2010. This paper reports on various aspects of the analyzed literature, including the motivations for combining the two concepts; contributions to specific stages of software engineering lifecycles; types of synergies and characteristics that are accomplished through combinations of the two concepts; and the methods used for and the rigor of the evaluations of the research conducted on the studied topic.
ACKNOWLEDGEMENTS

I am grateful for the support, guidance and mentoring from my essay supervisor, Dragan Gašević. As well as Bardia Mohabatti for his support and continual encouragement during all phases of the essay.

I would like to thank my employer, Canada Revenue Agency, for their commitment in providing support to pursue higher education while employed full-time.

Finally, this work would not have been possible without the support, patience and encouragement from my wife, Ines David.
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CHAPTER 1

INTRODUCTION

Throughout the lifecycle of software development, numerous techniques and tools encompassing languages, platforms, and hardware have dawned and demised. Distinct tools and techniques have been used to fulfill the business requirements as they seemed adequate. Over time, the application requirements grew and now, there are software systems that contain a wide variety and flavours of programming languages as well as platforms they reside in. One of the largest concerns that are on the rise currently is inefficient software development due to exponential increase in software system size and complexity. This is due to continual evolution, expansion, and the need to create applications that satisfy comprehensive business requirements. There are two cross-disciplinary paradigms that are changing the way software applications have been proposed, namely, Service Oriented Computing (SOC) and Software Product Line Engineering (SPLE) [1][2][3][4][5][6].

In respect to the demand, functionality abstraction being specified and created has progressed from modules, to objects, and now to services. In addition, there is a need for integration and exploitation of multiple products to provide services economically, and as a result, the distinct software products of one domain are being considered as a family or as a suite instead of a single product [7]. To address this, respectively, Service Oriented Architecture (SOA) and Software Product Line (SPL) engineering approaches are being used significantly when designing information systems.

SOA and SPL have individually proven to be software engineering concepts that add value to information systems architecture. There are diverse approaches that have
been brought to attention that combines both concepts, SOA and SPL. However, there are very little literature mapping study of the existing approaches combing the two concepts. This paper reports on the results of a systematic mapping of approaches combining SOA and SPL that have been evaluated by collecting and surveying research literature. This is accomplished by utilizing a systematic literature study of research papers published in this area from 2002 to 2010 in order to form the basis for evaluation. To assess the data, a systematic mapping study was selected, as it aims to minimize error and bias of the researchers conducting the survey, thereby increasing the quality of the study. This is achieved by employing rigorous methods to identify, appraise and synthesize research by establishing effective research questions prior to the actual study [49]. The research will address the following questions:

- What type of research is being done on combining SOA and SPL principles and what are the main contributions of that research?
- What are the motivations and the software engineering lifecycles in the existing research that combines the SOA and SPL principles?
- What are the synergies and characteristics that are being explored in the present research that combines SOA and SPL?
- What kind of the evaluations has research on combining SOA and SPL used and what is the quality of the evaluations?
- What kind of future research directions have been reported in the present literature on combining SOA and SPL principles?

In addition to establishing effective research questions, content analysis is utilized in our work to analyze and extract the collected data. Subsequently, the analysis is
reported accordingly. The expected results from this evaluation should benefit the researchers in understanding the current state and provide a starting point to future research in this field.

The remainder of this paper is structured as follows: Chapter 2 explains the details in regards to the systematic review methodology used in the study. This chapter outlines the structure behind the planning stage of the review, execution stage of the review and details the data collection instrument (a set of survey questions) used to collect data. Chapter 3 presents the results, as well as the analysis behind the study. It also describes the overview of the studies, evaluation methods used, quality of the evaluation, and validation details. In addition, it presents the findings of combining SOA and SPL, as well as the purpose, and then offers a future outlook. Chapter 4 provides an in-depth discussion on the results, while Chapter 5 outlines the limitations of the study. Lastly Chapter 6 concludes the paper.
CHAPTER 2
METHOD

2.1 Study Design

Systematic mapping study was used as the study method for the means of evaluating and interpreting the literary papers. The purpose behind utilizing the this method is due to its structure, as this method aims to present a fair evaluation of the research ensuring that it is trustworthy, rigorous and auditable [50]. This is accomplished through undertaking the study by using a predefined search strategy. The search strategy should enable the study to be complete and wholesome, without minding the researchers’ favoured hypothesis, in addition to sharing the evidence that does support the research. The advantages of using this mapping methodology is that it provides data in regards to patterns across a wide range of categories, and allows for combining various data to create coding schemes [50]. Some of the features that are unique to systematic mapping study as stated in [50] are:

- It starts by defining a study protocol that specifies the research question being addressed and the methods that will be used to perform the study.
- It is based on a defined search strategy that aims to detect as much of the relevant literature as possible.
- It documents the search strategy, so that the readers can access its rigour and completeness.
- It requires explicit inclusion and exclusion criteria to assess each potential primary study.
- It specifies the information to be obtained from each primary study including quality criteria by which to evaluate each primary study.
• It is a prerequisite for systematic analysis of the collected papers.

• It utilizes content analysis to code, extract and validate findings from the research.

There are numerous reasons for choosing this method, but the reasons this method was chosen for this study are [50]:

• To summarize the existing research already performed on combining SOA and SPL principles.

• To analyze and bring forward the identified gaps in current research in order to feed future research.

• To provide a current state position of this mapping study, so that new research can be built upon.

2.2. Research Objectives

Before starting the study, it is imperative that the researcher plans the mapping study. To ensure that this is done, the supervising team for this paper reviewed answers to the following checklist:

1. What was the research goal?

   To survey research literature systematically on the topic of combining SOA and SPL principles.

2. What is the abstract outline in regards to the focus of the paper?

   A systematic mapping study is to be conducted utilizing the data collection instrument presented in 2.3. Data Collection Instrument to collect the data. Then content analysis is to be performed on the collected data by creating coding schemes, as outlined in 2.5. Content Analysis. The analysis and findings obtained through content analysis is to be reported in Chapter 3.
3. What is the rationale for the research?

The growing significance in combining SOA and SPL principles call for a systematic mapping study of the literature in the area, so that current state and future direction of research in this area can be observed precisely. This research will be useful for researchers starting to explore this area to learn what the current state of the art is. Others will be able to learn what the open research questions are or to compare new research solutions with the findings given in the survey.

4. What are the timelines and planned schedules for the research?

Data Collection: April 2010 to October 2010

Coding and Analysis: November 2010 to February 2011

Reporting: March 2011 – May 2011

5. What are the anticipated results?

Provision of the current state of the research looking at the intersect of SOA and SPL; identification of the research being done, as well as any gaps that may be present.

6. What are the possible conclusions that can be reached based on the research?

Report the current state in this area, outline the research that is currently underway, as well as the future state.

7. What are the tools and resources needed to undertake the research?


8. What are the starting point references for this research?

The starting point references consisted of details in regards to what SOA and SPL are, as well as on how to perform systematic mapping study, and qualitative and quantitative analyses.
2.3. Data Collection Instrument

Once the answers to the above research questions were derived, a review protocol was introduced. This consisted of finding the underlying rationale in regards to the intersection of SOA and SPL, creating a repository of the research literature to be reviewed, and an instrument – a questionnaire with questions that were to be used for collection of data consistently in surveying all the papers. The supervising team created this instrument with a set of questions that were to be used in collecting the data. These questions were meant to mine and extract relevant trends and data pertaining to the papers published in this area. The questions from the questionnaire and the reasoning behind gathering data under each survey questions (SQ) are outlined below:

SQ1. What are the type of publication, the publication year and the name of the publication venue (Workshop, Conference, Journal, Other)?

*To determine the venue in which the research on combining SOA and SPL principles has been published and to narrow down the time of the publication.*

SQ2. What is the type/category of the paper? (Survey Paper, Evaluation Research, Solution Proposal, Position Paper, Experience Paper, Other/Suggested Category)?

*To categorize and to determine the types of research outcomes presented in the papers.*

SQ3. What is the motivation of the present research results on combining SOA and SPL principles? What research gaps have reported by the authors?

*To identify the reason/purpose behind combining SOA and SPL principles and to discover whether there were any tangents.*

SQ4. What is the major contribution of the paper (Process, Methodology, Models, Tool, Area Overview)?
To identify the contribution the paper is making to the particular part of the software engineering discipline.

SQ5. To which stage of the software engineering lifecycle does the paper focus on (Requirements Engineering, Analysis, Design, Implementation, Verification and Validation, Deployment, Maintenance)?

To determine the specific software engineering task and/or lifecycle stages the paper contributes to.

SQ6. Specify the kind of synergy between SPLs and Service-Oriented Computing (Applying SO to SPL – Integration of services in SPLs, Applying SPL to SO – Application of SPL principles in development of services, other).

To determine which concept is being used as the core methodology and/or the concept that is being improved by applying one to another.

SQ7. Depending on the kind of synergy (SQ6), explain the purpose and the manner of identified characteristics of the possible exploitation.

To further identify the exploitation.

SQ8. What kind of evaluation does the paper report on and what are the main findings of the evaluation?

To understand the findings/evaluations as stated by the author.

SQ9. What are the conclusions reported in the paper, open research questions and future research directions.

To identify the future state and any conclusions in regards to the current state.

2.4. Data Source and Search Strategy
The key activity in a systematic mapping study is data collection. To ensure that this is done adequately, a search strategy must be identified. The search and validation of the
papers were assisted by the supervising team; thereby ensuring that there were no biased paper selections. As the papers were being reviewed, bibliographic details were entered into a spreadsheet as each survey document was completed for a paper.

We used a blended search strategy to gather the papers. This included a combination of the following search strings:

- “service-oriented product line”.
- “service-oriented architecture”.
- “business process family”.
- “dynamic software product line”.
- “software service family”.
- “service customization”.
- “variability modeling”.

These strings were used to perform the pre-review search using the following scholarly search engines: ACM digital library, IEEE Explorer, Science Direct, Google Scholar, and Citeseer. In addition, we manually checked the following resources to gather papers:

- Proceedings of the software product line conference (SPLC).
- Proceedings of the International Conference on Software Engineering (ICSE).
- Proceedings of the International Conference on Service-Oriented Computing (ICSOC).
- Software Engineering Institute’s (SEI) technical reports on SPL.

The following criterion was used to include a paper in our study:

- Introduced an approach or had any context related to combining SOA and SPL.
- Reported an overview or evaluation of combining SOA and SPL.
And a paper was excluded from the study if the paper:

- was published prior to 2002.
- did not introduce an approach nor had any context in regards to combining SOA and SPL.
- did not report an overview of evaluation of combining SOA and SPL.
- was a short paper.

When the collection of data is performed by a predefined questionnaire, it is imperative that a form of quality assurance be in place to ensure that there is none or minimal contamination in regards to the data that is to be analysed. To ensure pristine data extraction was done via the survey, the data collected was stored in a repository, where random verification was done by a reviewer. After the data was collected and a coding scheme was established, again, the validity of the context as well as the extracted findings was validated by a subject matter expert researching in the field (PhD student).

2.5. Content Analysis

Content analysis consists of words and observations made on the words and phrases, not numbers [51]. In this study, by utilizing the data collection instrument, mentioned in Section 2.3, we used a narrative data collection scheme – questions were used that generated single words, brief phrases, and full paragraphs. As it is evident with the questions in Section 2.3, some had choices and straight forward answers, and others required detailed or summarized elaboration. Then, the data was tabulated based on categorizations and groups on a row by row format – each row containing data that corresponded to a paper, leading to a total of 48 rows. The primary categories were
labelled for data grouping using the directive from each survey questions from Section 2.3.

To ensure coherent mapping and analysis can be done with the data, when tabulating the data from the questionnaire, each paper was tagged with an identification number ranging from 1 to 48. The questions and the corresponding coding schemes are outlined below pertaining to each survey question from Section 2.3:

**SQ1** What are the type of publication, the publication year and the name of the publication venue (Workshop, Conference, Journal, Other)?

We categorized the papers in to the four categories as shown in Figure 1. In addition, we were able to extract the data via this categorization and prepare a chart (c.f., Figure 2) that contained the quantity of research literatures that were published chronologically from 2002 to 2010.

**SQ2** What is the type/category of the paper? (Survey Paper, Evaluation Research, Solution Proposal, Position Paper, Experience Paper, Other/Suggested Category)?

As part of this question, we categorized six categories accordingly as outlined in Table 1. In the initial question, even though there was a choice, Other/Suggested Category, for cases that did not fit the six pre-set entries, there were not any literatures that were ambiguous when it came to paper type, so this category was removed when presenting Table 1.

**SQ3** What is the motivation of the present research results on combining SOA and SPL principles? What research gaps have reported by the authors?

To extract the main themes behind the motivating factors, the categories outlined in Table 2. were created and described, accordingly.
SQ4 What is the major contribution of the paper (Process, Methodology, Models, Tool, Area Overview)?

To identify the contributions, the entries were categorized into five unique categories. The categories and descriptions can be found in Table 3. In addition, we categorized the contribution in terms of the specificity of the solution being presented or explored within the literatures in Table 12.

SQ5 To which stage of the software engineering lifecycle does the paper focus on (Requirements Engineering, Analysis, Design, Implementation, Verification and Validation, Deployment, Maintenance)?

The data from this question was entered into the six pre-set categories. Table 4 contains the categories and their corresponding descriptions.

SQ6 Specify the kind of synergy between SPLs and Service-Oriented Computing (Applying SO to SPL – Integration of services in SPLs, Applying SPL to SO – Application of SPL principles in development of services, other).

Data collected from this question was categorized accordingly into three categories; the details of the categorization are presented in Section 3.2 and Table 5.

SQ7 Depending on the kind of synergy (SQ6), explain the purpose and the manner of identified characteristics of the possible exploitation.

From the data collected under this question, we categorized the purpose behind combining SOA and SPL in to five categories as outlined and described in Table 11.

SQ8 What kind of evaluation does the paper report on and what are the main findings of the evaluation?
The data from this question was an important aspect of the review as it pertained to the evaluation of the paper. We had created a detailed scheme that outlines and describes the categories accordingly in Table 5. In addition, Tables 6 and 7 outlines the evaluation methods and the scale of the evaluation used in the paper in a chronological manner from 2002 to 2010. As presented in Tables 8 and 9, evaluation criterion was categorized in terms of the provided solutions and research methods used, respectively, in the papers.

**SQ9 What are the conclusions reported in the paper, open research questions and future research directions.**

The data collected under this question was categorized accordingly in to whether the research was inconclusive, whether the research required further studies, currently research is being done in the presented approach, or no further research was required. The analysis from the data collected under this question is outlined in Chapter 4, under SQ9.
CHAPTER 3
RESULTS AND ANALYSIS

In this chapter, we present the results from the analysis. Figure 1 and Figure 2 illustrates the overview of the papers selected for this study, and Section 3.1 further outlines the demographic data. To understand the reason for research in this field, Section 3.1.2 presents the motivations and the research contributions. Section 3.2 outlines and presents the analysis behind combining SOA and SPL. Section 3.3 informs the evaluation methods used in the analysis of quality of the reviewed paper, and finally Section 3.4 presents the analyses on the quality of the evaluation.

![Publication Venue](image)

**Figure 1.** Publication Venue.
Prior to presenting the findings from the analyses, there was quite detailed information that was gathered during the coding phase of the analysis stage. Some trends and demographics are presented in Sections 3.1.1 and 3.1.2.

Table 1. Paper Types [52]

<table>
<thead>
<tr>
<th>Paper Type</th>
<th>#</th>
<th>Percentage</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Survey Paper</td>
<td>5</td>
<td>10.42%</td>
<td>A Survey Paper presents survey about the existing approaches in combining SPLs and SOAs</td>
</tr>
<tr>
<td>Evaluation</td>
<td>5</td>
<td>10.42%</td>
<td>Evaluation Research analyses and evaluates approaches, methodologies and tools (Solution Proposal) for combining SPLs and SOAs that are implemented in practice. It describes the solution and shows how the Solution Proposal is used in practice and what the consequences (benefits and drawbacks).</td>
</tr>
<tr>
<td>Proposal</td>
<td>16</td>
<td>33.33%</td>
<td>Solution proposal identifies a problem in combining SPLs and SOAs and proposes a solution to this problem. The proposed solution can be: a) a novel or an extension, b) an extension of an existing technique, c) an application of existing technique in the new context.</td>
</tr>
<tr>
<td>Position Paper</td>
<td>21</td>
<td>43.75%</td>
<td>Position paper expresses a personal opinion of somebody on an identified existing problem in combining SPLs and SOAs. It gives only an opinion, and eventually an initial idea for the solution. The solution is neither implemented nor evaluated. They do not rely on research methodologies.</td>
</tr>
<tr>
<td>Experience Paper</td>
<td>1</td>
<td>2.08%</td>
<td>Experience paper explains personal experience of the author on what and how combinations of SPLs and SOAs are used in practice. It has to be the personal experience of the author.</td>
</tr>
</tbody>
</table>

Total: 48 100%
3.1.1. DEMOGRAPHIC DATA. As seen in the publication venue chart (Figure 1), majority of the papers produced were from Conferences (34 out of 48, 70.83%); the rest are seven papers from Journals (14.58%), six from Workshops (12.5%), and one Technical report (2.08%). Of these papers, six (12.5%) were Surveys, five (10.42%) were evaluation research, 15 (31.25%) were solution proposals, 21 (43.75%) were position papers, and one (2.08%) was an experience paper; definition of the paper types are presented in Table 1. Since the majority of the papers were from conferences, the paper type breakdowns from this venue are: three (8.82%) were evaluations, 15 (44.12%) were position papers, 11 (32.35%) were solution proposals, and 5 (14.71%) were surveys.

The papers that were considered for this study were from 2002 to 2010. It can be seen from Figure 2 that there is a trend of continual increment in regards to papers being published in this field. The anomaly from 2003, 2004 and 2010 can be accounted for. In 2002, there was only one paper that was found, and for 2003 and 2004 none were found; which is likely due to the fact that this area or research is new and the topic has started attracting more research attention recently. It should be noted that for 2010, given that the data collection was completed in October 2010, research literatures that were being published and to be published after October 2010 was not part of this study.

3.1.2. MOTIVATIONS AND CONTRIBUTIONS. To understand the driving factors behind the research; data in regards to motivations behind the literature were collected. The 48 papers were categorized, as shown in Table 2., accordingly into six unique motivating factors, totalling 54 cases altogether (N.B., the number of cases is higher than the amount of papers due to some papers having more than one categorized motivation). These six factors were chosen to be utilized by way of recommendation.
from the subject matter expert, PhD student. By examining the motivations and the number of cases from Table 2., it is evident that there is a major driving factor behind architectural variability management and customization (29.63%); and for software reuse (24.07%). We broke down the categorization of variability management into the three parts (i.e., Variable functional and quality requirements, Variable Quality and Performance Requirements, and Architectural Variability Management and Customization). These categorizations were broken down into three parts was due to us noticing that there were numerous cases that fell into the generalized category Variability Management. Thus the subject matter expert recommended that it be broken down in the identified three categories. Based on the number of cases, 37 out of 54, that were identified to be a branch of Variability Management, it can be concluded that the a major motivation in this field is variability management, which in total comes to 50% of the total cases presented in Table 2..

<table>
<thead>
<tr>
<th>Motivation</th>
<th># of Cases</th>
<th>Percentage</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>VF</td>
<td>10</td>
<td>18.52%</td>
<td>Variable functional and quality requirements</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Motivated by various aspects of variability corresponding to function and</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>quality.</td>
</tr>
<tr>
<td>VP</td>
<td>1</td>
<td>1.85%</td>
<td>Variable Quality and Performance Requirements.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Motivated by dealing with variable quality requirements</td>
</tr>
<tr>
<td>A</td>
<td>16</td>
<td>29.63%</td>
<td>Architectural Variability Management and Customization</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Addressing and dealing with variability in software architecture construction</td>
</tr>
<tr>
<td>D</td>
<td>7</td>
<td>12.96%</td>
<td>Dynamic Product derivation</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Motivated by different aspects related to product derivation at run-time,</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>decision model for dynamic system reconfiguration, automatic selection of</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>variant and management of feature adaptation at run-time)</td>
</tr>
<tr>
<td>R</td>
<td>13</td>
<td>24.07%</td>
<td>Software reuse</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Motivated by systematic reuse and increasing and promoting software asset</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>reuse</td>
</tr>
<tr>
<td>O</td>
<td>7</td>
<td>12.96%</td>
<td>Overview of research area and approaches</td>
</tr>
<tr>
<td>Total</td>
<td>54</td>
<td>100%</td>
<td></td>
</tr>
</tbody>
</table>

Papers [3, 10, 12, 13, 15, 31, 32, 35, 42, 48] were categorized to be VF. By combining SOA and SPL, the motivation behind these papers were how variability can be
managed in terms of functional needs. [3] brought forward four principles that can lead to successful application within variation management: recognize the commonality and variants, leverage the recognized commonalities by building core assets, address the enterprise integration needs, and address the end-user needs for variation. Whereas, [10] presented an approach that concentrates on identifying and specifying services using product line technologies to manage variation. Adding to this, [12] noted that systematic variability handling was necessary at the business level, as well as during design time and at the software architectural level. The commonalities identified within these papers show a strong need for variation management in order to enhance the functional business needs. [31] was categorized as VP, where they presented an approach that organizes services as a product line architecture that uses feature models. In this approach they have a consistency checking process that makes it possible to help the user in selecting the customized services. Papers [9, 11, 14, 16, 18, 21, 23, 24, 29, 33, 38, 39, 45-48] were categorized under A in Table 2. The commonality amongst these papers was that majority of them were motivated to bring forward architecture frameworks that can be utilized for variability management. I.e. [9] presented a UML profile for architectural variability modeling in web service based systems, and use this profile to support variability in architecture; and [14] showed that feature-oriented programming can be used to implement product line. It should be noted that in 37 cases that pertained to various aspects within variability management did overlap amongst the three categories.

Papers [1, 2, 19, 25, 28, 37, 44] were categorized under D. The motivation amongst these papers was acquiring automation during run-time. [1] was motivated to
build an integrated production line framework, and [2] had a need to develop families of agents.

Papers [4, 5, 8, 16, 17, 19, 20, 22, 25, 26, 27, 34, 44] were categorized under R. The motivation in combining SOA and SPL in [4] is to identify services that can form the basis for reusable assets and assist with building synergies within services. It can easily be argued that almost all the cases in some sense were motivated to combine SOA and SPL in order to create reusability within assets. The cases analysed under the category R were primarily issues that need be addressed by an identified problem that may be solved by creating reusable assets, or directly by creating an approach that creates or takes advantage of reusable assets [4, 5, 8, 16, 17, 19, 20, 22, 25, 26, 27, 34, 44]. And the remaining papers were cases that brought forward an overview [6, 7, 30, 36, 40, 41, 43].

<table>
<thead>
<tr>
<th>Contribution</th>
<th># of cases</th>
<th>Percentage</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Process</td>
<td>6</td>
<td>11.76%</td>
<td>In this category, the contribution of the study can propose an algorithm to deal with different aspects such as variation point selection, configuration (specialization and customization), decision making mechanisms, etc.</td>
</tr>
<tr>
<td>Methodology</td>
<td>31</td>
<td>60.78%</td>
<td>In this category, a methodology is proposed, a methodology describes rules and guidelines of how things should be performed, e.g., activity for creating and developing reusable assets, architecture, and etc.</td>
</tr>
<tr>
<td>Modeling</td>
<td>2</td>
<td>3.92%</td>
<td>In this category the contribution of the study can be either conceptual modeling/ design for the problem under study or, novel or a significant extension of an existing modeling notation)</td>
</tr>
<tr>
<td>Tool</td>
<td>2</td>
<td>3.92%</td>
<td>A software tooling support is developed in order to support different aspects of problem under study</td>
</tr>
<tr>
<td>Area Overview</td>
<td>10</td>
<td>19.61%</td>
<td>In this category, comparison of different characteristics of existing approaches or area overview are considered</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>51</strong></td>
<td><strong>100%</strong></td>
<td></td>
</tr>
</tbody>
</table>

The contributions of the papers from the main study were identified and categorized through five categories in terms of whether the paper contributed to a process, methodology, modeling, tool, or an area overview. Table 3 outlines the distribution and the description of the categories accordingly. Overall, 31 cases out of 51 (60.78%), contributed to a methodology. It is important to note that a case was categorized into
Modeling only if its primary focus was modelling. This was due to numerous processes and methodologies utilizing models and meta-models within the presented approach. Given that Modeling as an approach was not the main focus, it was decided that these cases were not to be classified under “Modeling”.

Papers [4, 26, 27, 28, 38, 48] were categorized under Process in Table 3. These papers consisted of approaches that presented decisions [4] and development context [28] to aid in specification difficulties. The common aspects within this paper was that the authors stated that further work be done to include more elements in the study. Such as, develop and integrate supporting tools that design business process and domain service [26].

Papers [2, 3, 10 – 26, 29, 31 – 35, 37, 39, 42 – 44, 47] were categorized under Methodology. There were numerous approaches that were proposed: an approach that provides automated runtime support for service discovery, negotiation, monitoring, and service provide rating [2]; and proposing a technique to identify and specify reusable assets [20].

Papers [1, 9] were categorized under Modelling. [1] brought forward a framework of service-oriented production line based on model-driven approach to realize the production and management of service composition. And [9] presented a framework for modelling and managing the variability of web service-based systems for design and run-time. The commonality amongst these two papers was that they were frameworks which were utilized to model approaches.

Papers [9, 32] were categorized under Tool. [9] presented a framework along with a related tool suite to accomplish as stated in the previous paragraph. [32] presented an
UML based modelling approach for product lines based on web services. These two tooling support was designed to support the aspects of modelling within this area. And the remaining cases [5 – 8, 30, 36, 40, 41, 45, 46] presented overview of SOA and SPL.

<table>
<thead>
<tr>
<th>Software Engineering Life Cycle</th>
<th>Cases</th>
<th>Percentage</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Requirements engineering</td>
<td>3</td>
<td>6.12%</td>
<td>Requirements engineering is dedicated to specification of functionality and non-functional characteristics of systems to be developed.</td>
</tr>
<tr>
<td>Analysis</td>
<td>14</td>
<td>28.57%</td>
<td>Process of breaking complexity in to smaller parts to gain or produce better comprehension.</td>
</tr>
<tr>
<td>Design</td>
<td>23</td>
<td>49.94%</td>
<td>Development of solution models such as UML or software architecture models.</td>
</tr>
<tr>
<td>Implementation</td>
<td>8</td>
<td>16.33%</td>
<td>Development of complete code of the application (via transformation, manual, or combined)</td>
</tr>
<tr>
<td>Verification and validation</td>
<td>1</td>
<td>2.04%</td>
<td>This category includes quality assurance methods considering variability. This includes testing as well as formal verification and consistency checking techniques.</td>
</tr>
<tr>
<td>Total</td>
<td>49</td>
<td>100%</td>
<td></td>
</tr>
</tbody>
</table>

Papers [11, 17, 38] were categorized under Requirements engineering in Table 4. [11] presented an orthogonal variability model that explicitly models alternative composition of services to fulfill a specific process, by doing so, one of the benefits is that it aids the requirements engineering process to convey the various alternatives of service composition to the business process activity. Even though there were three cases that were categorized in to this category, the papers did not present strong research interest within this area.

Papers [3-7, 25, 31, 36, 40, 41, 45 – 48] were categorized into Analysis. The commonality amongst these cases were that they breakdown the approach and present principles on improving or application of the presented approach [3].

Papers [1, 8, 9, 10, 12 – 15, 18 – 22, 24, 26, 29, 32 – 35, 37, 43, 44] were categorized under Design. Under this category one of the more prominent trends among the papers
was that the design itself was conceptualized; due to this, the presented design is dependent on one or more principle/model from an external source [1, 8, 9].

Papers [2, 14, 16, 23, 27, 28, 39, 42] were categorized under the category Implementation. These papers proposed or presented various approaches that complimented system integration and deployment, i.e. [2] proposed a quality of service aware framework that facilitated system integration and deployment; and [14] presented an approach that generates services that aids with interoperability on demand or adapts existing services at runtime. And [30] was categorized under Verification and validation, as this paper systematically compared the two concepts.

In our analyses, we found that 49.94% of the cases were categorized under the Design stage within software engineering life cycle, as presented in Table 4. This is understandable, as from Table 1, the majority of the papers were solution proposals and position papers, where new approaches and methodologies were presented at the design level. As evident in Table 4, the category Deployment, originally presented in our questionnaire from Section 2.3 was not included. This was due to the fact that none of the cases from the literature explicitly addressed the deployment portion within software engineering life cycle. In addition, when we combined the total number of cases from categories Requirements Engineering, Analysis, and Design, the total percentage came to 84.63%. This validates the current state in this field as these three categories attribute to the earlier stages of a software engineering life cycle.

3.2. SOA and SPL in Combination

In addition to analysing the approach, we looked at which approach is being applied to the other in the combination of SOA and SPL. Thus, we categorized them, as
presented in Table 5. corresponding to SQ6 (c.f. Section 2.3), into applying SPL principles in development of service-oriented systems (SPL to SO), employing SOA and integration of services into SPLs (SO to SPL), and other papers that did not apply one approach to another. The category “Other” categorized papers that consisted of an overview, survey or presenting an approach or information in terms of SOA and SPL individually, but lacked details in regards to the application of one approach to the other and presented a general combination of the approaches, such as utilization of a tool that integrates SOA and SPL [8].

In order to identify the studies in regards to the combination of SOA and SPL, some exclusion from the selected papers were needed. We excluded the surveys, as they presented overview and details in regards to the concepts in general. We also excluded evaluation papers since the evaluation papers presented information based on previously published literature. We also decided to exclude experience papers, as they predominantly lacked structured study.

Table 5. Combining SOA and SPL

<table>
<thead>
<tr>
<th>Year</th>
<th>2002</th>
<th>2003</th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
<th>Total</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPL to SO</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>4</td>
<td>4</td>
<td>3</td>
<td>7</td>
<td>4</td>
<td>22</td>
<td>[1][17][19][28][10][35][20][38][39][11][18][22][12][34][42][43][44][5][6][31][48][13][25][29][37][24][21][2][14][27][33][16][23][26][32][15][7][30][36][40][41][3][4][9][45][46][47][8]</td>
</tr>
<tr>
<td>SO to SPL</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>3</td>
<td>1</td>
<td>5</td>
<td>4</td>
<td>14</td>
<td>[25][29][37][24][21][2][14][27][33][16][23][26][32][15][7][30][36][40][41][3][4][9][45][46][47][8]</td>
</tr>
<tr>
<td>Other</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>5</td>
<td>1</td>
<td>2</td>
<td>13</td>
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<tr>
<td>Total</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>5</td>
<td>9</td>
<td>9</td>
<td>13</td>
<td>10</td>
<td>48</td>
<td></td>
</tr>
</tbody>
</table>
Table 6. SOA and SPL Selection

<table>
<thead>
<tr>
<th></th>
<th>Position</th>
<th>Solution</th>
<th>Total</th>
<th>Percentage</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>MA</td>
<td>IP</td>
<td>RM</td>
<td>IP</td>
<td>RM</td>
</tr>
<tr>
<td>SPL to SO</td>
<td>4</td>
<td>5</td>
<td>2</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>18</td>
<td></td>
<td></td>
<td></td>
<td>50.00%</td>
</tr>
<tr>
<td></td>
<td>[9,11,17,18,22,23,27,30,40,47,48,1,2,4,6,14,28,31]</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SO to SPL</td>
<td>5</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>13</td>
<td></td>
<td></td>
<td></td>
<td>36.11%</td>
</tr>
<tr>
<td></td>
<td>[13,16,21,24,25,43,7,12,15,19,36,37,38]</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>1</td>
<td>0</td>
<td>2</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td>13.89%</td>
</tr>
<tr>
<td></td>
<td>[33, 45,46,32,39]</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>10</td>
<td>5</td>
<td>5</td>
<td>4</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>36</td>
<td></td>
<td></td>
<td></td>
<td>100.00%</td>
</tr>
</tbody>
</table>

This left 20 position papers and 16 solution proposals, for a total of 36 papers out of 48 as presented in Table 6. We found that, out of the 36 papers, SPL to SO was 18 (50%), SO to SPL was 13 (36.11%), and 5 (13.89%) were in the Other category.

In our analysis, we found that majority of the papers contributed to a Methodology (60.78%), as evident in Table 3.; the context of cases being categorized under Methodology being rules and guidelines on how a task should be performed. These methodologies identified in combining SOA and SPL were at the conceptual level, where adaptability and reusability were the focus due to variability management being the motivation, as per Tables 2, 3, and 7. We further analysed the contribution of these papers and found two papers where a model/framework was brought forward. In one paper [1], the authors brought forward a framework of service-oriented software production line on model-driven service composition in a collaborative manner. The other paper presented a framework for modeling and managing variability of web service-based systems for design and run-time [9]. To clearly understand the contribution, it is important to comprehend the level of study.

To understand the level of study being done in this area, we further categorized the papers, as presented in Table 6, in terms of the Methodology Addressing (MA) a specific problem (nine papers – 25%), Improving upon a Previous (IP) method (18 papers – 50%), or creating a Reusable Methodology (RM) technique and/or framework (nine
papers 25%). In addition, we investigated the approaches that were being identified amongst these 36 papers, and found that majority of the approaches addressed *Variability Management* (17 papers – 47.22%). The breakdown can be found in Table 7. This indicates that there is a significant research interest in variability management approaches.

| Table 7. Approaches Identified from the Selected Papers (from Table 6). |
|-----------------------------|------------------|-----------------|
| **Approach** | **Cases** | **Percentage** | **Description** |
| Service Identification/Composition | 6 | 15.0% | *Service Identification* categorizes approaches that focus primarily on identifying assets, either through the top-down, or bottom-up approaches; *Service Composition* categorizes approaches that are related to the abstraction of composite service itself as well as the identification of the services that will go in to the composition [53]. |
| Developing/Identifying reusable assets | 5 | 12.5% | Approaches that are reusable assets identifies approaches that focus on utilizing the collection of artefacts, such as, but not limited to, requirements, models, source code, and tests, to help other approaches or services be able to use within its framework, not need to recreate it separately. |
| Customization | 7 | 17.5% | Approaches that enable service customization, where flexibility can be achieved with ease. |
| Variability Management | 17 | 42.5% | Approaches that enable variability to be managed within a service with ease. |
| Dynamic Software Product Lines | 5 | 12.5% | Approaches that allow the ability to change configuration at run-time. |
| **Total** | 40 | 100% | |

When applying SPL to SO, the pattern that became clear was having a need to create variability management within service oriented architecture/service compositions. While analysing the collected papers, we found that one of the major motivation behind the research in this field is to resolve the challenge in management of features and their variations. As it is presented in Table 7, this expands from Table 3, in regards to the contribution type within the *Methodology* category, the *Variability Management* category has 17 cases out of 40, and that constitutes to 42.5% of the presented approaches. Variability management is a large part of SPLE, as variability tends to provide the needed flexibility for service identification and diversification [54]. There has been a great
amount of resources allocated for the research to address challenges in variability management [50]. For instance, one paper [10] presented an approach that eases this challenge by grouping various features into feature binding units, as well as by depicting these units as key drivers for describing reusable molecular services. In addition, another paper [11] presented an orthogonal variability modeling language (OVM) that can be used to interact with variability in service composition. However, some researches have concluded that in order to achieve service-oriented product lines, variability management is a must in software architecture itself [12]. Another important factor that we noticed was that the identified approaches are not easily generalized and cannot be applied to other domains. One report [13] states that based on their approach to perform a deep analysis about the process in order to bring forward commonality and variability, in addition to mentioning that it cannot be generalized to other domains, needs to be further investigated, and that additional empirical evidence is required.

Papers [1, 2, 12, 15, 16, 24, 31] were categorized under Service Identification/Composition in Table 7. Papers [2, 4, 19, 28, 40] were categorized under Dynamic Software Product Lines. Papers [1, 13, 14, 17, 21, 22, 23] were categorized under Customization. Papers [4, 6, 9, 11, 12, 18, 24, 25, 30, 36 – 39, 43, 45, 47, 48] were categorized into Variability Management. Papers [7, 25, 27, 32, 33] were categorized Developing/Identifying reusable assets.

Tables 2, 7, and 8 present data that are interrelated, but a clear distinction between them is imperative. Table 2 presents data specifically related to the motivations behind the need for research, whereas Table 7 presents data from the papers that were included
for analysis in regards to combining SOA and SPL in this section, as presented in Table 6. And Table 8 reports the specific purpose behind combining SOA and SPL.

As it can be seen from Table 8, the main purpose behind combining SOA and SPL is to achieve variability management (39.58 % of the total cases). This is not surprising as the motivation for research in this field is 50% (VF + VP + A from Table 2.) to solve variability management issues.

**Table 8. Purpose for Combining SOA and SPL**

<table>
<thead>
<tr>
<th>Purpose behind Combining SOA and SPL</th>
<th>Cases</th>
<th>Percentage</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variability Modeling and Management at the Architectural level</td>
<td>19</td>
<td>39.58%</td>
<td>Achieving flexibility in software architecture and enabling software configuration and customization with respect to functional and quality requirements</td>
</tr>
<tr>
<td>Analyzing, Identifying and Developing Reusable Assets for Service-Oriented Systems/Applications</td>
<td>6</td>
<td>12.50%</td>
<td>To achieve the high level of reusability</td>
</tr>
<tr>
<td>Dynamic Product Line and Adaptation</td>
<td>7</td>
<td>14.58%</td>
<td>To support dynamic variability at run-time, late binding, dynamic product derivation and run-time reconfiguration and adaptation, variable quality and performance management</td>
</tr>
<tr>
<td>Overview</td>
<td>4</td>
<td>8.33%</td>
<td>Outlines the benefits to combining SOA and SPL.</td>
</tr>
<tr>
<td>Purpose not very clear</td>
<td>12</td>
<td>25.00%</td>
<td>Purpose not clear due to the focus being something other than the integration of SOA and SPL.</td>
</tr>
<tr>
<td>Total</td>
<td>47</td>
<td>100.00%</td>
<td></td>
</tr>
</tbody>
</table>

Papers [2 – 4, 8, 10 – 12, 15, 18, 21, 22, 27, 32 – 34, 37, 39, 43, 48] were categorized under Variability Modeling and Management at the Architecture level in Table 8. Papers [13, 16, 20, 44 – 46] were categorized under Analysing, Identifying and Developing Reusable Assets for Service-Oriented Systems/Applications. Papers [5, 14, 7, 19, 23, 26, 29] were categorized into Dynamic Product Line and Adaptation. Papers [7, 36, 40, 41] were categorized under Overview. And papers [1, 6, 9, 24, 25, 28, 30, 31, 35, 38, 48] were categorized under Purpose not very clear.

The motivation to apply SOA to SPL was due to the need for automation and for on-demand adaptation during run-time and within an environment that is constantly
changing [14]. There were numerous approaches that became clear during the analysis. For example, one article [14] presented an approach where the services can be used to guide interoperability of other systems by isolating the functionality that was behind the service. Furthermore, another purpose for applying SO to SPL is to create an increase in reuse and flexibility, as well as being able to develop and deploy service oriented systems quicker, more economically, and especially being able to customize it for specific needs [15].

3.3. Evaluation Methods Used

It is important to use scientifically rigorous evaluation methods to evaluate the approaches presented [55]. One of the goals of this study was to identify the type of evaluation methods used by the researchers. For classifying the evaluation methods, the categorization was created based on the study from [49]. Categorization scheme and the descriptions are presented in Table 9.

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Research Method</td>
<td>---</td>
<td>Details the research method used to evaluate the paper or approach presented in the paper. “a specific research approach in which the researcher generates new… knowledge about an” approach, “while at the same time attempting to change it” [56].</td>
</tr>
<tr>
<td>Action Research</td>
<td></td>
<td>A research approach that provides an approach or methodology that is feasible in theory – proof of principle [56].</td>
</tr>
<tr>
<td>Conceptual Research</td>
<td></td>
<td>Using the artefacts from a completed research or implementation to aid in current research or approaches [56].</td>
</tr>
<tr>
<td>Lessons Learned</td>
<td></td>
<td>“research that utilizes mathematical techniques [56]” to present the approach.</td>
</tr>
<tr>
<td>Mathematical Conceptual Analysis</td>
<td></td>
<td>“examines a single approach in detail; involves no variable manipulation, experimental design or controls; is exploratory in nature” [56].</td>
</tr>
<tr>
<td>Case Study</td>
<td></td>
<td>A methodical procedure carried out to validate or invalidate a hypothesis.</td>
</tr>
<tr>
<td>Experiment</td>
<td></td>
<td>“research that is based on conducting an exploratory field study in which there is no test of relationships between variables” [56].</td>
</tr>
<tr>
<td>Descriptive/exploratory survey</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Presented Solution</td>
<td>---</td>
<td>Details the specificity to which the presented approach addresses.</td>
</tr>
</tbody>
</table>
Automation
Addresses automation within application services and/or product lines.

Collaborative Service
Addresses collaboration within the architecture, i.e. configurable, pluggable, interactive, and monitor [1].

Flexibility/Integration/Adaptability
Addresses flexibility or integration or adaptability within the architecture.

Product line development
Addresses software engineering principles that focuses on families of applications [16].

Reusability
Addresses on utilizing reusable components (usually by creating reusable repository) [16].

Service Orientation
Addresses on developing and/or deploying independent services on a networked environment [16].

Variability/Complexity Management
Addresses variability or complexity in architecture.

Content Described
---
Details the degree in which the content of the study is described.

Strong(1.0)
The approach and information presented is well organized and easy to comprehend.

Medium(0.5)
The approach and information presented is organized and can be comprehended.

Weak(0.0)
The approach and information presented is not very organized and difficult to comprehend.

Study Design Described
---
Details the degree in which the design of the study is described.

Strong(1.0)
The study design presented is well organized, logical and easy to comprehend.

Medium(0.5)
The study design presented is somewhat logical and can be comprehended.

Weak(0.0)
The study design presented is not very logical and lacks various explanations.

Validity Described
---
Details the degree in which the validity of the study is described.

Strong(1.0)
The validity of the approach or information presented is explained well.

Medium(0.5)
The validity of the presented approach or information is somewhat explained.

Weak(0.0)
The validity of the approach or information presented is not described well.

Subjects
---
Details, directly or indirectly, as to who the paper is intended for.

Practitioner
Intended for individuals with practical experience in the subject - implementation experience.

Researcher
Intended for individuals with theoretical/research experience in the subject.

Student
Intended for individuals who are new to the subject.

Context
---
Details the context in which the evaluation is made.

Academia
The approach(es) and the information presented in the paper is from an academic context (theoretical/research context).

Industry
The approach(es) and the information presented in the paper is from the industrial context (practical/implementation context).

Scale of Evaluation
---
Details the scale in which the evaluation is made.

Conceptual example
The example used to illustrate the approach is at a theoretical level.

Down-scaled real example
The example used to illustrate the approach is at the practical industrial level, but scaled down to illustrate just the important aspects.

Industrial
The example used to illustrate the approach is at the industrial level, the approach is implemented in
Not Mentioned

An example was not used to illustrate the approach.

Table 10. Evaluation Methods Used in the Reviewed Papers

<table>
<thead>
<tr>
<th></th>
<th></th>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>7</td>
<td>8.43%</td>
</tr>
<tr>
<td>Conceptual Research</td>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>4</td>
<td>9</td>
<td>7</td>
<td>9</td>
<td>9</td>
<td>39</td>
<td>46.99%</td>
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</tr>
<tr>
<td>Descriptive/exploratory Survey</td>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>0</td>
<td>1</td>
<td>7</td>
<td>8.43%</td>
</tr>
<tr>
<td>Experiment</td>
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<td>0</td>
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<td>0</td>
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<td>2</td>
<td>0</td>
<td>1</td>
<td>3</td>
<td>6</td>
<td>15</td>
<td>18.07%</td>
</tr>
<tr>
<td>Lessons Learned</td>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>6</td>
<td>15</td>
<td>18.07%</td>
</tr>
<tr>
<td>Mathematical Conceptual Analysis</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>4</td>
<td>1</td>
<td>6</td>
<td>15</td>
<td>18.07%</td>
</tr>
<tr>
<td>Case Study</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>5</td>
<td>15</td>
<td>83</td>
<td>100.00%</td>
</tr>
<tr>
<td>Total</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>10</td>
<td>17</td>
<td>14</td>
<td>19</td>
<td>21</td>
<td>83</td>
<td>83</td>
<td>100.00%</td>
</tr>
</tbody>
</table>

About a third (17) of the 48 papers reviewed used more than one evaluation method. This is the reason why the total number of cases in Tables 10 and 11, are more than the total number of papers selected for the study. It is evident that a vast majority of the researchers used conceptual research by itself, or in addition to another, as the evaluation method such as proposing an optimal heuristic algorithm that aims at production in a large scale [1], presenting an approach to advance the service-oriented user agents development using a systematic method to derive the customized versions or the agents [17], and presenting an approach that generates services that can be used to “enforce the interoperability of different systems by abstracting the functionality from the system behind services” [18]. This shows that this field is at its infancy and the growth will lead to more action researches, case studies, and experiments. This is also evident in Table 11, as the majority of the papers presented conceptual examples and less industrial and down-scaled real examples in terms of the scale of evaluation. An analysis of the temporal distribution of the evaluation approaches reported in Table 11 shows a
trend in conceptual research and action research increasing over time. This once again can be related back to the field being in its early stages.

**Table 11. Scale of Evaluations Used in the Reviewed Papers.**

<table>
<thead>
<tr>
<th>Scale Of Evaluation</th>
<th>2002</th>
<th>2003</th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
<th>Total</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conceptual Example</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>5</td>
<td>26</td>
<td>62</td>
<td>41.94%</td>
</tr>
<tr>
<td>Down-scaled real example</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>0</td>
<td>5</td>
<td>5</td>
<td>8.06%</td>
</tr>
<tr>
<td>Industrial</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>6</td>
<td>4</td>
<td>17</td>
<td>17</td>
<td>27.42%</td>
</tr>
<tr>
<td>Not Mentioned</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>4</td>
<td>2</td>
<td>2</td>
<td>4</td>
<td>14</td>
<td>14</td>
<td>22.58%</td>
</tr>
<tr>
<td>Total</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>5</td>
<td>14</td>
<td>11</td>
<td>17</td>
<td>13</td>
<td>62</td>
<td>100%</td>
</tr>
</tbody>
</table>

3.4. Quality of Evaluation

To comprehend the quality and the details of evaluation in the papers, we formulated and categorized the paper as per Table 9. To prevent subjective categorization, this part of the coding scheme was left until the end to ensure that the reviewer had examined all papers prior to categorizing a paper as being strong, medium, or weak in such categories as *Content Described, Study Design Described,* and *Validity Described.* Then, we assigned scores corresponding to the categorization as follows: strong = 1, medium = 0.5, and weak = 0. The categorization and scoring framework was adopted from [49] and [55]. Using this categorization and scoring, we were able to catalogue the contribution in terms of the approach presented vs. the overall paper’s quality.

From Table 12., the type of solution being presented can be identified. We found that the solutions presented in the papers focused more around Variability/Complexity Management (35.65%), Flexibility/Integration/Adaptability (31.17%), and Reusability/Economic (19.48%), than the remaining categories (13.7%). Looking back at Table 2, the solutions provided, as presented in Table 12, correspond accordingly. In Table 2, the highest motivating factors were Variability Management (50%), and
Software Reuse (24.07%). Table 8 corresponds accordingly, as Variability/Complexity Management is 35.06%, and Reusability is 19.48%.

**Table 12. Solution and its Evaluation**

<table>
<thead>
<tr>
<th>Provided Solution</th>
<th># of Cases</th>
<th>Percentage</th>
<th>Content Described (avg.)</th>
<th>Study Design Described (avg.)</th>
<th>Validity Described (avg.)</th>
<th>Subjects</th>
<th>Context</th>
<th>Scale of Evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Automation</td>
<td>3</td>
<td>5.66%</td>
<td>0.67</td>
<td>0.5</td>
<td>0.5</td>
<td>1 3 0</td>
<td>2 1 2 2 2 0</td>
<td></td>
</tr>
<tr>
<td>Collaborative Service</td>
<td>1</td>
<td>1.89%</td>
<td>0.5</td>
<td>0.5</td>
<td>0</td>
<td>1 0 0</td>
<td>0 1 0 0 1 0</td>
<td></td>
</tr>
<tr>
<td>Flexibility/ Integration/Adaptability</td>
<td>14</td>
<td>26.42%</td>
<td>0.61</td>
<td>0.39</td>
<td>0.54</td>
<td>4 13 2</td>
<td>14 5 9 1 5 5</td>
<td></td>
</tr>
<tr>
<td>Product line development</td>
<td>2</td>
<td>3.77%</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0 2 0</td>
<td>2 0 2 0 0 0</td>
<td></td>
</tr>
<tr>
<td>Reusability</td>
<td>10</td>
<td>18.87%</td>
<td>0.65</td>
<td>0.7</td>
<td>0.75</td>
<td>1 6 2</td>
<td>8 5 6 0 5 2</td>
<td></td>
</tr>
<tr>
<td>Service Orientation</td>
<td>3</td>
<td>5.66%</td>
<td>0.67</td>
<td>0.67</td>
<td>0.5</td>
<td>0 3 0</td>
<td>3 0 2 0 0 1</td>
<td></td>
</tr>
<tr>
<td>Variability/Complexity Management</td>
<td>20</td>
<td>37.74%</td>
<td>0.55</td>
<td>0.33</td>
<td>0.48</td>
<td>4 19 2</td>
<td>19 5 7 1 5 9</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>53</td>
<td>100.00%</td>
<td>0.66</td>
<td>0.58</td>
<td>0.54</td>
<td>11 46 6</td>
<td>48 17 28 4 18 17</td>
<td></td>
</tr>
</tbody>
</table>


**Table 13. Chronological Evaluation of the Reviewed Papers**

<table>
<thead>
<tr>
<th>Number of Papers</th>
<th>2002</th>
<th>2003</th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paper Strength</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Strength (avg)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Content Described</td>
<td>0.5</td>
<td>-</td>
<td>-</td>
<td>0.5</td>
<td>0.5</td>
<td>0.56</td>
<td>0.67</td>
<td>0.65</td>
<td>0.60</td>
</tr>
<tr>
<td>Study Design Described</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>0</td>
<td>0.6</td>
<td>0.39</td>
<td>0.39</td>
<td>0.54</td>
<td>0.55</td>
</tr>
<tr>
<td>Validity Discussed</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>0</td>
<td>0.6</td>
<td>0.56</td>
<td>0.44</td>
<td>0.58</td>
<td>0.60</td>
</tr>
<tr>
<td>Subjects (No.of Cases)</td>
<td>Practitioner</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>0</td>
<td>2</td>
<td>2</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Researcher</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>1</td>
<td>2</td>
<td>7</td>
<td>9</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>Student</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Context (No.of Cases)</td>
<td>Academia</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>1</td>
<td>3</td>
<td>9</td>
<td>9</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>Industry</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>0</td>
<td>4</td>
<td>4</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Scale of Evaluation (No.of Cases)</td>
<td>Conceptual Example</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>0</td>
<td>2</td>
<td>5</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Down-scaled Real Example</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Industrial Example</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>0</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Not Mentioned</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>1</td>
<td>1</td>
<td>4</td>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>

The content described, as presented in Table 12, overall appears to be at the same level, lightly above medium (0.66). Meaning the context of the study all across the collected papers remains slightly above the mid-level. This can be attributed to the current state of this area we are exploring; the field is maturing so the content that is being
described is getting stronger. Since there are more papers published in the recent years, the content described are stronger in the more recent papers than that of the papers published in the earlier years, as evident in Table 13. This is understandable; as many researchers build upon previous works and the content being described becomes stronger and stronger. This is evident with papers [19], [10], [20] and [2], as the same researcher, Lee et al, contributes and builds upon some of the previous studies in combination with other researchers.

Since majority of these papers were from the academic background, the study design described was expected to be strong. However, the study design expressed in the papers was just slightly above the medium level (0.58) – Table 12. This can be attributed to majority of the research method being used in the studies were conceptual research (46.99%), as per Table 10. Due to the nature of conceptual research, study design being described tended to be less than strong (1.0) in the collected papers. Validity described is slightly above medium (0.54) as well; this can once again be attributed to 46.99% of the research method employed being Conceptual Research. With this type of research, validity described cannot be established with strength, as the approach being presented would bring forward an approach or a methodology at the conceptual level.

One of the indicators of the maturity level within a research topic is the use of research method that is being employed in the papers that are being published. We found that experiment and action research combined to be only 12.04%, as presented in Table 14., of the total cases in regards to the research method being used in the papers. In addition, lessons learned and case studies totalled 25.3%. This indicates what we observed earlier, that this field is at its infancy. This is not only due to experiments, case
studies, lessons learned, and action researches being low, but due to conceptual research method being utilized is very high amongst the literary papers. This can also be interpreted in terms of the future outlook; due to large number of cases utilizing conceptual research, this research field is on the verge of growing at a steady pace.

Table 14. Research Method and its Evaluation

<table>
<thead>
<tr>
<th>Research Method</th>
<th># of Cases</th>
<th>Percentage</th>
<th>Content Described (avg.)</th>
<th>Study Design Described (avg.)</th>
<th>Validity Described (avg.)</th>
<th>Subjects</th>
<th>Context</th>
<th>Scale of Evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Action Research</td>
<td>7</td>
<td>8.43%</td>
<td>0.64</td>
<td>0.57</td>
<td>0.71</td>
<td>6</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>Conceptual Research</td>
<td>39</td>
<td>46.99%</td>
<td>0.58</td>
<td>0.44</td>
<td>0.50</td>
<td>11</td>
<td>34</td>
<td>4</td>
</tr>
<tr>
<td>Lessons Learned</td>
<td>9</td>
<td>10.84%</td>
<td>0.56</td>
<td>0.50</td>
<td>0.67</td>
<td>7</td>
<td>6</td>
<td>0</td>
</tr>
<tr>
<td>Conceptual Mathematical Analysis</td>
<td>6</td>
<td>7.23%</td>
<td>0.83</td>
<td>0.67</td>
<td>0.75</td>
<td>1</td>
<td>6</td>
<td>0</td>
</tr>
<tr>
<td>Case Study</td>
<td>12</td>
<td>14.46%</td>
<td>0.67</td>
<td>0.58</td>
<td>0.67</td>
<td>4</td>
<td>11</td>
<td>0</td>
</tr>
<tr>
<td>Experiment</td>
<td>3</td>
<td>3.61%</td>
<td>0.67</td>
<td>0.33</td>
<td>0.67</td>
<td>2</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Descriptive/exploratory Survey</td>
<td>7</td>
<td>8.43%</td>
<td>0.50</td>
<td>0.43</td>
<td>0.43</td>
<td>0</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Total</td>
<td>83</td>
<td>100.00%</td>
<td>0.63</td>
<td>0.50</td>
<td>0.63</td>
<td>31</td>
<td>69</td>
<td>9</td>
</tr>
</tbody>
</table>

Key: Under the category Subject: P – Practitioner, R – Researcher, S – Student.
CHAPTER 4
DISCUSSION

In Section 2.5, the survey questions were presented and the reasoning behind why these questions were used to collect data, in this chapter, we present the discussion of the trends and information that is of importance below – the discussion is set under the corresponding survey questions.

SQ1. What are the type of publication, the publication year and the name of the publication venue (Workshop, Conference, Journal, Other)?

The findings through analysis from this systematic mapping study have revealed that there are numerous approaches that are consistently being researched and being published in this field. The conferences in this area are contributing to majority of the papers being published in this area. Based on the chronological trend from Figure 2, the number of papers being published will proportionally grow as the interest in the intersection of SOA and SPL is growing.


As mentioned earlier in Section 3.1, the majority of the papers that were selected for this study, as shown in Table 1, were categorized as position papers (43.75%). Then, there were quite a few of solution proposals (33.33%). Position papers, in general, express an opinion on an identified existing problem in combining SPLs and SOAs; along with usually giving an initial idea for a solution that is normally neither implemented nor evaluated. This can be identified as there is a great amount of research interest in the field, but there is research being done to address particular problem sets by combining
SOA and SPL. With the motivation to create efficiency and economies within systems architecture, numerous researchers have identified the research problems and have presented approaches to solve them [6]. Experience papers constituted to 2.08% (one paper), this yet again shows the infancy in the field.

SQ3. What is the motivation of the proposed approach? Did you observe any research gaps reported by the authors?

The main motivating force behind proposing/presenting approaches was variability management, that is, 50% of the presented approaches were motivated by this in some form, as shown in Table 2. Since variability management constituted 50% of the presented approaches, we further broke the category down in to specifics within the variability management categorization: Variability Functional and Quality Requirements (18.52%), Variable Quality and Performance Requirements (1.85%), and Architectural Variability Management and Customization (29.63%). Another mentionable motivating factor was the need for software asset reuse; this is due to the current need in the industry to create systems that are economic, both in cost and time.

SQ4. What is the major contribution of the paper (Process, Methodology, Models, Tool, Area Overview)?

The major contribution from the papers was mainly software development methodologies that composed 60.78% of the total contributions, as presented in Table 3. Methodologies included illustrating a systemic method to derive customized versions of agent within SOA [17], approaches to modeling variability [21], approach to design an interface that enables communication between systems through interoperability with multiple systems [14], model-driven framework [22], approach that customizes composite web services to
users’ requirements by applying SPLE [23], and numerous others. Hindsight, when we extracted the data and categorized the approach as a Methodology, it would have been more beneficial, if we broke the category further down in to the particular approaches. We were not looking for this granular level of detail when we started the data collection and extraction for this categorization.

SQ5. To which stage of the software engineering lifecycle does the paper focus on (Requirements Engineering, Analysis, Design, Implementation, Verification and Validation, Deployment, Maintenance)?

Extracting data for this category proved cumbersome as the approaches and methodologies presented in the papers touched on numerous software engineering life cycles. In this categorization, we tried to avoid as much multiple categorizations as possible for a single paper, as presented in Table 4. This was partly due to not wanting to document convoluted findings. We looked at the overall paper’s approach and categorized it to the most prominent category it represented. Evidently, 49.94% were categorized to be under Design; this category represents development of solution models and methods. This correlates with majority of the contribution being methodologies from SQ4.

SQ6. Specify the kind of synergy between SPLs and Service-Oriented Computing

(Applying SO to SPL – Integration of services in SPLs, Applying SPL to SO – Application of SPL principles in development of services, Other).

Applying SO principles to SPL principles and applying SPL to SO came to be 29.17% and 48.83% respectively. This shows that there is a higher interest in applying SPL in the development of service orientation. Some utilization of synergies behind applying SO to
SPL was to increase the adaptability of Web Services [24], core assets development [25], decision to choose feature-oriented programming to realize an SPL for SOAs [14], provide guidelines to identify, design and document architectural elements [15], provide a feature-based development approach that is used to develop reusable domain services with commonality [26], and nine other approaches that utilized the application of SO to SPL. By applying SPL to SO there is an approach that aims at defining activities and models to address the development of customized agents [17], framework consisting of a feature model that defines non-functional constraints in SOA [22], an approach that integrates product line engineering with service-orientation by adapting feature-oriented product-line engineering [27], an approach to obtain variability in SOA [12], an approach that aims to automate the decision tables management and transform business process model in executable workflows for SOA systems [13], and 17 other papers applying SPL to SO.

SQ7. *Depending on the kind of synergy and identified exploited characteristics, explain the purpose and the manner of identified characteristics of the possible exploitation.*

The characteristics of SOA and SPL were exploited to mainly address issues concerning variability management, as evident in Table 8, which was the highest motivation factor for the approaches presented (50% of total cases), and for the purpose of integration (39.58% of the total cases) between the two concepts. There were 25% of the cases where the purpose behind integration was not clear. This is highly due to some papers solely focusing on enhancing one of the concepts, with very minor utilization of the other concept. Because 25% of the cases did not present the integration clearly, this category was labelled as not being clear.
SQ8. What kind of evaluation does the paper report on and what are the main findings of the evaluation?

Since majority of the cases in regards to the research method utilized were conceptual research (46.99%), from Table 14, the research evaluation in regards to content described, study design, and validity described were slightly above the medium level. The details of the scoring are presented in Tables 9, 12, and 13. And Table 14 presents detailed results of the evaluations from the paper.

SQ9. What are the conclusions reported in the paper, open research questions and future research directions?

There authors concluded predominantly with indicating the usefulness of their approaches and how it can aid other domains. The emerging pattern from the conclusions was that the authors suggested that further research be done in addition to their presented work. This included: exploring better ways to tailor the service granularity of service-oriented product line to enhance reusability [7][25]; conduct extensive experimental study to measure effectiveness of their approach so that it can be further explained in a service composition process [28]; take the presented service-oriented product line architecture approach and apply it for other domains to validate the real benefits [10][29]; a need to investigate further for specific web services domains [30][31][32]; extending the presented approach to include dynamic adaptation of agents and integration to support automation [24][33]; and propose to create supporting tools and models to aid in service-oriented application development and variability management [11][22][34][6][8].
CHAPTER 5
LIMITATIONS

The analysis and the findings of this systematic mapping study may have been affected by some uncontrollable limitations. First and foremost, there might be bias in regards to the papers selected for this study. In addition, there might be inaccuracy in data collected, inaccuracy in data extracted, inaccuracy in categorizing papers, inaccuracy in categorizing approaches, inaccuracy in assigning scores, and inaccuracy in categorizing the reported evaluation approaches and methodologies.

When we selected the papers for this study, we tried our best to gather all papers that were published in the intersection of SOA and SPL since 2002 to 2010. There are possibilities that we may have rendered the search string, or the way we selected papers, not be able to capture all papers in that time period. As mentioned earlier, not all papers from 2010 were captured due to the limitation of having to finalize the data extraction by September 2010. We also considered the amount of time available for a three-credit master’s essay in COMP 696, and decided, with the supervisor’s consent, to limit the work to the selected collection. One of the other mentionable information is that there could have been approaches combining SOA and SPL in the industry that could have not been published, as we depended on papers from credible search sources. This is common with systematic mapping studies as it has been reported by many other reviewers [50].

When collecting the data, if the reviewer was unsure or was not clear about the details, the reviewer double checked and got clarifications from a subject matter expert (PhD student) prior to finalizing the data. The same principle was applied when categorizing the papers, approaches, and evaluation methods. To aid with the
categorization strategies, numerous other systematic mapping studies and reviews, such as [49][50][52][54][55], were reviewed and parts and pieces were used as a guiding reference in this study. Even though references were utilized, the categorization involved very subjective decisions to be made by the reviewer, but the subjectivity was minimized by establishing clear definitions. When interpreting the results and findings from this mapping study, it is imperative that the limitations mentioned in this study be taken into account.
CHAPTER 6

CONCLUSIONS

The combination of SOA and SPL is becoming an area of interest for numerous researchers. This is due to the value it brings to the software engineering discipline. In the past eight years, there have been numerous papers published in this field, but lacked systematic mapping study of the papers. To fill this gap, we conducted a systematic mapping study of papers that were published between 2002 and 2010 in the area of intersection between SOA and SPL.

Through our search, selection, and exclusion approach, we selected 48 papers that were used in the data extraction/coding phase. We have presented various analyses in regards to the data collected. We believe that the findings will be useful both, to researchers and practitioners.

A large number of the surveyed papers in this field are being published via conferences, and as per the trend we analysed, the number of publication is bound to increase. Majority (77%) of the papers published from 2002 to 2010 in this field were either position papers or solution proposals, of course in addition to these papers, the remaining (23%) papers were surveys, evaluation researches, and experience papers. The main motivating factor (50%) for the research papers in this field was variability management, variability management composed of variable functional and quality requirements, variable quality and performance requirements, and architectural variability management and customization. The remaining 50% of the motivation was driven by dynamic product derivation, software reuse, and overview of the research area and approaches.
Of these presented approaches, the major (61%) contribution from these papers to the field was methodologies; the remaining 39% of the contribution were processes, modelling approaches, tooling support, and area overviews. These approaches utilized characteristics from one approach, by applying them to the other. SO characteristics and approaches were applied to SPL 36%, and SPL characteristics to SO, 47%. Once again the motivation behind the application and combination of these two concepts were driven by having a need for variability management (40%); in addition, they were motivated by having a need to achieve reusability, and to support dynamic product line adaptation.

One of the patterns that emerged on a constant basis is that there are a large number of conceptual researches being currently done in this area, and that majority of the authors indicated that either they are conducting further research in regards to the presented details, or they suggested that further research be done respectively to their presented approach. It is very clear that this topic within the software engineering discipline is still at its infancy and that there should be more research conducted to address the numerous problem sets identified.
BIBLIOGRAPHIC DETAILS OF THE 48 ASSESSED PAPERS:


Service-Oriented Architectures and Software Product Lines (SOAPL 2009), San Francisco, CA, USA.


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