

Conceptualizing a New Domain Using Topic Modeling and Concept Mapping: A Case Study of Managed Security Services for Small Businesses

Michael Weiss and Steven Muegge

“ A body of formally represented knowledge is based on a conceptualization: the objects, concepts, and other entities that are assumed to exist in some area of interest and the relationships that hold among them. ”

Tom Gruber,
Co-creator of Siri

The objective of this paper is to show how topic modeling and concept mapping can be used to conduct a literature review in a new domain. The paper makes two contributions. First, it uses topic modeling to map out the literature in the new domain. Topic modeling provides an alternative to manual clustering of articles and allows the identification of non-obvious connections between ideas expressed in a collection of articles. Second, it identifies the underlying concepts in the new domain and their relationships by creating a concept map from the extracted topics. As a case study, the paper reviews the recent literature in the intersection of managed security services and small businesses. In particular, it identifies elements of the managed security services concept as it applies to small businesses. The audience of the paper includes anyone who is exploring a new domain by reviewing the literature, and in particular, students, researchers, and members of industrial R&D projects.

Introduction

Conducting a literature review in a new domain presents unique challenges, as previously noted by Weiss (2016). In existing domains, researchers can use established classifications of knowledge to guide their search for and interpretation of the literature. However, in a new domain, such classifications are not available.

There is a need for tools that can assist researchers in forming a conceptualization of a new domain in a short time frame. Gruber (1995) defines a conceptualization as the “objects, concepts, and other entities that are assumed to exist in some area of interest and the relationships that hold among them”. Topic modeling (Blei et al., 2003) was developed as an alternative to manually clustering articles. It allows researchers to identify non-obvious connections between ideas expressed in a collection of articles (see, for example, the topic model created by McPhee et al. 2017 to examine the themes covered in the first ten years of the TIM Review). To add to the discourse of topic modeling, we look at concept mapping (Novak & Cañas, 2010), a tool for representing knowledge as a hierarchical structure of

concepts and relationships between concepts that are created by propositions or statements.

The objective of this paper is to show how topic modeling and concept mapping can be used to conduct a literature review in a new domain. The paper makes two contributions. First, it points to topic modeling as a way to map out the literature in a new domain in terms of the underlying topics or themes. Second, it identifies key underlying concepts in the new domain, as well as charting their relationships by creating a concept map from the topic model.

To demonstrate our approach, we review the recent literature at the intersection of managed security services and small businesses, and uncovers elements of the managed security services concept as they apply to small businesses. We hope that the article will be relevant to readers of the TIM Review both for the method used to conduct the literature review, and for the content of the case study, given that security is a central concern to most small business managers as well as technology entrepreneurs.

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The paper is organized as follows. Section 1 identifies the case study. Section 2 describes the method used to create the topic model and concept map using literature review. Section 3 presents the results of the literature review. This is followed by a discussion of the implications of the method and results for managers and researchers in Section 4. Section 5 concludes the paper.

Managed Security Services

Small businesses are as exposed to cyber attacks as their larger counterparts, but they lack the requisite expertise and resources to protect themselves. Within the general trend towards the outsourcing of computing infrastructure, it is an interesting phenomenon that businesses have also started to outsource security to managed security service providers (Gupta & Zhdanov, 2012; Cezar et al., 2017). The application of managed security services to small businesses has not yet received much attention in the literature. This paper aims to fill this gap and to identify the elements of the managed security services concept as it applies to small businesses.

A Managed Security Service (MSS) is a solution that protects the security of a business, which is difficult to implement for the businesses themselves (Zhao et al., 2013). Outsourcing the security of a business to an outside party leads to economies of scale and greater access to information (Jansen & Jeschke, 2018). A Managed Security Services Provider (MSSP) can offer its capabilities to multiple customers at the same time and is, therefore, more cost-effective than customers setting up their own internal security controls. Since an MSSP can aggregate security events from its customers and combine them with external threat intelligence, it also has access to more information that can improve its quality of service.

Method

We first identified candidate papers for the literature review from online databases such as Web of Science and Google Scholar. We then used topic modeling to detect latent themes within these articles. Topic modeling is a probabilistic technique for clustering documents that does not require a human to label the documents. A common topic modeling technique is Latent Dirichlet Allocation (LDA) (Blei et al., 2003). Given a corpus of documents and a number of topics, LDA produces a probability distribution that indicates the

topics each document is about, as well as a probability distribution of keywords associated with each topic.

To construct the topic model, we used only paper abstracts as documents, rather than full articles. By focusing on the abstracts, we emphasize highlights of the articles as summarized by its authors. We also recommend using abstracts if the documents in the corpus vary in length. In the example of the literature on MSSs, the corpus includes papers, white papers, and theses of widely different length. We first created topic models of different sizes, and increased the number of topics until stable topics emerge that are common among the topic models generated [the number cannot become stable as it steadily increases, only the topics, which, beyond some number of topics, tend to recur in the topic models generated]. We then sorted those [no processing on topics] topics by weight (based on the number of documents that have each topic as their first) and only included the top 90%, thus serving to eliminate topics that lack support in the corpus (Mathew et al., 2017).

To interpret the topics, we first used agglomerative clustering to identify the main topics and subtopics (Quinn et al., 2010). We then manually created a concept map from the topic keywords. This concept map presents groups of related keywords and graphically shows salient relationships between keywords. Constructing the map was an iterative process, during which time the key concepts related to the new domain were identified. Finally, alongside of the concept map, we plotted the number of articles published per year and the distribution of topics within each year to understand how the new domain is emerging and taking shape.

Results

Corpus of Articles

We first searched the Web of Science database for articles on “managed security services”. Since this search only returned 22 articles, we complemented this corpus with articles from the “grey” literature. By searching Google Scholar for articles that match the query “managed security services” AND “small companies” OR “sme”, we identified 67 additional articles that included conference papers, theses, and reports, but excluded patents, white papers (with the exception of market surveys), magazine articles, and books. Table 1 shows the composition of the corpus of articles.

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Table 1. Description of the corpus

<i>Database</i>	<i>Web of Science</i>	<i>Google Scholar</i>	<i>Total</i>
Count	22	67	89
<i>Date Range</i>			
Oldest article	2003	2001	2001
Newest article	2018	2019	2019
<i>Type</i>			
Journal article	13	25	38
Conference paper	9	10	19
Thesis	0	28	28
Report	0	3	3
Book section	0	1	1

Table 2. Topics and their associated keywords, sorted by weight.

Topic	Keywords
1	security, services, managed, network, risks, detection, cloud, outsourcing, infrastructure, outsourced
4	business, software, management, firms, monitoring, mss, companies, operation, competition, intrusion
2	open, computing, test, positive, tool, adoption, multi, dynamic, light, provided
6	system, manage, ensure, sites, complex, transition, novel, attacks, analysts, operations
8	tool, private, traffic, proactive, scan, iaas, vpm, infected, hosts, clouds
10	critical, areas, source, trusted, program, organization, production, house, interaction, verisign
3	mssp, large, risk, independency, practices, growth, investment, externalities, caused, industry
5	detection, intrusion, threat, potential, enterprise, rate, scan, real, defender, leverage, optimal, tools
7	project, process, aspects, platform, measures, configuration, team, organizational, industrial, training
9	worm, traffic, networks, requirement, presented, clients, rate, scan, managing, hosts

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Topic Modeling

To determine the best right number of topics, we iterated the topic model with different numbers of topics, until a set of mostly independent clusters of documents emerged. The literature also suggests that 10-12 topics are a good heuristic value (Mathew et al.,

2017). We found 10 topics to be a good fit for our corpus. At this point, several stable topics had emerged, with little overlap between keywords across topics. After sorting the topics by support in the corpus, three topics were eliminated by applying the 90% cut-off. Table 2 shows the topics and their associated keywords.

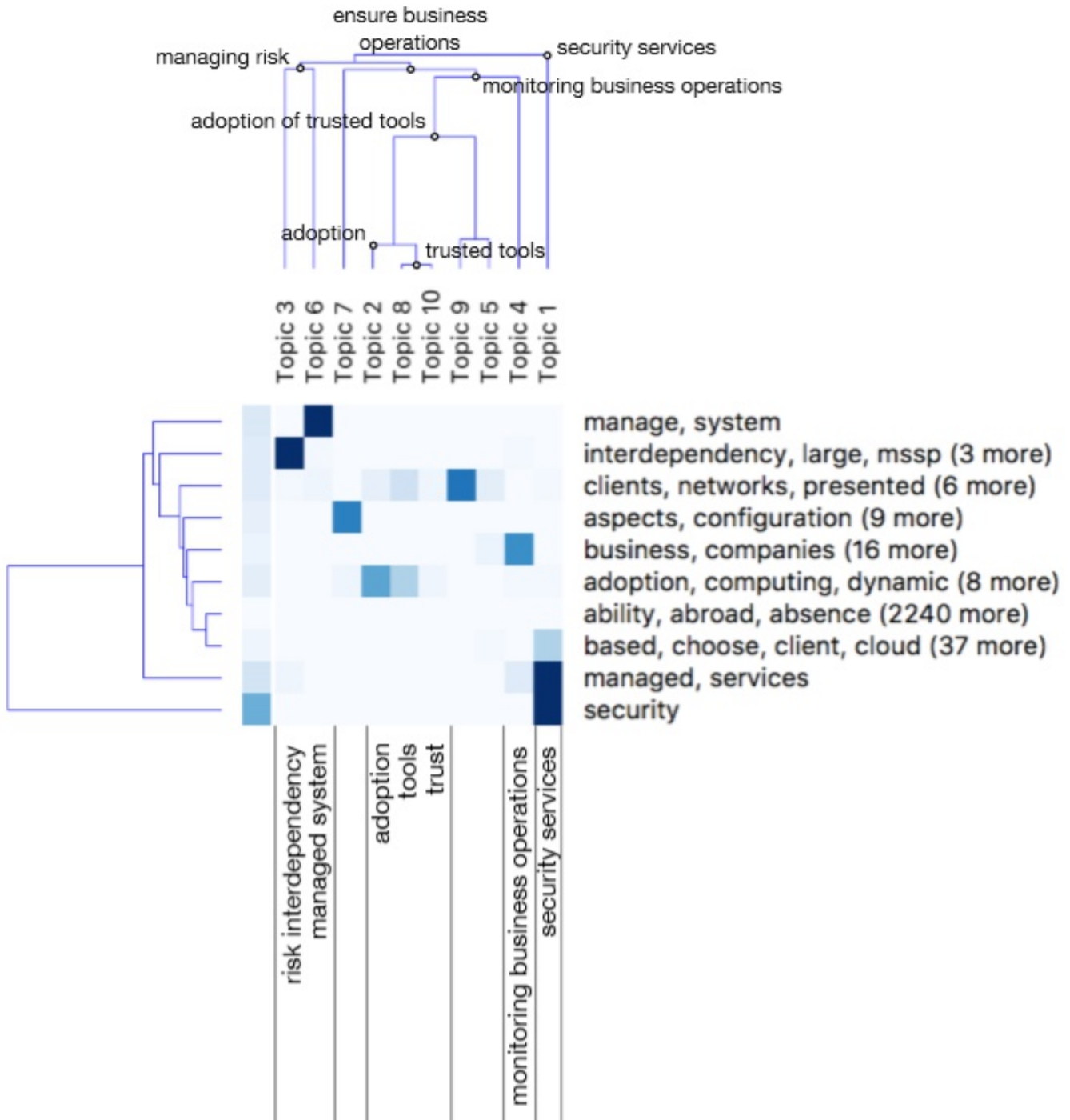


Figure 1. Clustering the topics into main topics and subtopics.

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Clustering the Topics

The topics were clustered by merging two topics (which then become subtopics of a new topic that is produced as the result of clustering) at a time that are similar and proceeding recursively in this manner, until only a single topic remains. (Topics eliminated during the previous step were included in the clustering process and then merged with the most closely related topic.) The dendrogram produced by clustering is shown in Figure 1. The lower the height at which two topics or groups of topics are connected, the more similar they are (Quinn et al., 2010). Labels were assigned to nodes in the dendrogram by examining keywords in the connected topics.

From this analysis of the MSS for small businesses domain, three top-level topics emerged: the security services that a small business adopts, ensuring the operations of the small business, and managing risk. The second topic can be subdivided into four topics: monitoring business operations, adoption of managed security services, tools, and trust. The third topic (managing risk) comprises two subtopics: risk from interdependency, and a managed system.

Emerging Topics over Time

Plotting the topics over time shows an overall increase in interest in the topic of managed security services, as shown in Figure 2. However, we can identify two waves of publications. The first wave peaks in 2009, the second

wave in 2015. The three most popular topics in 2009, according to the articles included in our sample, were security services, monitoring business operations, and a managed system. In 2015, they were security services, adoption of security services, and risk from interdependency. From 2009 to 2015, a noticeable shift in focus occurs from operations and systems to reasons for adoption and risk considerations.

Concept Mapping

We created a concept map to identify the elements of the MSS concept as it applies to small businesses. We grouped the topic keywords into concepts to construct the concept map in Figure 3. For example, topic 1 contains the concepts MSS and outsourcing, and topic 4 includes the concepts business, managing operations, monitoring, and intrusion detection. Each concept in the concept map is represented by its own cluster of keywords related to the concept.

We labeled the clusters in the concept map: business, MSS, managed system, intrusion detection, outsourcing, managing operations, and risk from interdependency. We established links between concepts when they were either part of the same topic (e.g. MSS and outsourcing), or semantically related (e.g. “hosts” in the managed system concept and “infected” in the intrusion detection concept are related terms: as in a host that is infected by an intrusion).

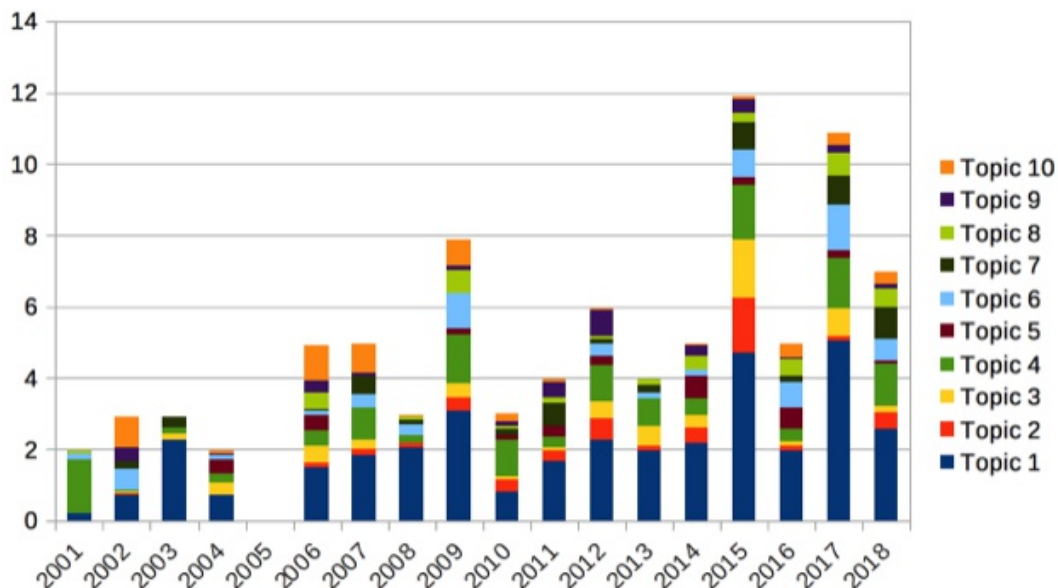


Figure 2. Emergence of the topics over time.

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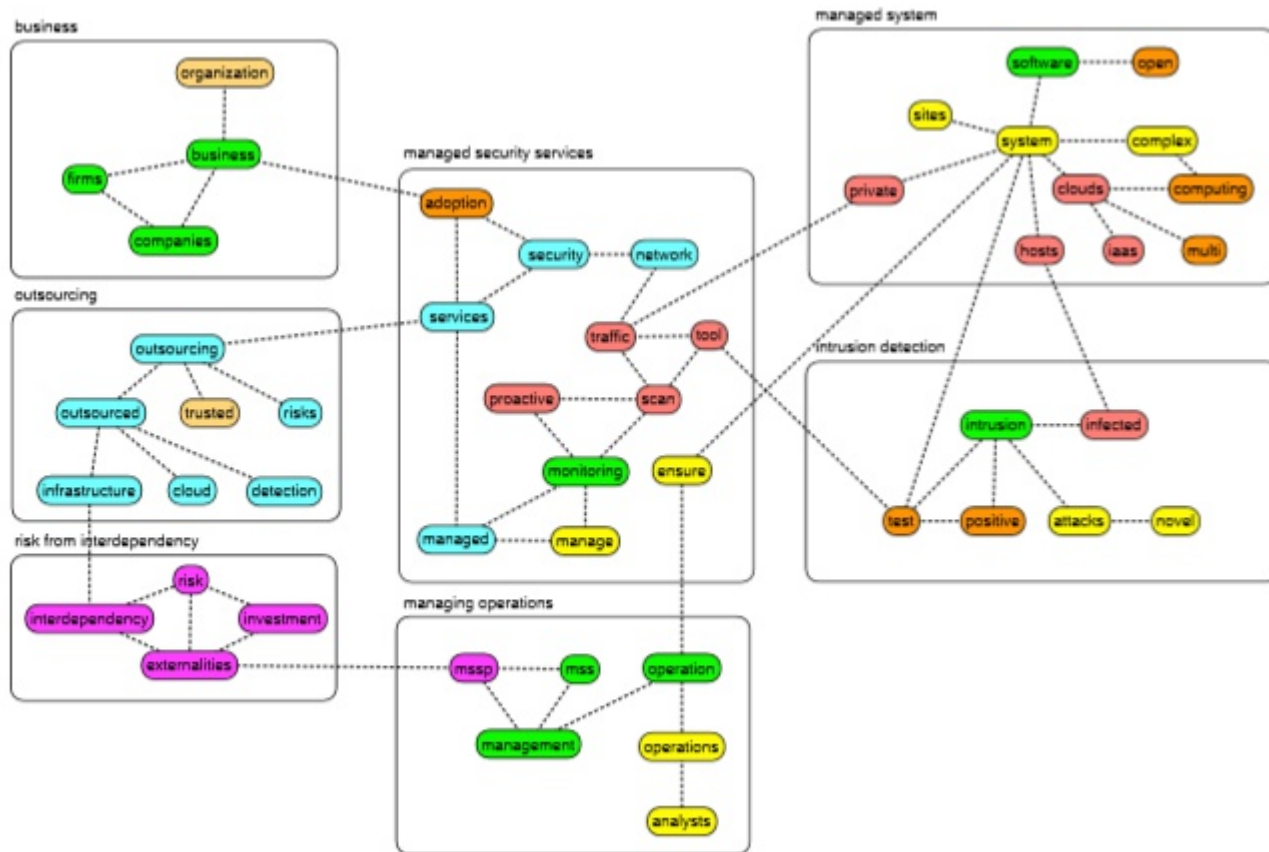


Figure 3. Concept map for the elements of the managed security services concept

Note that, in Figure 3 below, links between concepts are not labelled. Rather, concept maps as described by Novak and Cañas (2010) connect the concepts through propositions. These propositions cannot be obtained from the topic model directly, but it is possible to extract them from a close analysis of specific sentences in documents in the corpus that contain those concepts. It is worth adding that existing work on “ontology learning” (Wohlgenannt et al., 2012) also appears promising as a way to help automatically extract links between concepts.

Discussion

For managers, this paper highlights a crucial shift from operations to risk considerations when small businesses outsource their security. The early literature, focused almost exclusively on the benefits of outsourcing security, such as reduced cost and increased quality, for example, Broom (2009). Whereas recent literature takes a more systemic perspective in which businesses and MSSPs should be considered as agents in a complex

system of interdependencies, as noted by Cezar et al. (2017).

The implications for researchers are twofold. The paper shows that topic modeling is a promising approach to review literature in a new research area, and [this introduces a new idea that goes beyond topic modeling] proposes a technique for interpreting topics that involves constructing a concept map from the keywords. Previously, the interpretation of extracted topics has relied mostly on generalizing from the keywords associated with each topic. Combining concept maps with topic models provides greater visibility into the context in which the keywords associated with the topics are embedded.

Conclusion

This paper shows how a new domain like that of MSS for small businesses can be studied to discover new insights by combining topic modeling with concept mapping. Topic modeling enables researchers to identify latent

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topics from the literature related to a new domain and to study how these topics have emerged over time. By creating a concept map from the topics and their associated keywords, researchers can identify a set of concepts in the new domain along with their relationships.

This paper's novel contribution is to identify and begin to articulate the process of creating a concept map from a topic model. Currently, the process has to be performed manually. However, we believe that creating concept maps from a topic model can be, at least partially, automated, and therefore suggest that future research efforts be directed towards that goal.

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