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Bibliometric analysis of service innovation research: Identifying knowledge domain and global network of knowledge

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ABSTRACT

The concept of service innovation is significant for innovation strategy and economic growth. However, since the term "service innovation" represents a broad sense, there does not exist common understanding about what is service innovation even among experts. We developed a methodology to determine the structure and geographical distribution of knowledge, as well as to reveal the structure of research collaboration in such an interdisciplinary area as service innovation by performing journal information analysis, citation network analysis and visualization. Our results show that there are mainly two groups relating to service innovation. Knowledge in these areas has been growing rapidly in recent years. In particular, the fields of ecosystem and IT & Web are exhibiting high growth. We also demonstrated that the global network of knowledge is formed around the powerful hub of the US. The research competency of Asian countries lags behind that of the US and EU. With respect to research collaboration, we identify room for enhancing international collaboration. Our methodology could be useful in forming policies to promote service innovation. Finally, we propose the creation of an international collaboration fund.

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1. Introduction

The concept of service innovation or service science, management and engineering (SSME) proposed by IBM is widely recognized as a key driver for economic growth. Service science is an emerging area of research [1,2], and Maglio and Spohrer [3] define service science as the study of service systems, which are dynamic value co-creation and configuration processes of resources. Spohrer et al. [4] argue that service science can be thought of as a mashup or integration of many areas of study known as service management, service marketing, service operations, service engineering, service computing, service human resources management, service economics, management of service innovation and others. Wu [5] suggests that the concept of SSME is an emerging interdisciplinary approach that combines fundamental management and engineering theories.

The concept of SSME plays a significant role in policy making in many countries. And, for policy makers, effective investment on promising and emerging technology alternatives has become a significant task in order to develop their competence and competitiveness and also to realize economic and social development. In Japan, the government established a roadmap named the Technology Roadmap of Service Engineering (TRSE), which describes the goal of service innovation. However, the scope of the concept, SSME, is so broad that there is no common understanding and consensus about what is service innovation even among experts [3,5]. Although TRSE describes forty-nine technology elements and the relationship between technology and industry,

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these descriptions lack concreteness because it is so conceptual. Therefore, prior to developing a roadmap, it is necessary to establish the academic landscape of SSME in order to understand what has been researched relating to this topic.

The aim of this paper is to create the academic landscape in SSME for envisioning the future of SSME and to elucidate the global structure of research and collaboration, which can be utilized in roadmapping and policy making for the advancement of SSME. Service science, service innovation or SSME has the interdisciplinary nature in their approach [5,6]. Tracking the evolution of an interdisciplinary research domain, such as SSME, is a significant but difficult task because of the complexity of the domain. A previous study argues that interdisciplinary research should not be conceptualized within a discipline [7]. Some indicators measuring interdisciplinarity such as diversity of classifications and topological measures have been proposed and evaluated in previous papers [8,9]. But existing classification schema such as categorization with journal names may not matter because interdisciplinary researches vary beyond the boundaries of journals. On the other hand, experts are not able to track the entire trends in such specialized and segmented research areas. Therefore, a computational approach is essential to support experts and policy makers in order to comprehend the current global structure of academic research among a mass of academic publications.

In order to create an academic landscape, there are two types of computer-based methodologies, which can complement the expert-based approach: text mining and citation mining. In the text-based approach, it is assumed that documents with common terms or terms appearing in common documents are regarded as similar, while in the citation-based approach, it is assumed that citing and cited papers have similar research topics. As an example of the former, Kostoff et al. analyzed multi-word phrase frequencies and phrase proximities, and extracted the taxonomic structure of energy research [10,11]. An example of the latter is the work by Tijssen who used journal citation data or journal classification data to describe the network of energy-related journals using [12].

In this paper, we adopt the latter one, the citation-based approach to create the academic landscape in SSME, because text mining requires subjective parameters to obtain relevant results in text extraction and in clustering, compared to citation-based approaches. A citation-based approach is increasingly recognized as useful for an overview of research domains. Klavans and Boyack illustrate how to map science overall using journal citation interactions [13]. By clustering the citation network, we can divide academic papers into groups of papers. Kajikawa et al. apply clustering of the citation network to illustrate an academic landscape and to extract emerging domains in energy research to assist roadmapping [14]. Previous research has investigated a citation-based approach with a text-based approach in another interdisciplinary research, sustainability science, and extracted the major topics relating to this interdisciplinary research field [15].

From the perspective of policy making, in addition to comprehensive understanding on the intellectual world from the academic landscape, it is also important to understand the overall geographical distribution of research and partnerships. By understanding regional distribution and partnerships, it is possible to discuss the relationship between the number and nature of policies adopted in a particular region and the study of SSME, and it is also helpful to develop a plan for global partnership in the field of research. Hence, the second aim of this paper is to draw a research network diagram that includes information on the geographical distribution of knowledge and inter-regional collaboration.

To create a research network diagram, we will use author information such as organizations to which authors are affiliated, nationalities of such organizations and co-authors from the same database and corpus used for creation of the academic landscape. There are several studies that use co-authorship as a quantitative indicator [16,17]. Co-authorship is usually used as an indicator of international collaboration [18–20]. Katz and Martin point out four key advantages of using co-authorship as an indicator of collaboration including its verifiability, statistical significance, data availability, and ease of measurement [21]. On the other hand, bibliometric analysis of multiple-author papers is not accurate as it can only be used to measure collaborative activities where the collaborating participants have entered their names on joint papers. We are aware of a bias where each research paper published separately despite the collaboration cannot be correctly identified. Nevertheless, this unique analytical method and data provide useful and clear empirical evidence, and when used with appropriate caution reveal new insights for international science policy. Therefore, our analysis is expected to offer an intellectual basis for constructing a policy and strategy.

As stated above, the concept of SSME is yet to be clearly defined. This concept has been mainly used in the US so far. It is possible that by using the term SSME as a query keyword, research fields growing in countries other than the US will be underestimated. In evaluating the academic landscape and research network diagram, it will be necessary to consider this possibility.

2. Methodology

First of all, the methodology for creating an academic landscape is shown. Analyzing schema is schematically depicted in Fig. 1. Step (1) is to collect data of the knowledge domain. We collected citation data from the Science Citation Index Expanded (SCI-

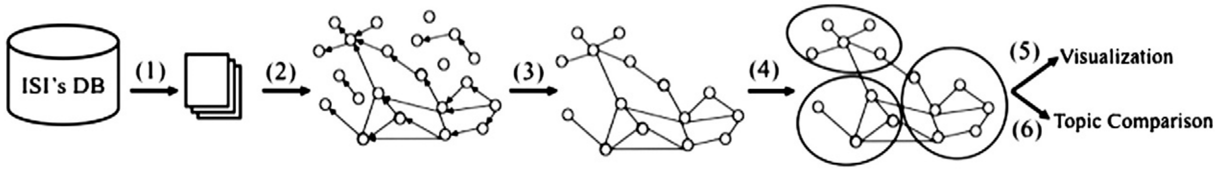

Fig. 1. Methodology proposed in this paper.

EXPANDED), the Social Sciences Citation Index (SSCI), and the Arts & Humanities Citation Index (A&HCI) compiled by Thomson Reuters, which maintain citation databases covering thousands of academic journals and offer bibliographic database services, because they are three of the best sources for citation data. The problem of how we should define a research domain is difficult to solve. One solution is to use a keyword that seems to represent the research domain. When we collect papers retrieved by the keyword, we can make the corpus for the research domain.

In step (1) for creating academic landscape, we searched for papers using the terms "service* and (science* or management* or engineering*)" as the query. As a result, we obtained the data of 54,928 papers published until the end of 2008. The number of annual publications is shown in Fig. 2.

Step (2) is to make citation networks for each year. We constructed citation networks by regarding papers as nodes and intercitations as links. According to the previous study, intercitation, which is also sometimes known as direct-citation, is the best way of detecting emerging trends [22]. In network analysis, only the data of the largest component on the graph was used. Because we collected papers by query, our corpus included papers that are not relevant to SSME. By focusing on the largest component, we can identify papers from our study that are not linked with any others in step (3) and therefore those noisy papers are expected to be eliminated.

After extracting the largest connected component, in step (4), the network was divided into clusters using the topological clustering method [23], which does not need the number of clusters by users like k-means clustering algorithm. Newman's algorithm extracts tightly knit clusters with a high density of links within the cluster. The clustering algorithm is based on the idea of the maximization of modularity. Modularity is defined as the fraction of links that fall within clusters, minus the expected value of the same quantity if the links fall at random without regard for the clustered structure of that network. A high value of modularity represents a good division of clusters where only dense clusters remained within clusters and sparse links between clusters. Newman's algorithm [23] can efficiently find the point to maximize modularity over all possible divisions by cutting off links which connect clusters sparsely and extract clusters within which nodes are connected densely.

After the clustering, we visualized the citation networks and named the major clusters of emerging topics as in steps (5) and (6), respectively. In step (5), in order to visualize citation maps, we applied a large graph layout (LGL), an algorithm developed by Adai et al. [24], capable of dynamically visualizing large networks comprised of hundreds of thousands of nodes and millions of links. We visualized the citation network by expressing intra-cluster links in the same color, in order that the clusters are intuitively understood. In step (6), experts in the research domain assign a name to each cluster manually after they have seen the titles and abstracts of the papers in each cluster.

Second, we created a research network diagram from the same database used for the creation of academic landscape, and for the extraction of data related to the organizational affiliation of authors, geographical location of such organizations and co-authorships. Two types of analysis were conducted: analysis on research competency and that on co-authorship. Research competency of each country and organization was evaluated from the number of papers by them. Collaboration pattern between organizations was analyzed by equally regarding all combinations of organizations of co-authors as one collaboration. Authors in co-authored papers are not weighed by the order listed. For example, if one paper is written by four different authors, and each author belongs to a different organization, the paper is considered to include six co-authorship relations. In addition, combinations of organizations that have more co-authorship relations are identified.

In addition, a co-authorship is defined as an international co-authorship if the authors belong to organizations in different countries. The same calculation schema was adopted to analyze the international collaboration pattern with that of the organizational pattern. Then, the result was visualized as a "research network diagram" with the author's country as a node and the co-authorship relation as a link between the nodes. In the diagram, organizations are grouped into the country to which they belong. The hub of international co-authorships was also obtained from the analysis.

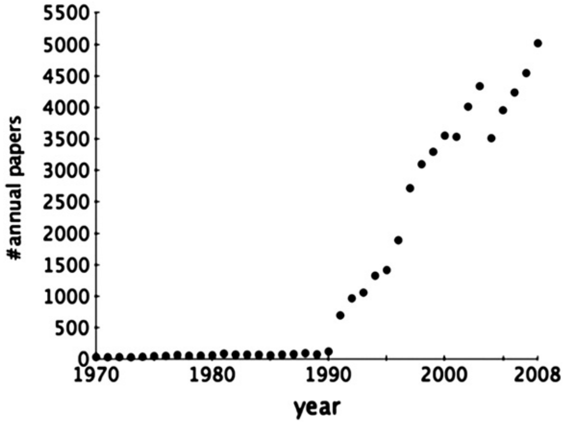

Fig. 2. Number of annual papers relating to SSME.

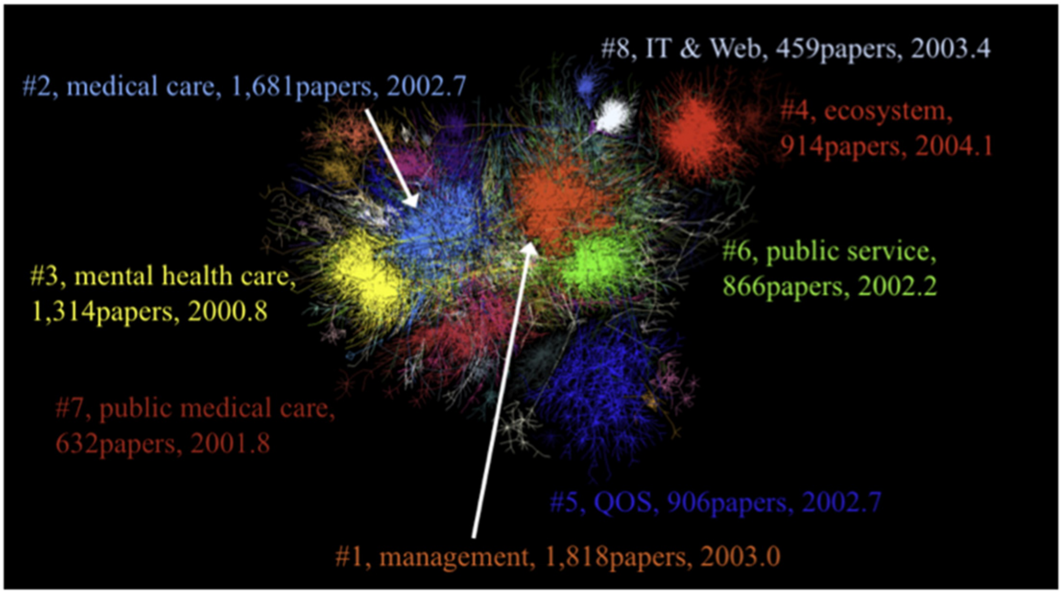

Fig. 3. Visualization of citation network in 2008.

3. Results

After constructing the largest connected component, in step (4), we divided papers into clusters by topological clustering method. With this clustering, citation networks as of 2008 were divided into specific clusters in step (4) and visualized as Fig. 3 in step (5). Focusing on the visualization in 2008, eight major clusters emerged as shown in Table 1. Each contains more than 400 papers. The clusters #1, #2, #3, #4, #5, #6, #7 and #8 contained respectively 1818, 1681, 1314, 914, 906, 866, 632, and 459 papers. Their average publication years were 2003.0, 2002.7, 2000.8, 2004.1, 2002.7, 2002.2, 2001.8, and 2003.4. Younger average publication year of a cluster means that the cluster has more recent papers than other clusters, and therefore we can regard that the research field is rapidly growing. In the final step, step (6), our experts named each cluster, using semantic information such as the titles and abstracts of highly-cited documents in each cluster, shown in Table 1. The clusters #1, #2, #3, #4, #5, #6, #7 and #8 related to management, medical care, mental health care, ecosystem, QOS, public service, public medical care, and IT & Web, respectively. Issues on health service are overlapped among clusters, i.e., S2, S3, and S7. These clusters about health care appear in close positions, i.e., left hand side of Fig. 3, which means that these clusters share many citations and there are large overlaps among these clusters. S1 (Management) and S8 (IT & Web) also appear at close positions in Fig. 3, and therefore, utilization of IT & Web is regarded to have a strong impact on management and business service. On the other hand, S4 (ecosystem) and S5 (QOS) locate at distant positions from the other clusters, which mean little overlaps with the issues discussed in the others. Among these 8 clusters, management, ecosystem, IT & Web are emerging new research fields and research fields relating health care are relatively old, while average publication year of all of 8 clusters are after 2000, which reflects emerging and nascent nature of SSME.

Next, a research network diagram is created. The number of organizations is 20,549, and the number of links among organizations based on the co-authorship is 72,484. Thus, a collaborative research network of 20,549 nodes and 72,484 links is formed in the field of SSME. Analysis at the country level was conducted based on data about these nodes and links. The top five countries in the research competency are the US, England, Germany, France and Australia (see Table 2). As a single country, it is notable that the US significantly leads the others. The research competency of EU as a total is slightly higher than that of the US. The sum of the number of publications by EU countries who ranked within the top 30 is 8694, while the US has 7694 papers. Asian countries (China, Korea, India and Taiwan) are ranked between 10 and 18, although they show a rapid increase in their competencies.

Table 1
Major 8 clusters.

ID	# papers	Average publication year	Name
S1	1818	2003.0	Management
S2	1681	2002.7	Medical care
S3	1314	2000.8	Mental health care
S4	914	2004.1	Ecosystem
S5	906	2002.7	QOS
S6	866	2002.2	Public service
S7	632	2001.8	Public medical care
S8	459	2003.4	IT & Web

Table 2
The top 30 countries in research competency.

Rank	Country	# papers
1	USA	7649
2	England	2572
3	Germany	1466
4	France	1116
5	Australia	965
6	Canada	923
7	Italy	788
8	Spain	625
9	Japan	598
10	People's R China	469
11	The Netherlands	453
12	India	425
13	South Korea	339
14	Switzerland	339
15	Brazil	319
16	Scotland	304
17	Sweden	295
18	Taiwan	287
19	Finland	232
20	Greece	200
21	South Africa	192
22	New Zealand	180
23	Norway	180
24	Austria	179
25	Israel	177
26	Mexico	177
27	Belgium	169
28	Russia	151
29	Denmark	150
30	Ireland	145

By analyzing the data of organizations (Table 3), it is clear that organizations with strong competency are often found in the US. Harvard University ranks first in the number of papers. Organizations other than the US include the Univ. Manchester and UCL (England), Univ. Toronto (Canada), and Univ. Sydney, Univ. New South Wales, Monash Univ., and Univ. Queensland in Australia. No organization in Asia appears in the list.

Table 4 shows a list of organization pairs that exhibit a high number of co-authorships. There are more co-authorship relationships between organizations with high research competency. In addition, the number of collaborations between universities and their affiliated hospitals located nearby is notable. Geographically, many co-authorship relations are found in organizations within the same country, while international co-authorship is rare. In general, it has been noted that collaborative researches are often conducted by research organizations located within the same geographical region [19]. Nevertheless, collaboration in the SSME field is characterized by the dominance of domestic relationships compared to studies in the renewable energy field [25].

A research network diagram was created by consolidating the data described above, as shown in Fig. 4. Organizations in the same country are placed together and shown as a node. The size of each node is proportional to the number of papers written by authors from the country. Each link between two nodes of different countries indicates that there is a co-authorship between countries. The width of lines connecting the countries is proportional to the number of co-authorships. In a geopolitical sense, it is clear that the US is a powerful hub of the global network. This is completely different from the network structure of renewable energy in which there is a well-balanced structure between North America, Europe and Asia [25]. In particular, there are thick lines between the US and countries such as Canada (1319 links), England (1319 links), Australia (506 links), Germany (475 links), China (414 links), The Netherlands (325 links) and France (331 links). Among the relationships that do not involve the US as a hub, the thickness of lines between England and countries such as Germany (294 links), Australia (291 links) and The Netherlands (281 links) is notable, illustrating that England is another major hub behind the US.

4. Discussion

As described above, we performed citation network analysis on the SSME research domain. Our basic idea was that papers dealing with a similar topic cite each other and are strongly connected while papers dealing with different topics are weakly connected. Therefore, the division of a knowledge domain into strongly connected clusters by citation analysis can detect what kinds of topics are discussed in the SSME research domain. As a result, we found mainly eight clusters. Moreover, this SSME research domain is so interdisciplinary that several clusters are overlapped while others do not so much. An example of clusters having large overlapped is health care related clusters. Another example is management and IT & Web.

The eight major clusters we extracted can be divided into two groups; basic research (S1 management, S4 ecosystem, and S5 QOS) and application for society (S2 medical care, S3 mental health care, S6 public service, S7 public medical care and S8 IT &

Table 3
The top 30 organizations in the research competency.

Rank	Organization	Country	# papers
1	Harvard Univ.	USA	544
2	UCLA	USA	487
3	Univ. Texas	USA	453
4	Univ. Manchester	England	449
5	Univ. Toronto	Canada	448
6	Univ. Michigan	USA	393
7	Univ. Maryland	USA	392
8	Univ. N Carolina	USA	390
9	Univ. Illinois	USA	374
10	Univ. Minnesota	USA	371
11	Johns Hopkins Univ.	USA	344
12	Univ. Penn	USA	344
13	Univ. Wisconsin	USA	319
14	Yale Univ.	USA	315
15	Univ. Pittsburgh	USA	309
16	Columbia Univ.	USA	304
17	Univ. Colorado	USA	289
18	UCSF	USA	287
19	Univ. Calif Berkeley	USA	277
20	Univ. Sydney	Australia	275
21	Stanford Univ.	USA	274
22	Univ. Melbourne	Australia	271
23	Duke Univ.	USA	262
24	Univ. So Calif	USA	252
25	Univ. New S Wales	Australia	243
26	Monash Univ.	Australia	242
27	Ohio State Univ.	USA	242
28	UCL	England	230
29	Univ. Queensland	Australia	228
30	Indiana Univ.	USA	223

Table 4
The top 30 pairs of co-authored organizations.

Rank	Organization 1	Country 1	# papers	Organization 2	Country 2
1	Brigham and Women's Hosp	USA	59	Harvard Univ.	USA
2	Univ. Calif Los Angeles	USA	56	RAND Corp	USA
3	Harvard Univ.	USA	47	Massachusetts Gen Hosp	USA
4	Monash Univ.	Australia	34	Univ. Melbourne	Australia
5	Univ. New S Wales	Australia	33	Univ. Sydney	Australia
6	Grp Hlth Cooperat Puget Sound	USA	33	Univ. Washington	USA
7	Univ. Calif San Francisco	USA	32	Univ. Calif Los Angeles	USA
8	Univ. Toronto	Canada	29	St Michael's Hosp	Canada
9	Univ. So Calif	USA	27	Univ. Calif Los Angeles	USA
10	Univ. N Carolina	USA	27	Duke Univ.	USA
11	Univ. Toronto	Canada	26	Inst Clin Evaluat Sci	Canada
12	Boston Univ.	USA	25	Harvard Univ.	USA
13	Univ. Washington	USA	24	Univ. Calif Los Angeles	USA
14	Mcgill Univ.	Canada	24	Univ. Montreal	Canada
15	USDA	USA	23	USDA Ars	USA
16	Yale New Haven Med Ctr	USA	23	Yale Univ.	USA
17	Hosp Sick Children	Canada	22	Univ. Toronto	Canada
18	Harvard Univ.	USA	21	Children's Hosp	USA
19	Va Puget Sound Hlth Care Syst	USA	21	Univ. Washington	USA
20	Mcmaster Univ.	Canada	20	Univ. Toronto	Canada
21	Univ. Calif Los Angeles	USA	20	Harvard Univ.	USA
22	Case Western Reserve Univ.	USA	19	Univ. Hosp Cleveland	USA
23	Univ. Connecticut	USA	19	Yale Univ.	USA
24	Johns Hopkins Univ.	USA	19	Univ. Maryland	USA
25	Yale Univ.	USA	18	VA Connecticut Healthcare Syst	USA
26	Royal Prince Alfred Hosp	Australia	18	Univ. Sydney	Australia
27	Beth Israel Deaconess Med Ctr	USA	18	Harvard Univ.	USA
28	New York State Psychiat Inst & Hosp	USA	18	Columbia Univ.	USA
29	Univ. Liverpool	England	18	Univ. Manchester	England
30	Univ. Toronto	Canada	17	Univ. Hlth Network	Canada

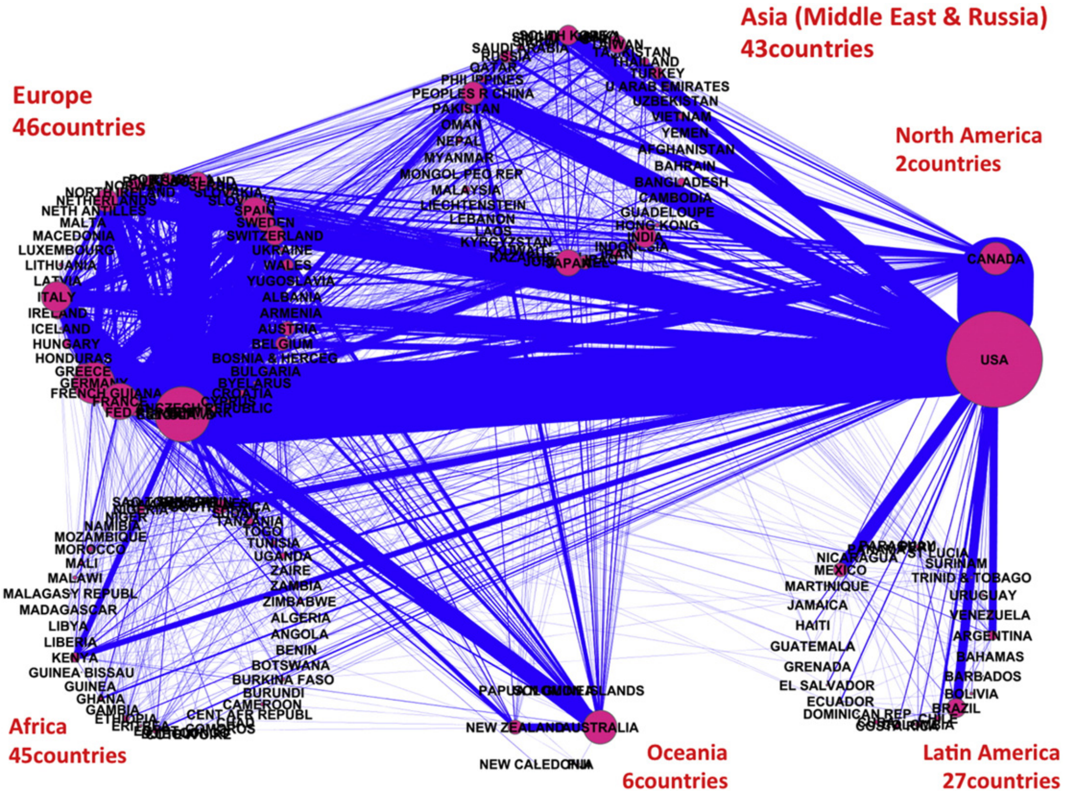

Fig. 4. Research network diagram (2009).

Web). Academic research in SSME tends to deal with topics of public social systems, such as S2 medical care, S3 mental health care, S6 public service, and S7 public medical care, in terms of service innovations. This point is different from the definition by Spohrer et al. [4]. As long as we discuss with the experts, there might be two reasons. The first one is the lack of popularity of the concept SSME. Especially in research fields that have a clear boundary and have already been industrialized, the researcher might not mention SSME even if they wrote about service innovations in their field. A typical example is financial services. The financial services sector is one of the most innovative service sectors and needs intensive input of software technology [26]. However, most papers discussing innovation of financial services do not use science, management or engineering as an important term. The second reason is the increasing attention toward public systems. The number of researches relating to public services, such as S6, has increased recently (as shown in Fig. 5(b) described in the next paragraph).

Detailed analysis of each cluster reveals emerging clusters. Regarding the average publication year shown in Table 1, S1, S4 and S8 seemed to contain many recent papers. Fig. 5 indicates the number of annual publications in each cluster. In this figure, clusters S1, S2, S4, S6 and S8 are still so growing that they can be emerging research fronts, while S3 and S5 seem to peak around 2000 and to be mature at the end of 2008. Many previous studies identify that IT & Web such as computer science, software engineering and

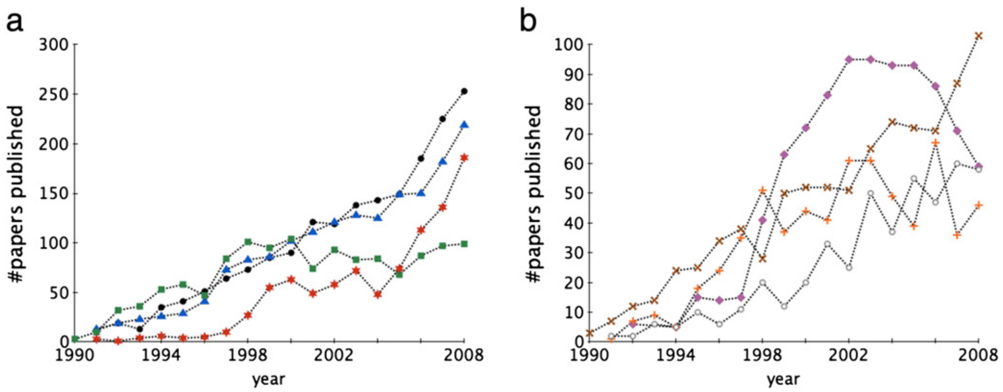

Fig. 5. The annual number of publications in each cluster; (a)●: S1 management, ▲: S2 medical care, ■: S3 mental health care, ★:S4 ecosystem and (b)♦:S5 QOS, ×:S6 public service, +: S7 public medical care, ○:S8 IT & Web.

grid computing are the base and driving force of service innovation [4,27–29]. OECD innovation strategy [30] points out that there is considerable scope to innovate in the delivery of public service. Our findings are consistent with these studies.

With this method, we can extract research topics in an interdisciplinary research area such as service innovation by computational calculation. Currently, some research activities tend to explore common concepts, crossing the boundaries of existing research areas or journals. However, we face increasing difficulty in creating an academic landscape of these diverse research domains. Our topological approach can become a tool for future "Research on Research" (R on R) and can meet a commensurate increasing need as scientific and technical intelligence to discover emerging research fronts in an era of information flooding.

The research network diagram objectively shows the knowledge distribution and collaborative relationships in the field of SSME. In terms of the structure of co-authorships, there are more co-authorship relations between organizations in the same country or those within a close spatial proximity. This corresponds with other previous studies identifying the relationship between co-authorship of organizations and spatial proximity, culture, and language [18–20,31,32]. Furthermore, there are more co-authorship relations between organizations with high research competency.

The motivation for this may include some of what Bozeman and Corley point out: access to expertise and equipment, to obtain prestige or visibility, to gain tacit knowledge, and to enhance productivity [33]. Modern technology is increasingly complex and demands an ever-widening range of knowledge and skills. Often, no single country or institution will possess all the knowledge and skills required. Previous studies have shown that a high level of collaboration is correlated with high paper productivity [18,34,35]. The number of international collaborations is small in the field of SSME. The share of international co-authorship in the fields of SSME is only 13.4%. The number of SSME is significantly smaller than those of green technologies. This fact indicates that it is possible to significantly enhance the efficiency of global service innovation by adopting a policy to promote collaboration. The need for service innovations to fuel economic growth and to raise the quality and productivity levels of services has never been greater [6]. In addition, SSME is a technology that could play a major role in finding solutions to global challenges such as an ageing society and the sustainability of the Earth. Framework Programmes of Europe played a major role in promoting collaborative researches in the field of solar cells in and out of Europe. We hope that a similar framework to promote researches by international cooperation will be created for solving global and common challenges based on the methodology discussed in this paper.

Service sector has been a major component of study for the community of technology and innovation management [36–39]. Our analysis showed that current SSEM research both advance basic research in management and also expand their focus of research to applications in healthcare, public, and IT sectors. The methodology proposed and adopted in this study is a promising approach to comprehend this rapidly growing research field and global collaboration structure there.

5. Conclusion

The concept of service innovation is significant for innovation strategy and economic growth. However, the definition of service innovation is controversial, even among experts. We developed a methodology for determining the structure and geographical distribution of knowledge, as well as for determining the structure of research collaboration in such an interdisciplinary area as service innovation by performing network analysis and visualization. Our results show that there are two main groups of research relating to service innovation: applications of service innovation to society such as health and medical care, IT & Web, and public service; and basic theories for service innovation such as management, ecosystem, and QoS. Knowledge in these areas has been growing rapidly in recent years. In particular, the fields of ecosystem and IT & Web have been exhibiting high growth, which are plausible candidates of development for practitioners, researchers, or policy-makers.

We also demonstrate that the global network of knowledge is formed around the powerful hub of the US. On the other hand, in research collaboration, we demonstrate that most research is conducted within the same country or within close spatial proximity and, therefore, there is plenty of room for enhancing international collaboration. This academic landscape and diagram could be useful in forming policies to promote service innovation. As shown in our diagram, US is the hub of research in SSME, and therefore, the other countries can learn from accumulated knowledge in US and collaboration with researchers in that country to absorb and develop expertise and capabilities in service science, engineering, and management. We propose creation of an international collaboration program to solve global challenges such as the ageing society and the sustainability of the Earth.

In this study, the term "SSME" is used in developing queries. The definition of the term affects analysis. Determining a better query setting suitable in the interdisciplinary area is another subject to be studied in the future.

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