SSMED AND ITS MULTIDISCIPLINARY NATURE: AN AUTOMATIC LITERATURE REVIEW

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Purpose – In recent years, the academic world has seen the spread of a growing interest in understanding the dynamics characterizing studies conducted in different research areas. This trend seems to have taken hold also in the scientific community interested in issues related to Service Science Management Engineering and Design. In this regard, the present study aims to investigate whether the multidisciplinary nature of SSMED, theoretically recognized, implies an effective orientation of academics towards manifold research areas.

Design/Methodology/approach – The work is based on an automatic literature review, conducted by using knowledge extraction techniques integrated in an IT tool developed for the objective pursued with this research. The tool has been applied on several databases (such as Wiley, etc.), enabling the analysis of different studies about SSMED and the extraction of the main trend characterizing the evolution of this science known as multidisciplinary along the time line.

Findings – The results emerging from the analysis show that, despite SSMED has progressively developed as a multidisciplinary science, actually, most of the studies related to it focuses on topics linked mainly to business management. However, the consideration of the time variable allows understanding that, within SSMED, especially in recent years, the number of contributions linkable to topics belonging to other research areas is progressively growing up.

Research limitations/implications – The research involves considerable theoretical implications, fostering an important advancement in the state of art in terms of more concrete and greater awareness of the multidisciplinary nature of SSMED. However, the study presents the limit of considering only two databases. In fact, the involvement of additional databases, perhaps, would have been capable of leading to potentially different findings.

Originality/value – The work proposes a novel approach to carry out conceptual analytics summarizing trends along the timeline. It allows going far beyond the traditional techniques used in science mapping through the evaluation of scientific publications indexed or stored in big databases (such as systematic literature review, meta analysys, bibliometric analysis, and research performance analysis), enabling the assessment of the (chrono) logical evolution of the studies dedicated to SSMED. Moreover, unlike what occurs with other techniques (e.g. systematic literature review, bibliometrics, and research performance analysis), the development and the subsequent use of a specific IT tool for the analysis guarantees the advantage to automatically consider, extract and analyze in real time all contributions available on the selected databases.

I. INTRODUCTION

The availability of huge and growing amount of research findings included in scientific publication hosted by international publishers emphasizes the urgent need for enabling literature-based information services to provide useful solution addressing literature- or systematic- review, trends detection, individual or community of experts finding, and so forth. Many research initiatives are coming out and these information services allow detecting new research trends of scientific communities focused on a specific sub-topic that is often obscured by the existence of a plethora of other information. Nevertheless, the heterogeneous and unstructured nature of these information sources requires the definition of complex text-mining methods capable of facing with the text ambiguity, synonymy, polysemy, to carry out concepts instead of keywords. The work proposes an automatic literature review, conducted by using knowledge extraction techniques integrated into an IT tool developed for the objective pursued with this research. The tool has been applied to several databases (such as Wiley, Springer, IEEE, etc.), enabling the analysis of different studies about SSMED and the extraction of the main trend characterizing the evolution of this science known as multidisciplinary along the time line. Specifically, the work adopts a methodology named TAKE (Time Aware Knowledge Extraction) introduced in (De Maio et al., 2016) to support several information services in the domain of Service Science (SS). TAKE is an approach to perform conceptual and temporal data analysis of concepts embedded in unstructured text that extends Fuzzy Formal Concept Analysis (De Maio et al., 2012) introducing time dependencies among concepts in the underlying fuzzy lattice, to mine relations and their validity along the timeline. TAKE relies on well-assessed Natural Language Processing that exploits Wikipedia knowledge base to determine the meaning of the words encountered in the unstructured resources available in the collected repositories (De Maio et al., 2015). This technique may trivially allow to track concept-cloud along timeline and relations among people and topics of interest as well. The main contributions of the proposed work are listed below:

- A novel application of an existing knowledge extraction methodology to automatically address literature reviews.
- Discussion of the results of a literature review performed to analyze the multidisciplinary nature of SSMED along the timeline in order to carry out what are the last trends, what is the main application field, and so forth.

Automating literature review by using text-mining solution allow us to prune the time cost and enable us to yield more robust results because it is possible to augment the amount of information sources processed. The strength points of automating literature review are essentially: scalability and time cost reduction. From the quality of extracted information, the results of the automated literature-based services may introduce some approximation due to false positives or false negatives unavoidable applying text-mining techniques on unstructured content. Nevertheless, recently advancements of Semantic Web, Linked Data, and Common Sense Knowledge Bases or Controlled Vocabulary (e.g., Wikipedia) allow us to improve the quality of the extracted information. The paper is organized as follow: Section II provides an overview of the related works; Section III details the TAKE methodology; Finally, Section IV describes the results of performed literature review and argues the obtained results.

II. RELATED WORKS

Over the years, numerous authors have conducted studies to demonstrate how the multidisciplinary nature of SSMED allows dealing with themes linkable to different but integrated disciplines. In this regard, one of the most frequent techniques used for this purpose is the systematic literature review, a secondary scientific research tool aimed at allowing systematization of information extracted from primary research tools. In other words, it is a technique that offers a sort of synthesis of state of the art in a particular disciplinary field or even in several related fields (Kitchenham et al., 2009). More in detail, the systematic review takes into consideration a set of studies related to a particular topic, conducted in different moments and places, in order to submit them to a systematic process of critical analysis and evaluation (Connolly et al., 2012). These studies, then, are collected in a single document that includes the gathering of the best available evidence (Cooper, 2016).

With the term systematic it is possible to identify different types of analysis of the studies conducted on a particular topic, but generally it indicates a descriptive analysis of their methodological quality and relevance. However, in some scientific communities the term systematic review is used as a synonymous of meta-analysis, although it should be more appropriate to consider the latter as the statistical part of a systematic review. More in detail, it is a quantitative analysis of data contained in single studies aimed at minimizing errors and generalizing their conclusions (Schmidt and Hunter, 2014). In other words, meta-analysis is a "quantitative systematic review" by which the results of single studies are statistically associated and aggregated into a cumulative result.

Another technique frequently used to study the multidisciplinary nature of SSMED is bibliometric analysis, developed in the 1920s, this technique has progressively evolved, especially in recent times due to the availability of large online databases (Hood and Wilson, 2001). Like systematic review and meta-analysis, bibliometric analysis is based on mathematical and statistical techniques to analyse publication distribution patterns and to explore impact within scientific communities (Hicks, 1999). Specifically, it requires a twofold approach (Osareh, 1996): a qualitative approach, which focuses on peer-review; and a quantitative approach that takes into account a several data, such as patentability, number and type of companies interested in a specific research topic, etc. Important measures considered in bibliometric analysis are the number of citations and the impact factor (calculated as the ratio between the number of citations received in the current year to articles published in the previous two years and the number of articles published over the same two years) (Shapiro, 1992).

A further innovative technique often used is TAKE, which extends Fuzzy Formal Concept Analysis (Fuzzy FCA or FFCA) by considering temporal dimension of the input data. In literature, there are several methodologies adopting traditional Formal Concept Analysis (FCA) (Ganter and Wille, 2012) as the theory useful for knowledge structuring and ontology building (Huang and Jin, 2005). Fuzzy extension of the FCA was defined in (De Maio et. al., 2012) for improving hierarchical classification of the collected resources by considering partial memberships and uncertainty in the text-mining. This work investigates the applicability of temporal extension of Fuzzy FCA embedded in TAKE methodology for addressing literature-review needs. In particular, we emphasize the summarizing attitude of hierarchical knowledge structure retrieved by Fuzzy FCA and the capability of temporal relation to point out the evolution of extracted concepts. This is useful for instance to identify what are the main concepts along the time line,

which one are more referred with respect others, which authors shifted from one topic of interest to another, and so on.

III. RESEARCH METHOD: TAKE

The proposed literature review adopts as research method TAKE methodology introduced in (De Maio et al., 2016) to perform temporal and conceptual data analysis on unstructured content of reports attaining with Service Science and published by some international publishers. Figure 1 sketches the whole process of the system that is composed of following main phases:

- Scientific Content Analysis (see Section III-A). It takes as input the abstract and keywords of scientific publication and performs wikification service, to determine the meaning of the publication, and ad-hoc term weighting;

- Conceptual Data Analysis (see Section III-B). It takes as input a term weighted scientific publications matrix and corresponding timestamps to perform Time Aware FFCA in order to arrange scientific publication into a hierarchy carrying out also time dependencies among extracted concepts;

- Conceptual Analytics. It takes as input the timed fuzzy lattice and it performs algorithms for retrieving visual analytics useful to simplifying the results understanding.

Additional technical and formal details about each macro phases are given in the next subsections.

A. Scientific Content Analysis

This step involves the identification of main concepts involved in the collected unstructured text. Specifically, the content will be annotated via sentence wikification that is the practice of representing a sentence with a set of Wikipedia concepts (i.e., entries) (Mihalcea and Csomai, 2007; Miao and Li, 2010). Wikify service1, provided by University of Waikato, enable us to identify main concepts (i.e., topics) in the input text disambiguating keywords with respect to Wikipedia article that will represent their meaning. Indeed, Wikification enables us to recognize sense of main concepts and named entity mentioned in the text associating a Wikipedia link and a corresponding weight representing confidence degree of the disambiguation result. In particular, wikification service extracts a set of pairs (*topic*, *rel*), where *topic* is a Wikipedia article representing the meaning of the content along with corresponding membership degree, called *rel* (i.e., relevance) (Mihalcea and Csomai, 2007) ranging in the (0, 1) interval. The relevance degree (in the range (0, 1)) of the topic with respect to the input text. In particular, topics returned by applying the wikification upon resource content helped us to characterize the given text. Just to provide an example of the wikification results, let us consider the following portion of text extracted from research article (wikified terms are bolded and underlined in the snippet):

“The objective of this paper is to review recent developments in service theory and systems theory with a view to identifying common features between the two. In particular, the study explores the issue of whether so-called ‘smart service systems’ can be understood in terms of the “viable systems approach” of systems theory. The paper begins

with a review of recent developments in service theory by examining the fundamental principles of Service Dominant logic (S-D logic) and Service Science. The similarities and differences of the two are explored, with particular emphasis on the common feature of the service system. The study then moves to the realm of systems theory by exploring the main proposals of the viable systems approach (VSA), which is an interdisciplinary systems theory that includes elements derived from resource-based theory, biology, sociology, and mechanics. (. . .) especially with regard to harmonization, systems governance, and successful value co-creation processes" (. . .)

Taking into account the example above, the resulting set of pairs (*topic*, *rel*) characterizing the meaning of the text are:

- systems theory → (SS management and engineering; 0.9);

- interdisciplinary → Interdisciplinary; 0.82);

- systems theory → (Systems theory, 0.8);

- viable systems → (Viable system model; 0.75);

- biology → (Biology; 0.7);

- sociology → (Sociology; 0.7);

- process → (Business process; 0.7).

This process is performed on each collected resource in order to obtain a mathematical representation of them, namely the Fuzzy Formal Context (see Definition 1 in Section III-B). At the end of execution, the content of "$paper_i$" will be annotated via wikification results and other information, as:

$$paper_i = \{(time_i)\} \cup \{(topic_{i1}, rel_{i1})\} \cup \{(topic_{i2}, rel_{i2})\}, \ldots . , \{(topic_{im}, rel_{im})\}$$

where, considering the paperi, m is the number of topics detected by sentence wikification , and $time_i$ represents the timestamp (i.e., publication data) of paper.

B. Conceptual Data Analysis

TAKE performs conceptual data analysis taking into account also temporal relation among resources to consequently reveal concepts development over the timeline. The proposed approach to address this aim relies on Fuzzy Formal Concept Analysis (briefly, Fuzzy FCA or FFCA) (De Maio et al., 2012). Fuzzy FCA deals with fuzzy relations between objects (e.g., scientific publication, etc.) and their features (e.g., topics, named entities, and so on) considering membership varying in (0,1), instead of binary relation of traditional FCA (Ganter and Wille, 2012), and so it enables us to specify more or less relevant features to represent resources enabling granular representation of them. Following, some definitions about Fuzzy FCA are given.

Fig. 1: *Overall Process of the framework*

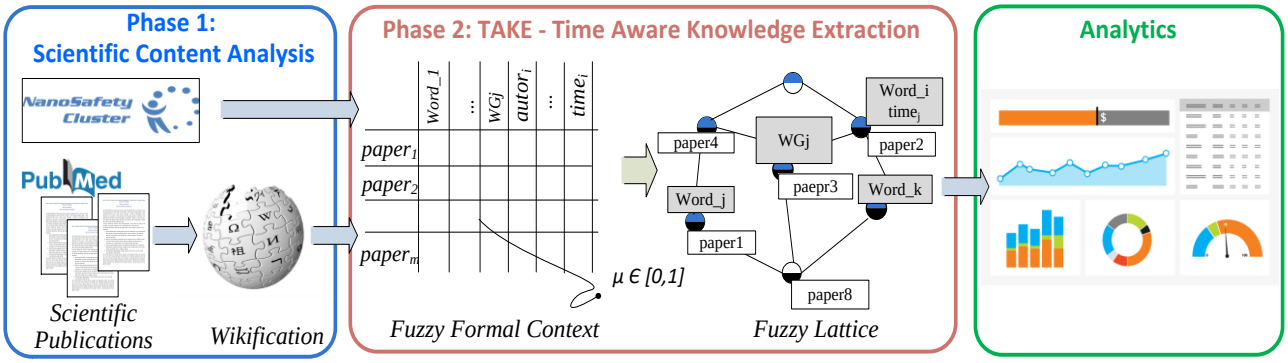
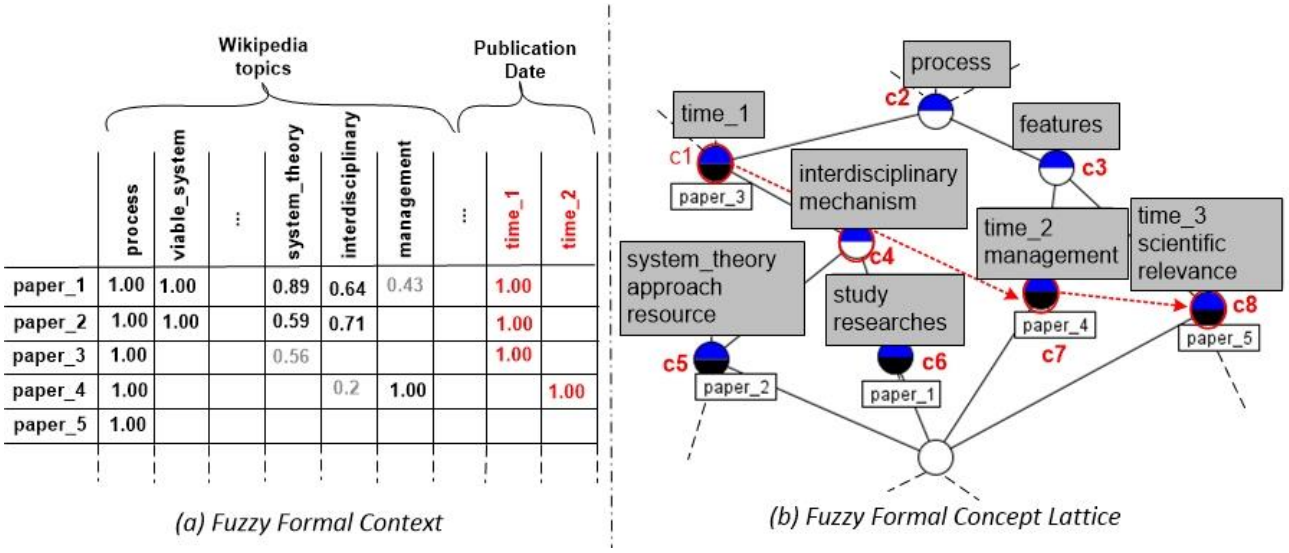


Fig. 2: *Time Aware Fuzzy FCA: portion of temporal fuzzy formal context (a) and the relative temporal fuzzy concept lattice*



Definition 1: A Fuzzy Formal Context is a triple *K = (G, M, I)*, where G is a set of objects, *M* is a set of attributes, and *I = ((G ↠M), μ)* is a fuzzy set. Recall that, being I a fuzzy set, each pair *(g,m) ∈ I* has a membership value *μ(g,m)* in *(0,1)*. In the following the fuzzy set function μ will be denoted by μI .

Definition 2: Fuzzy Representation of Object. Each object O in a fuzzy formal context K can be represented by a fuzzy set *ϕ(O)* as *ϕ(O)={A1(μ₁), A2(μ₂),…, Am(μₘ)}*, where *{A₁, A₂,. . . , Aₘ}* is the set of attributes in K and μ_i is the membership of O with attribute A_i in K. ϕ(O) is called the fuzzy representation of O.

Unlike FCA that use binary relation to represent formal context, Fuzzy Formal Context enables the representation of the fuzzy relation between objects and attributes in a given domain. So, fuzziness enables to model a relation among object and attribute in a more smoothed way ensuring more precise representation and uncertainty management. Fuzzy Formal Context (see Definition 1) is often represented as a cross-table as shown in Figure 2(a), where the rows represent the objects, while the columns, the attributes. Let us note that each cell of the table contains a membership value in *(0, 1)*. Specifically, Fuzzy Formal Context shown in Figure 2(a) has a confidence threshold *T=0.6*, that means all

the relationship with membership values less than 0.6 are not shown. Taking into account Fuzzy Formal Context, Fuzzy FCA algorithm is able to identify Fuzzy Formal Concepts and subsumption relations among them. More formally, the definition of Fuzzy Formal Concept and order relation among them are given as follows:

Given a fuzzy formal context $K = (G,M, I)$ and a confidence threshold T, for $G' \subseteq G$ and $M' \subseteq M$, we define $G^* = \{m \in M \mid \forall g \in G', \mu_I (g,m) \geq x\}$ and $M^* = \{g \in G \mid \forall m \in M', \mu_I (g,m) \geq x\}$

Definition 3: Fuzzy Formal Concept. A fuzzy formal concept (or fuzzy concept) C of a fuzzy formal context *K* with a confidence threshold *x*, is $C = (I_{G'},M')$, where, for $G' \subseteq G$, $I_{G'} = (G', \mu)$, $M' \subseteq M, G^* = M'$ *and* $M^* = G'$.

Each object *g* has a membership $\mu_{IG'}$ defined as

$$\mu_{IG'} (g) = min_{m \in M'} (\mu_I (g,m)) \quad (1)$$

where μ_I is the fuzzy function of *I*.

Note that if $M' = \emptyset$ then $\mu_I (g) = 1$ for every g. *G'* and *M'* are the extent and intent of the formal concept $(I_{G'},M')$

respectively.

An example of Fuzzy Formal Concept is c_4 that is composed of objects $A_f = \{paper\_1, paper\_2\}$ and attributes B = { *time_1, Process, "interdisciplinary,mechanism*", . . . } with $\mu_{paper1} = 0.61$ and $\mu_{paper2} = 0.54$, as shown in 2(b).

Definition 4: Let $(I_{G'},M')$ and $(I_{G''},M'')$ be two fuzzy concepts of a Fuzzy Formal Context (G,M, I). ($I_{G'}$,M') is the subconcept of $(I_{G''},M'')$, denoted as $(I_{G'},M') \preceq (I_{G''},M'')$, if and only if $I_{G'} \sqsubseteq I_{G''}$ ($\leftrightarrow$M'' $\subseteq$ M'). Equivalently, ($I_{G''}$,M'') is the superconcept of ($I_{G'}$,M').

For instance, let us observe in Figure 2(b), the concept c_5 is subconcept of the concept c4. Equivalently the concept c_4 is superconcepts of the concept c_5. Let us note that each node (i.e. a formal concept) is composed by the objects and the associated set of attributes, emphasizing by means fuzzy membership the object that are better represented by a set of attributes. In the figure, each node can be colored in different way, according to its characteristics: a half-blue colored node represents a concept with own attributes; a half-black colored node instead, outlines the presence of own objects in the concept; finally, a half-white colored node can represent a concept with no own objects (if the white colored portion is the half below of the circle) or attributes (if the white half is up on the circle). Furthermore, given a Fuzzy Formal Concepts of Fuzzy Formal Context, it is easy to see that the subconcept relation $\preceq$ induces a Fuzzy Lattice of Fuzzy Formal Concepts. As a matter of fact the lowest concept contains all attributes (e.g., Wikipedia entities) and the uppermost concept contains all object (i.e., scientific publications) of Fuzzy Formal Context. Figure 2(b) shows an example of lattice coming from the related table. In fact, FCA provides also an alternative graphical representation of tabular data that is somewhat natural to navigate and use (Ganter and Wille, 2012). In literature, some approaches extend formal concept analysis to handle temporal properties and represent to temporally evolving attributes (Neouchi et al., 2001; Elzinga et al., 2012). Analogously, this work extends FFCA to consider timeline defining special attributes for epresenting time relations among formal objects. Formally, a time aware fuzzy formal context is defined as follow:

Definition 5: A Time Aware Fuzzy Formal Context is a fuzzy formal contexts $K_t = (G, M^+ = M \cup T, I_M = \varphi (G \times M), I_T)$, where T is the set of time attributes and I_T is a binary time relation $I_T \subseteq G \times T$ representing the relation between formal object $g \in G$ and time attributes $t \in T$. For instance, if $g \in G$ and $t \in T$ are in relation IT means that g happens at time $t \in T$, in our case the timestamp is the publication date. Hence, time extension of Fuzzy FCA allows to organize scientific publications in a weighted hierarchical knowledge structure, that is a timed fuzzy lattice. Let us consider timed fuzzy formal context and correspondent timed fuzzy lattice in Figure 2. Specifically, Figure 2(b) emphasizes that each node (i.e., a formal concept) includes the objects, attributes and timing. The resulting timed fuzzy lattice emphasizes a temporal correlation among concepts and highlights how the concepts change over the timeline (Figure 2). To represent the concept development over the timeline in a timed fuzzy lattice temporal edges have been introduced (in Figure 2 red dashed arrows) among related concepts. The temporal edges represent the evolution of attributes to be followed over time. The direction of the arrow indicates this precedence.

C. Conceptual Analytics

This phase may be customized to retrieve some analytics useful for supporting some hypothesis or for pointing out some evidence. In the presence of big unstructured data, and when the meaning is embedded in the text, it is important to provide useful analytics operating at various levels. For instance, it could be helpful to carry out a tag cloud of most occurring keywords, but it should be done at the different level of abstraction. We point out that by using timed fuzzy lattice, we can extract a concepts cloud for summarizing at a higher level the evidence in the data. The use of temporal relations and monitoring people that authored the collected content (in our case authors of the papers) it is possible to carry out trends, patterns of co-occurring concepts, and the author's interactions along the timeline. In a nutshell, this phase completes the proposed methodology implementing visual analytics useful to understand the interesting information embedded in the collected text. Indeed, the overall method aims at cross-relating heterogeneous features characterizing the collected data for enabling a particular kind of business intelligence, i.e. text intelligence.

IV. EXPERIMENTAL RESULTS

In this section we explain how the experimentation was conducted describing dataset and discussing the obtained results.

A. Dataset & Full-text Technologies

We collected the papers published in the period 2006−2017 by using software API exposed by the publishers. Then, we indexed the papers abstracts and keywords by means of open source platform, i.e. Apache SolR. The platform provides an abstraction layer for maintaining and interacting with full text index (Lucene) and for easily using natural language processing algorithms on which the proposed methodology relies (see Section III). The publishers that we

have selected among whose that expose freely accessible APIs to crawl papers are shown in Table 1. The table illustrates also how many papers we crawled for each publisher.

Table 1: *List of selected Publishers*

PUBLISHER	NUMBER OF SELECTED PAPERS
Elsevier	708
Institite of Electrical & Electonics Engeeners (IEEE)	1059
Springer	34
Cambridge University Press (CUP)	55
Oxford University Press	37
Wiley	215

B. Findings

Figure 3 shows the "concept cloud", in which the most frequent concepts are represented. Each concept has been constructed by applying filters that allow the automatic aggregation of words with an identical or at least similar meaning, pertinent to a particular subject, which in turn can be linked to a specific discipline. In the graphic cloud, the dimension of the represented concepts is variable: it increases whether the number of times in which a word associable to it is extracted. It is worth pointing out that the cloud does not contain all the concepts considered in the analysis, but as mentioned above, only those linkable to words extracted more than once. Therefore, its value is especially to provide an appreciable result already graphically.

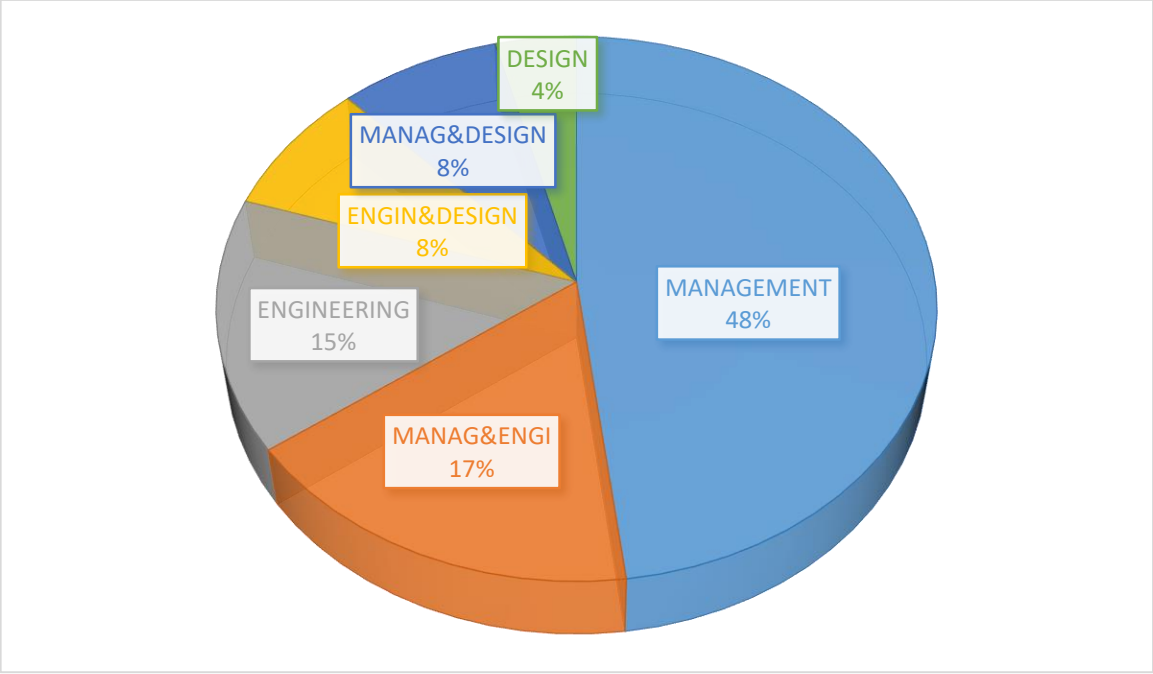
Fig. 3: *The concept cloud emerging from the analysis*

Source: *Authors' elaboration*

However, for a more complete and detailed estimation, the authors have considered all the extracted concepts, not only those depicted in the cloud of figure 3. Subsequently, each concept has been associated to a discipline or multiple disciplines, depending on the circumstances. For example, considering the results emerged from the analysis, the concept expressible through the word "marketing" has been associated with "management", while the concept "technology" has been associated with three disciplines: "management", "engineering" and "design", not being able to automatically determine the discipline of the articles containing that concept.

The consideration of all the extracted concepts has allowed believing that about 48% of SSMED articles deal only with management topics, 17% deal with "management" and "engineering" topics, 15% is attributable only to “engineering”, 8% simultaneously to “engineering” and “design”, 8% to “management” and “design” and 4% only to design (see figure 4).

Fig. 4: *The percentage distribution of the extracted articles*



Source: *Authors’ elaboration*

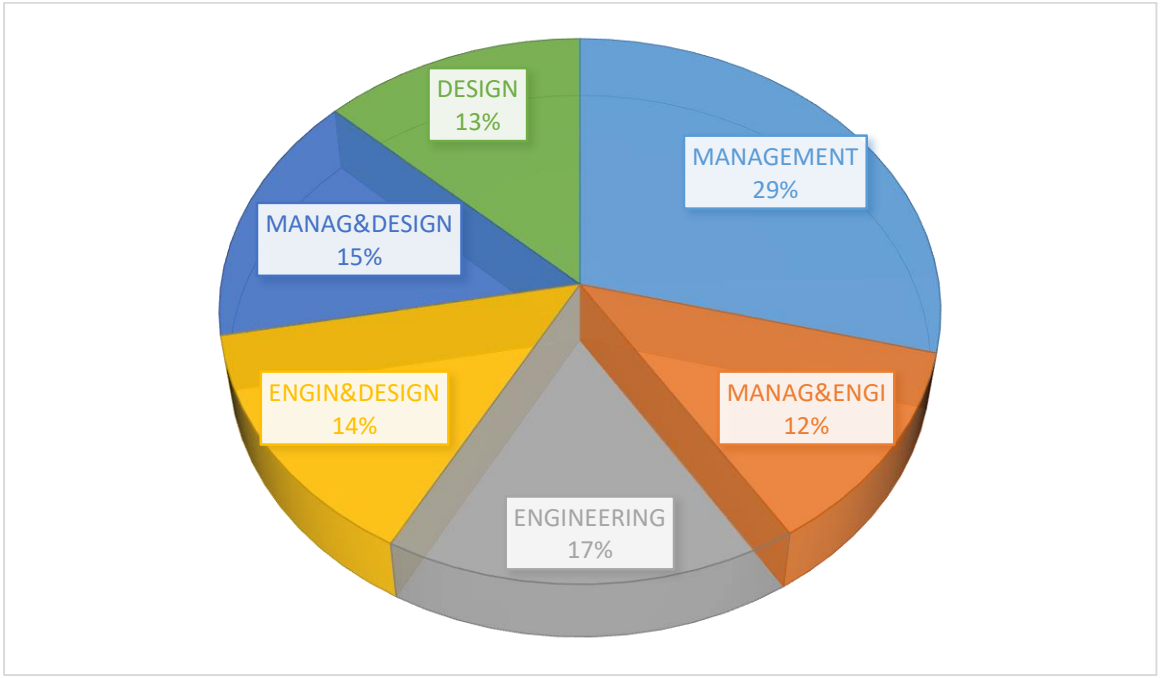
The findings emerging from the analysis show that, despite SSMED has progressively developed as a multidisciplinary science, actually, most of the studies related to it focuses on topics linked mainly to business management. However, repeating the same analysis by considering only the papers published in 2016, the results appear more equally distributed (see figure 5): 29% for management; 17% for engineering; 15% for both management and design; 14% for engineering and design; 13% for design; and 12% for both management and engineering.

Hence, the consideration of the time variable allows understanding that, within SSMED, especially in recent years, the number of contributions linkable to topics belonging to other research areas is progressively growing up (Polese et al., 2016; Russo Spena et al., 2013; Barile and Saviano, 2010).

C. Implications and research limitations

The research involves considerable theoretical implications, fostering an important advancement in the state of art in terms of more concrete and greater awareness of the multidisciplinary nature of SSMED.

Fig. 5: *The percentage distribution of the extracted articles published in 2016*



Source: *Authors' elaboration*

The work proposes a novel approach to carry out conceptual analytics summarizing trends along the timeline. It allows going far beyond the traditional techniques used in science mapping through the evaluation of scientific publications indexed or stored in big databases (such as systematic literature review, bibliometrics, and research performance analysis), enabling the assessment of the (chrono) logical evolution of the studies dedicated to SSMED. Moreover, unlike what occurs with other techniques (e.g. systematic literature review, bibliometrics, and research performance analysis), the development and the subsequent use of a specific IT tool for the analysis guarantees the advantage to automatically consider, extract and analyze in real time all contributions available on the selected databases. However, the study presents the limit of considering few databases and taking into account not all the content but title and sometimes the abstracts. In fact, the involvement of additional databases, perhaps, would have been capable

of leading to potentially different findings. Furthermore, the paper presents another limit: it does not provide any discussion about the content of the considered paper, but it merely indicates the percentage distribution of the articles linkable to the various disciplines (management, engineering and design) of SSMED.

V. CONCLUSION

The dissemination activity of scientific communities is often obscured by the existence of a plethora of other information. There is a urgent need to define a platform to easily support deployment of intelligent information services. This paper focuses on the analysis of scientific activity performed in the area of Service Science, but the work may be adopted for other case studies. In the future TAKE will be used to perform deeper investigations and provide more descriptive results. The results emerging from the analysis show that, despite SSMED has progressively developed as a multidisciplinary science, actually, most of the studies related to it focuses on topics linked mainly to business management. However, the consideration of the time variable allows understanding that, within SSMED, especially in recent years, the number of contributions linkable to topics belonging to other research areas is progressively growing up. In the future, we are planning to hybridize content-based literature review, proposed here, with some other approaches, such as whose based on co-citation analysis in order to get more exhaustive and robust findings.

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