Opportunities and Potential of the Internet of Things for Solving Social Issues

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Abstract—**The Internet of Things (IoT) is expected to change society, although it is a general-purpose technology and its concrete application, value, and feasibility are still obscure. In this study, we explored plausible social issues to which IoT solutions can be applied. First, we extracted promising research areas of IoT by measuring text correlations between citation networks of papers and those of patents. Then, semantic linkages between extracted research areas and social issues were investigated. In this research, we targeted social issues proposed at the World Summit on Sustainable Development in 2002, WEHAB (i.e. water, energy, health, agriculture, and biodiversity). On the basis of the results, we discuss potentials and challenges for IoT to solve social issues.**

I. INTRODUCTION

A. Internet of Things

The Internet of Things (IoT) is a concept related to the "pervasive presence around us of a variety of things or objects which, through unique addressing schemes, are able to interact with each other and cooperate with their neighbors to reach common goals" [1]. IoT has started to be recognized as an essential emerging technology among various stakeholders, such as industry, academia, and government. In industry, promotional organizations such as the Industrial Internet Consortium (IIC) have been founded. McKinsey conducted a bottom-up analysis of IoT applications, and estimated that the IoT has a total potential economic impact of U.S. $3.9 trillion to $11.1 trillion per year by 2025 [2]. Academia has also focused on IoT, and the number of papers including the terms "Internet of Things" or "IoT" has been increasing exponentially. A total of 197 papers with these terms were published before 2010, and the number increased to 1,870 by 2014. Because the potential is huge, governments consider IoT as one of the main technologies that should be strategically promoted. For instance, the Council for Science, Technology, and Innovation (CSTI) devoted much attention to IoT in the fifth Science and Technology Basic Plan (fiscal 2016-2020) [3]. Another indication is that IoT became a main topic in the World Economic Forum in January 2016 [4]. Therefore, IoT has been highly expected in the society, and thus it is important to comprehend IoT trends.

B. Emerging technology and social issues

When new technologies appear, researchers in various fields seek solutions to social issues [5]. Even though IoT is also expected to solve social issues, many studies tend to focus on industry applications such as supply chain [6-7] and manufacturing [8-9]. Meanwhile, few studies have targeted social issues. A trial study for seeking new applications of IoT to solve social issue was conducted in [5]. The study analyzed the types of social issues by defining them through analysis of previous studies, and a crime prevention security system was proposed to prevent crimes in deteriorated areas by IoT. However, the procedure these studies took might be too time-consuming to investigate such linkages between technology and social issues solved by the technology because the authors manually reviewed the previous studies. In addition, IoT systems consist of many subsystems. Studies that focus on IoT hardware include many prior technologies, such as near-field communication (NFC), sensor networks (SN), and radio-frequency identification (RFID) [10]. It is difficult to grasp the "big picture"; IoT is a broad technology whose purpose is general, and its concrete application, value, and feasibility are still obscure.

In the field of management of technology, there are two approaches for detecting emerging research domains: expert-based approach and computer-based approach [11]. Expert-based approach, such as Delphi technique could be more accurate, but it is often time-consuming and is also subjective. On the other hand, the result could be obtained by computer-based approach automatically, in relatively short time, and objectively. Several previous studies analyzed large numbers of papers and patents by applying information science. It is important for technology intelligence to comprehend social issues and technological candidates for solving them from a vast stream of information flow. Lee, Sungjoo, et al. used RFID patents as a proxy measure of technological capability for technology planning and ends with a business opportunity analysis for the marketplace [12]. Bei-Ni Yan et al. mapped the intellectual structure of the IoT field by using a co-word analysis of articles published from 2000 to 2014 [13]. These previous studies have investigated intellectual structures of IoT, and its technological trends. However, there is no research that explored plausible social issues where IoT can be applied. Thus, in this study, we explored IoT-related technologies that can be used to solve social issues by measuring semantic similarity of the clusters. An efficient method using a literature-based discovery approach for finding linkages between technology and social issues was proposed by Ittipanuvat et al. [14]. In their paper, articles in the field of robots and the elderly society were retrieved and semantic linkages among them were investigated. We followed their methodology. Social issues analyzed in this study were selected by using the *WEHAB* (water, energy, health, agriculture, and biodiversity) [15] framework, which has been considered a globally essential theme. The linkages between these issues and IoT-related technologies including IoT, NFC, SN, and RFID were investigated. Then, the extracted linkages were evaluated.

II. METHODOLOGY

An overview of the methodology used in this study is shown in Fig. 1. First, technology papers, social issue papers, and technology patents were collected from databases. Those

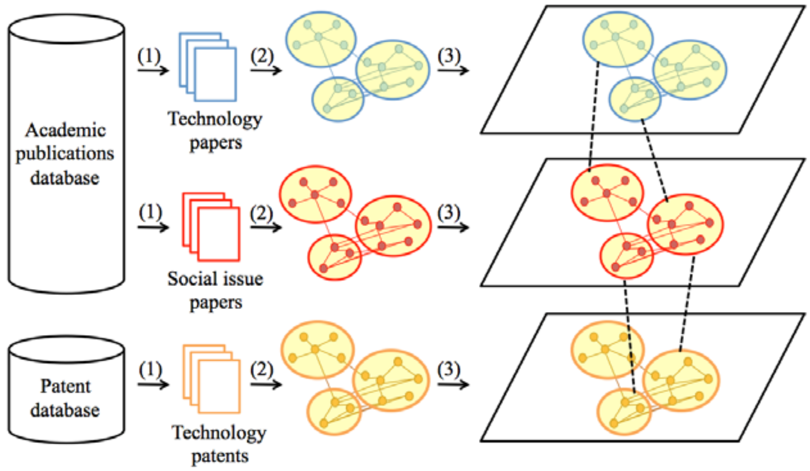


Figure 1. Overview of the methodology used in this study.

documents were connected by citation and created networks. Then, the networks were divided into subgroups. Technology networks of papers and patents networks were recursively divided so that concrete technology domains could be obtained. We collected both papers and patents for IoT-related technologies because the condition of papers and patents in the domain were used to offer an intellectual basis for discovering potential opportunities for industrial commercialization [16], thus we also utilized that method. Finally, semantic similarities between the three kinds of networks were measured to investigate semantic linkages of technology for solving social issues. Extracted linkages were further analyzed and their opportunities and potentials demonstrated.

A. Data collection

In step (1) shown in Fig. 1, bibliographic records were obtained from databases. In this study, two kinds of database records were used to collect papers and patents. Papers were collected from the Science Citation Index Expanded, Social Sciences Citation Index, and Conference Proceedings Citation Index- Science using Web of Science. Patents were collected from the Enhanced Patent Data- Derwent Patent Citation Index (DWPI) and Derwent Patent Citation Index (DPCI) by Thomson Innovation. DWPI contains members of patent families, and DPCI contains citation references for each patent family.

Three kinds of documents were obtained. First, technology papers regarding IoT, NFC, SN, and RFID were gathered. Papers published before 2014 were obtained. Second, social issue papers including water, energy, healthcare, agriculture, and biodiversity were retrieved from international journals registered in Web of Science, which include the name of the research field in the title of the journal (for instance, “water resources” were selected in the field of water). Their papers published from 2010 to 2014 were collected because we are interested in recent social issues. Third, technology patents in the fields of IoT NFC, SN, and RFID published until March 20, 2013 were collected. The queries applied in this step are shown in Table 1.

TABLE 1. QUERIES USED IN THIS STUDY (WC IS A FIELD TAG OF WEB OF SCIENCE THAT DESIGNATES THE NAME OF THE JOURNAL)

Domain	Query
IoT	“internet of things” OR “IoT”
NFC	“near field communication” OR “NFC”
SN	“sensor networks”
RFID	“radio frequency identification” OR “RFID”
Water	WC = ("water resources")
Energy	WC = ("energy fuels")
Healthcare	WC = ("public environmental occupational health" OR "health care sciences services" OR "health policy services")
Agriculture	WC = ("agriculture multidisciplinary" OR "agricultural economics policy" OR "agriculture dairy animal science")
Biodiversity	WC = ("biodiversity conservation")

B. Creating a citation network

Step (2) shown in Fig. 1 involves the creation of citation networks. Our study does not depend on citation network analysis, and text-based analysis (e.g., topic modeling) is also able to utilize. However, citation network analysis has long history and has been utilized widely to detect emerging research fields, thus, citation network analysis was also applied in this study. Retrieved documents were connected by the citations among them, and the maximum component of the network was obtained. However, in the case of patents, the size of the maximum component tends to be small. To solve this problem, patent family analysis was conducted [17]. A patent family is defined as a collection of patents that are filed in different countries but refer to the same invention. The maximum component of the patent network was enlarged by aggregating patents inside the family members as one node and all cited references of the family as edges.

Then, networks were divided into groups by clustering the citation networks using Newman's algorithm, which can identify tightly knit clusters in a large network [18]. Clusters were divided into a minimum scale of sub-clusters with sizes approximately several tens or hundreds [19]. These sub-clusters were then mapped into an academic landscape [20-22], which helped visualize the relationships between technologies. Sub-clusters separated from the main network or sub-clusters that were too small to be research fields were removed as noise by checking their research focus. The number of documents and clusters used in this study are summarized in Table 2. The coverage of documents is shown in parentheses.

C. Linkage analysis

Step (3) shown in Fig. 1 is conducted for linkage analysis between technology and social issues that could be solved by the technology. This step consists from three sub-steps; linkage extraction, division of linkages, and demonstration of linkages. The sub-steps are summarized in Fig. 2.

In step (3)-1, linkage extraction was conducted. Semantic similarities between clusters were measured. Similarity was calculated by cosine similarity [14] of all pairs of documents in a cluster, as shown by

$$CosineSimilarity(t,s) = \frac{\overline{j_t} \cdot \overline{j_s}}{\sqrt{\sum_i j_t^{(i)} \cdot j_s^{(i)}}} \quad (1)$$

where t and s are clusters in each domain, and j_t and j_s are term vectors of clusters t and s, respectively. Threshold is defined as the average cosine similarity of each combination of IoT-related technologies and social issues. When the similarity of a linkage is higher than the threshold, the linkage is extracted. Then, the number of linkages and percentage of linkages are calculated to comprehend the distribution of social issues that have opportunities and potentials for being solved by IoT-related technologies.

TABLE 2. NUMBER OF DOCUMENTS AND CLUSTERS USED IN THIS STUDY

Domain	Paper		Patent	
	# papers	# clusters	# patents	# clusters
IoT	908 (95.4%)	13	76 (100%)	9
NFC	119 (100%)	10	2644 (94.4%)	24
SN	28448 (92.0%)	221	17 (100%)	5
RFID	7253 (92.5%)	39	22907 (91.2%)	217
Water	40643 (95.0%)	40	-	-
Energy	94825 (95.0%)	17	-	-
Healthcare	114103 (95.0%)	54	-	-
Agriculture	36110 (95.1%)	53	-	-
Biodiversity	11454 (95.0%)	39	-	-

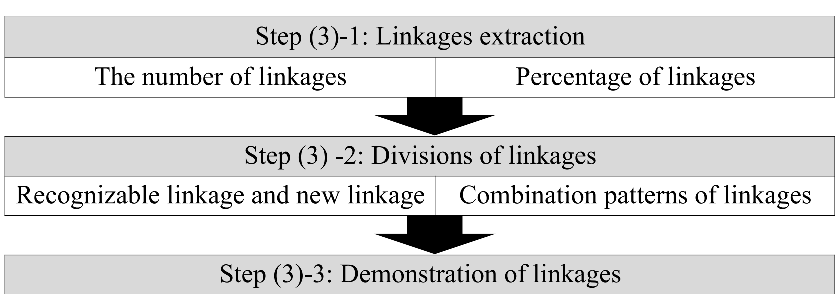


Figure 2. Three substeps of step (3).

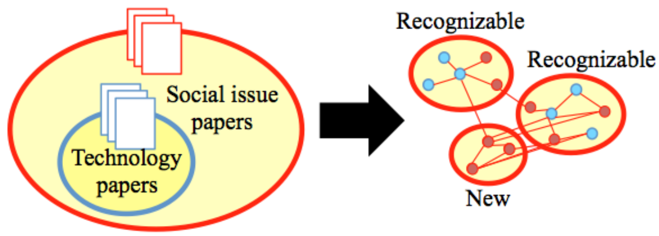
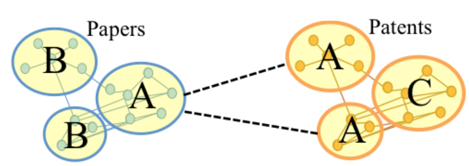


Figure 3. Recognizable cluster and new cluster.

In step (3)-2, divisions of linkages are conducted. First, linkages are divided into those already recognizable among experts in the research field, and others where even experts do not know the new opportunity or potential. Some social issue papers referred to papers about technologies for solving the issue when they were retrieved from database. In this case, some of the clusters consisted of social papers that contain solution information. Here, such clusters are defined as recognizable clusters, whereas clusters that do not refer to technology papers for solving the issue are called new clusters (Fig. 3). A linkage connected to a recognizable cluster is defined as a recognizable linkage, and a linkage connected to a new cluster is defined as a new linkage.

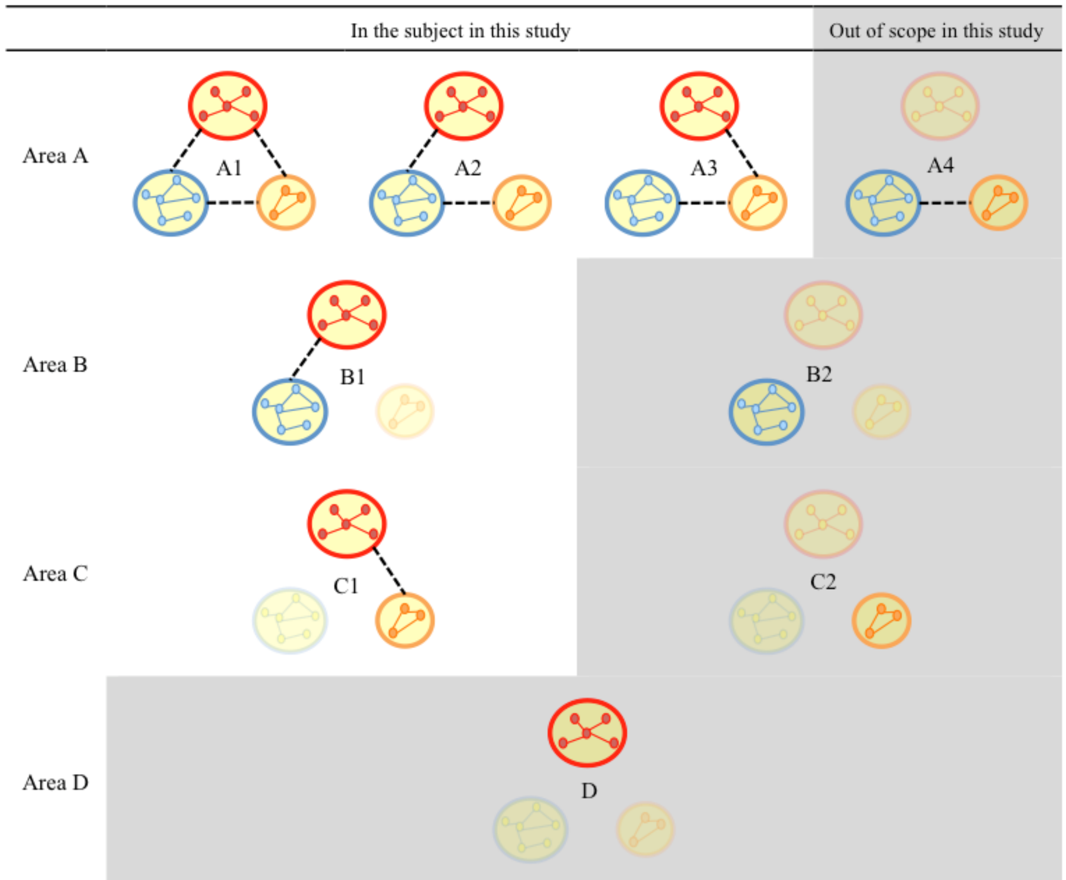
Second, combination patterns of linkages are categorized to use them as indicators for evaluating the opportunity and potential of solving the social issue. Science and technology tends to emerge in research institutes or academia, but when emerging technology is applied in real society, the role of the industry sector is necessary. In industry, business is “at its best: innovating to meet society’s needs and build a profitable enterprise” [23] and “achieving those twin goals represents the next competitive frontier for companies” [24]. Hence, for stakeholders involved in technology, it is important to detect what are suitable issues, and what are the technologies with a high potential to solve these issues. To evaluate such potential, Shiabta et al. [16] proposed the framework shown in Fig. 4 to offer an intellectual basis for discovering potential opportunities for industrial commercialization. In their study, the structure of a citation network of scientific publications (blue clusters in Fig. 4) with those of patents (orange clusters in Fig. 4) was compared, and the differences between them were discussed. Semantic similarities between those networks were measured and they were categorized by the value of text correlation. When text correlation, or cosine similarity of texts, is higher than average, the technology is categorized as area A, where the technology is already commercialized but their R&D are also active. On the other hand, when similarity is less than average, the technology is categorized as area B or C. Networks composed of patents belong to area C, whose technology is too application-oriented and difficult to be academic research. In area B, the network of the technology consists of academic papers, and the research areas have opportunities for commercialization in the near future. Therefore, investigating the correlative relationship between academic papers and patents is significant in enabling the detection of the gap between both layers. IoT-related technologies as expedients for solving social issues are evaluated by this framework.



Papers \ Patents	Exist	Not Exist
Exist	Text similarity: more than average A: Already commercialized, but their R&D are also active	Text similarity: less than average B: Research areas with opportunities for commercialization
Not Exist	Text similarity: less than average C: Too much application oriented, and difficult to be research targets	Text similarity: zero D: Research area to which no one pay attention

Figure 4. Framework for discovering potential opportunities for industrial commercialization and network relationships.

TABLE 3. COMBINATION PATTERNS OF LINKAGES



Because our study mainly focuses on social issues to be solved by IoT-related technologies, another dimension is added to the conventional framework: social issues. Then, it is possible to discover which social issues could be solved by which IoT-related technology in what condition. The combination patterns of linkages among clusters are shown in Table 3. Red indicates clusters of social issue papers, blue indicates clusters of IoT-related papers, and orange indicates clusters of IoT-related patents. They are categorized into area A, B, C, or D. Dotted lines between clusters show semantic linkages that contain more than the threshold of cosine similarity. Combination patterns of linkages shown with a gray background (A4, B2, C2, and D) were out of scope in this study because we focused on finding linkages between technology and social issues to be solved by the technology. Therefore, only A1, A2, A3, B1, and C1 were used in this study.

Finally, demonstration of linkages is conducted. Here, linkages that have the following two conditions are selected as targets for each social issue: the linkage is new, and the semantic similarity is highest among the candidates. New linkages were selected because recognizable linkages might already have been recognized among experts, whereas new linkages might contain new information even for experts in the fields. At the same time, linkages having the highest similarity were chosen because those technologies might contain a high possibility of solving the issue.

III. RESULTS and DISCUSSION

A. Extraction of semantic linkages

Heat map analysis was conducted to find semantic linkages between IoT-related technologies and social issues. Linkages were extracted when their similarities was higher than the threshold. The numbers of extracted IoT-related technologies for each social issue are shown in Table 4. The number of SN technologies for H was the largest, including 53 technologies from papers and 3 technologies from patents. These consisted of applications for monitoring daily living activities, fall and movement detection applications, location tracking applications, medication intake monitoring applications, and medical status monitoring applications, including “Body Area Network (BAN), Personal Area Network (PAN), and Wide Area Network (WAN)” [25].

TABLE 4. NUMBER OF IoT-RELATED TECHNOLOGIES FOR SOLVING SOCIAL PROBLEMS

Domain		Water	Energy	Healthcare	Agriculture	Biodiversity
IoT	paper	3	0	2	1	2
	patent	0	0	3	3	1
NFC	paper	0	0	20	1	2
	patent	1	1	1	1	3
SN	paper	7	2	53	18	20
	patent	0	0	3	0	3
RFID	paper	1	0	21	17	5
	patent	10	2	5	12	10

TABLE 5. PERCENTAGE OF IoT-RELATED TECHNOLOGIES FOR SOLVING SOCIAL PROBLEMS

Domain		Water	Energy	Healthcare	Agriculture	Biodiversity
IoT	paper	0.58%	0.00%	0.28%	0.15%	0.39%
	patent	0.00%	0.00%	0.62%	0.63%	0.28%
NFC	paper	0.00%	0.00%	3.70%	0.19%	0.51%
	patent	0.10%	0.25%	0.08%	0.08%	0.32%
SN	paper	0.08%	0.05%	0.44%	0.15%	0.23%
	patent	0.00%	0.00%	1.11%	0.00%	1.54%
RFID	paper	0.06%	0.00%	1.00%	0.82%	0.33%
	patent	0.12%	0.05%	0.04%	0.10%	0.12%

Then, percentages of extracted IoT-related technologies for each social issue were calculated. The numbers of extracted IoT-related technologies shown in Table 4 were used as numerators; the combination of the number of technology clusters and social issue clusters shown in Table 1 were calculated and used as denominators. The result is shown in Table 5. The percentage of NFC technology for healthcare was the largest, containing 3.70% technologies from papers, and 0.08% technologies from patents. Because of NFC's property of easy use with lower power consumption, NFC is regarded as a plausible technology in the healthcare domain [26]. The system of the technology includes "user-friendly remote health monitoring, controlling, and tracking systems, and electronic data capturing services, prescription system, storage of encrypted medical data on tags, adverse drugs reaction and allergy detection systems in pharmaceutical and medical care" [27].

B. Division of the semantic linkages

In the previous section, semantic linkages between IoT-related technologies and social issues were investigated. Here, those linkages are divided into some categories to illustrate their characteristics.

1. Division by degree of recognition

Extracted linkages were divided into recognizable linkages and new linkages. A recognizable linkage connects to a social issue cluster including technology papers because the social issue cluster contains a similar theme with the technology cluster. Meanwhile, a new linkage does not connect to a social issue cluster including technology papers. The result is shown in Table 6, where the number stands for the number of each type of linkage, and the value inside parentheses is its percentage. Except for energy, in all of the cases of social issues, the number of new linkages was larger than that of recognizable linkages. The number of new linkages in healthcare was the largest, where there seems to be a high potential of new applications.

2. Division by technology readiness levels

To illustrate the technology readiness levels of the linkages, they were categorized into five cluster combinations: Areas A1, A2, A3, B1, and C1. The result is shown in Table 7, where the number stands for the number of each type of clustering combination, and the value inside parentheses is its percentage. For all of the cases of social issues except energy, the number of B1 was largest among the combinations. The average percentage of B1 was 51.4%, which means more than half of social issues could be solved by IoT-related technologies—not now, but in the future. Interestingly, the second largest combination pattern was C1, whose percentage was 31.4%. The result shows that there might be social issues that companies have opportunities and potentials to solve.

TABLE 6. NUMBER AND PERCENTAGE OF RECOGNIZABLE LINKAGES AND NEW LINKAGES

	Water	Energy	Healthcare	Agriculture	Biodiversity
Recognizable linkag	1 (4.5%)	4 (80.0%)	12 (11.3%)	18 (35.3%)	10 (21.7%)
New linkage	21 (95.5%)	1 (20.0%)	94 (88.7%)	33 (64.7%)	36 (78.3%)

TABLE 7. NUMBER AND PERCENTAGE OF CLUSTER COMBINATION PATTERNS

	Water	Energy	Healthcare	Agriculture	Biodiversity
A1	0 (0.0%)	0 (0.0%)	2 (1.9%)	1 (2.0%)	7 (15.2%)
A2	0 (0.0%)	0 (0.0%)	21 (19.8%)	7 (13.7%)	5 (10.9%)
A3	2 (9.1%)	0 (0.0%)	3 (2.8%)	2 (3.9%)	3 (6.5%)
B1	11 (50.0%)	2 (40.0%)	73 (68.9%)	28 (54.9%)	20 (43.5%)
C1	9 (40.9%)	3 (60.0%)	7 (6.6%)	13 (25.5%)	11 (23.9%)

TABLE 8. NUMBER AND PERCENTAGE BY INTEGRATED DIVISIONS

	Water		Energy		Healthcare		Agriculture		Biodiversity	
	Recognizable	New	Recognizable	New	Recognizable	New	Recognizable	New	Recognizable	New
A1	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (0.9%)	1 (0.9%)	1 (2.0%)	0 (0.0%)	0 (0.0%)	7 (15.2%)
A2	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	3 (2.8%)	18 (17.0%)	4 (7.8%)	3 (5.9%)	2 (4.3%)	3 (6.5%)
A3	0 (0.0%)	2 (9.1%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	3 (2.8%)	0 (0.0%)	2 (3.9%)	0 (0.0%)	3 (6.5%)
B1	1 (4.5%)	10 (45.5%)	2 (40.0%)	0 (0.0%)	8 (7.5%)	65 (61.3%)	8 (15.7%)	20 (39.2%)	3 (6.5%)	17 (37.0%)
C1	0 (0.0%)	9 (40.9%)	2 (40.0%)	1 (20.0%)	0 (0.0%)	7 (6.6%)	5 (9.8%)	8 (15.7%)	5 (10.9%)	6 (13.0%)

3. Integrated divisions

Here, division by degree of recognition and division by technology readiness levels were integrated. Tables 6 and 7 were merged, and Table 8 was obtained. By using this table, it is possible to select the type of solution towards the social issue. For instance, in Section 3.2.1, it was determined that IoT-related technologies might have a high potential of new applications in healthcare. Here, the number of B1 with new linkages in healthcare was the largest. The fact added another insight that IoT-related technologies will contribute to solve healthcare issues in the future.

C. Demonstration of linkages

For this section, demonstration of extracted linkages was conducted. For each social issue, linkages that have the following two conditions were selected as targets: the linkage is new, and the semantic similarity is highest among the candidates. We selected analysis targets that fulfill those requirements; they are summarized in Table 9. The number after the name of data is cluster ID. The number after the name of data is cluster ID.

First, the content of social issue's cluster and solution's cluster that have semantic linkage were demonstrated. Then, a possible scenario about how the issue could be solved by the solution was proposed based on the content of the clusters. Finally, plausible condition of the scenario based on the combination patterns of linkages was mentioned.

1. Water issue and technology solving the issue: Water4 & SN4-4-1

Water4 was extracted as a social issue of water, and a semantic linkage was investigated with SN4-4-1 that had the potential of solving the issue. The co-words appearing in both clusters were "irrigation," "crop," and "soil." Its cosine similarity was 0.4393, and combination pattern was B1.

The content of Water4 was irrigation, ground water, and agricultural water. The most cited paper of Water4 that contained the co-words was about content analysis of articles published in the journal *Water Policy* in 2010 and 2011 [28]. The objective of the study was to identify issues and trends in the field of water policy. Nine thematic groups were extracted, and one of the themes was "agricultural water issues." Inside

TABLE 9. QUALITATIVE ANALYSIS TARGETS AND THEIR CONDITIONS

	Water	Energy	Healthcare	Agriculture	Biodiversity
Linkage	Water4 & SN4-4-1	Energy2 & NFC11	Healthcare6 & SN2-3-3	Agriculture6 & SN4-4-1	Biodiversity5 & SN4-4-7
Co-words	Irrigation, Crop, Soil (0.4393)	Battery (0.1097)	Care, Patient, Elderly (0.399)	Soil (0.4313)	Soil (0.25)
Division	B1	C1	B1	B1	B1

the issue, four contents compiled from six irrigation-related studies were introduced: sustainable use of groundwater for irrigation, historical irrigation water management, efficiency of irrigation water use, and irrigation water rights. The number of agricultural water issues papers saw the largest increase from 2010 to 2011 among other issues, and thus it was determined that irrigation was a main water issue.

The content of SN4-4-1 was wireless sensor networks in agriculture. The most cited paper of SN4-4-1 that contained the co-words was about SN for precision horticulture [29]. SN could play an important role in precision agriculture. It can handle and manage water resources for irrigation. This paper introduced and deployed an experimental SN at an ecological horticultural enterprise. Four types of nodes (soil mote, environmental mote, water mote and gateway mote) were used, and some of them were connected to different sensors distributed in the field. Some soil characteristics, such as temperature, volumetric moisture content, and salinity were measured and used in the proposed system. The system was successfully implemented on a crop of ecological cabbage in a horticultural environment.

From the above qualitative analysis, it was confirmed that Water4 linked to SN4-4-1. Efficient irrigation management systems could be achieved by SN. The cluster combination pattern was B1, which means this irrigation issue is going to be solved by SN in the future.

2. Energy issue and technology solving the issue: Energy2 & NFC11

Energy2 was extracted as a social issue of energy, and a semantic linkage was investigated with NFC11, which had a potential of solving the issue. The co-word appearing in both clusters was “battery”. Its cosine similarity was 0.1097, and the combination pattern was C1.

The content of Energy2 was lithium battery, lithium ion battery, and fuel cell. The most cited paper of Energy2 which contained co-words was about state of the art, prospects and future of lithium batteries [30]. In this paper, R&D approaches in the lithium battery technology were reviewed with the demands for the technology: reforming present energy economy based on fossil fuels, reducing CO_2 emissions associated with climate changes and air pollution in urban areas. These issues might be solved by “replacing internal combustion engine (ICE) cars with ideally, zero emission vehicles, i.e. electric vehicles (EVs) or, at least, by controlled emission vehicles, i.e. full hybrid electric vehicles (HEVs) and/or plug-in electric vehicles (PHEVs).” Lithium ion batteries are seen as the power sources of such transportations, but scaling up the chemistry of common lithium ion batteries in view of their application is still problematic. Higher capacity, lower cost, safer and more reliable batteries are needed.

The content of NFC11 was device and/or battery using NFC technology. The most cited patent of NFC11 which contained co-words was about system and methods for inductive charging [31]. While mobile devices provide connectivity and communication to people, most of them have been powered or charged through traditional use of wired power supplies and chargers. To solve this problem, solutions such as wireless method for powering or charging one or several mobile devices, batteries, or electronics devices have been proposed. However little progress has been made for the technology in terms of increasing efficiency (e.g. improvement of transfer of wireless power, and new uses and applications for such systems). Therefore, applicant of this patent, Mojo Mobility, Inc., proposed solution to improve transfer of wireless power to mobile devices and batteries. Others leading progresses were achieved by companies. For instance, portable terminal having a wireless charger with communication function was proposed by Samsung Electronics Co., Ltd. [32]. The patent proposed technology to “implement both the NFC function and the wireless charging function in a single portable terminal, an NFC antenna element taking the form of a loop antenna and a secondary coil for wireless charging should be mounted in the portable terminal”. The solution could offer chance to reduce weight of battery in mobile devices if wireless power supply system were implemented in society.

From the above qualitative analysis, it was confirmed that Energy2 linked to NFC11. Batteries for vehicles or devices could be alternated by wireless power technologies or supported by them. The cluster combination pattern was C1, which means there is possibility that existed technology of company could solve the battery issues.

3. Healthcare issue and technology solving the issue: Healthcare6 & SN2-3-3

Healthcare6 was extracted as a social issue of healthcare, and a semantic linkage was investigated with SN2-3-3, which had the potential for solving the issue. The co-words appearing in both clusters were “care,” “patient,” “elderly,” and “healthcare.” Its cosine similarity was 0.399, and its combination pattern was B1.

The content of Healthcare6 was healthcare for elderly patients. The most cited paper of Healthcare6 focusing on elderly persons concerned an elder mistreatment study [33]. The study estimated the prevalence and assessed correlates of emotional, physical, sexual, and financial mistreatment and potential neglect of adults aged 60 years or older. A standardized computer-assisted telephone interview was conducted and obtained 5,777 respondents, and prevalence estimates and mistreatment were analyzed by logistic regression. The result showed that the one-year prevalence was 4.6% for emotional abuse, 1.6% for physical abuse, 0.6% for sexual abuse, 5.1% for potential neglect, and 5.2% for current financial abuse by a family member. The authors concluded that “our data showed that abuse of the elderly is prevalent. Addressing low social support with preventive interventions could have significant public health implications.”

The content of SN2-3-3 was wireless sensor networks for personal health monitoring. The most cited paper of SN2-3-3 that contained the co-words concerned a review paper of wireless sensor networks [25]. In the paper, the benefit of healthcare monitoring systems was described, especially for the elderly, children and chronically ill. Several benefits were summarized as follows: “Remote monitoring capability is the main benefit of pervasive healthcare systems. With remote monitoring, the identification of emergency conditions for at risk patients will become easy and the people with different degrees of cognitive and physical disabilities will be enabled to have a more independent and easy life.” Herein, another leading health monitoring technology in SN2-3-3 was detected [34]. This paper describes two new topic models. Sensors were allocated in five places; kitchen, living room, bathroom, bedroom, and hallway. Through the proposed models were based on Latent Dirichlet Allocation topic models, human behavior in homes was analyzed.

From the above qualitative analysis, it was confirmed that Healthcare6 linked to SN2-2-3. The cluster combination pattern was B1, which means the elderly mistreatment or abuse issue is going to be solved by SN in the future. For example, if elderly persons are monitored by SN and their behaviors are analyzed, it is possible to detect anomalies. This might contribute to preventing mistreatment or abuse.

4. Agricultural issue and technology solving the issue: Agriculture6 & SN4-4-1

Agriculture6 was extracted as a social issue of agriculture, and a semantic linkage was investigated with SN4-4-1, which had the potential of solving the issue. The co-word appearing in both clusters was “soil.” Its cosine similarity was 0.4313, and the combination pattern was B1.

The content of Agriculture6 was sustainable agriculture, environment (e.g. climate, soil), conservation agriculture, and ecosystem services. The most cited paper of Agriculture6 that contained the co-word was about sustainable intensification in agriculture [35]. The paper focused on agriculture in Africa because agriculture there had been considered to be badly performed. Focused themes were extracted from 40 projects and programs where sustainable intensification has been developed during the 1990s–2000s. They included crop improvements, agroforestry and soil conservation, conservation agriculture, integrated pest management, horticulture, livestock and fodder crops, aquaculture, and novel policies and partnerships.

Soil conservation and agroforestry were extracted as important themes. According to the paper, “soil conservation on its own does not necessarily increase yields (the past focus has often been on avoiding future loss of soils), but conservation methods that capture water and add new system components (e.g. trees and livestock) can result in improved productivity of staples.” To evaluate the conservation situation, geographical photographs tend to be taken. Then, pictures of same place at different times are compared.

The content of SN4-4-1 was wireless sensor networks in agriculture. The most cited paper of SN4-4-1 that contained the co-word concerned applications for precision agriculture [36]. The paper presented a simulated application of a wireless SN (WSN) capable of providing on-the-fly field parameter estimates for end users for a precision agriculture task. According to the user’s objective, parameters such as type of interpolation, measurement range of interest, or choice of soil variable to measure could be changed. Herein, another leading precision agriculture technology in SN4-4-1 was detected [37]. In the agricultural domain, decision making processes could be effectively supported by integrating current local environmental status and agricultural monitoring with a geographic information system and WSN. The presented paper describes conceptual approaches to context-based cartographic visualization methods for agricultural and metrological data acquired by WSN and a portal prototype for integrated visualization. Sensor characteristics (soil temperature and moisture, atmospheric temperature and moisture) automatically monitored and data acquired by the system were aggregated with geospatial data from both local and remote (web-based) sources. The authors mentioned that the application and potential of the proposed system for use in orchards, vineyards, and gardens is higher. This is because of the more intensive levels of crop management found there, and the higher demand for agrometeorological data.

From the above qualitative analysis, it was confirmed that Agriculture6 linked to SN4-4-1. A monitoring system supported by SN could monitor the status of soil conditions. Appropriate decision making could be performed for soil conservation depending on the soil condition. The cluster combination pattern was B1, which means the soil condition monitoring for soil conservation issue is going to be solved by SN in the future.

5. Biodiversity issue and technology solving the issue: Biodiversity5 & SN4-4-7

Biodiversity5 was extracted as a social issue of biodiversity, and a semantic linkage was investigated with SN4-4-7, which had a potential of solving the issue. The co-word appearing in both clusters was “soil.” Its cosine similarity was 0.25, and the combination pattern was B1.

The content of B5 was environmental change (climate change including temperature and precipitation change, soil condition change such as acidification, nitrogen deposition) and biodiversity. The most cited paper of Biodiversity5 that contained the co-word concerned the relationship between soil organic matter decomposition and increasing temperature [38]. The relationship is a critical aspect of ecosystem responses to global change. To investigate the relationship between decomposability and the response of decomposition rate to temperature, studies were surveyed. Through the survey, three component processes were identified for which variation in rates could affect the response to temperature: depolymerization of biochemically complex compounds, production and conformation of microbial enzyme production, and processes that limit the availability of soil organic matter. As a part of conclusion, the authors mentioned that “it is important to recognize that temperature as well as its indirect effects via soil moisture will alter plant production, partitioning of that carbon to roots and leaves and to litter, and litter quality, which were not addressed in this review. Temperature-driven changes in inputs, together with decomposition losses, will determine the fate of soil carbon in a warmer world; understanding those processes underlying these inputs and losses is the grand challenge."

The content of SN4-4-7 was WSN for measuring soil moisture and soil water content. The most cited paper of SN4-4-1 that contained the co-word was about reactive soil moisture sensor networks [39]. The paper described the design and implementation of a novel reactive sensor network for monitoring soil moisture. The reactivity, robustness, and longevity of the network in the field were evaluated. The unit costs for these network components, and battery costs and performances were compared and summarized. WSN has been actively studied for environmental monitoring. Herein, another leading precision agriculture technology in SN4-4-1 was detected [40]. In this paper, the state of the art with respect to measuring, analyzing, and modeling the spatio-temporal dynamics of soil moisture at the field scale were reviewed. Discussions on soil moisture sensor networks, hydrogeo-physical measurement techniques, novel remote sensing platforms, and cosmic ray probes were conducted. As a part of the conclusion, the author indicated that future research in the era of "big data" in the field of soil moisture sensing with datasets changes the situation. Millions of soil moisture measurements could be achieved, providing unique opportunities to study soil water dynamics. Finally, some challenges such as managing, sharing, analyzing, and visualizing soil moisture data were described.

From the above qualitative analysis, it was confirmed that Biodiversity5 linked to SN4-4-7. Soil moisture SN could contribute to monitoring soil conditions, which could lead to recognizing indirect effects on increasing temperature. The cluster combination pattern was B1, which means the soil organic matter decomposition issue is going to be solved by SN in the future.

IV. CONCLUSION

IoT is expected to change society, although it is a general-purpose technology and its concrete application, value, and feasibility are still obscure. Hence, previous studies have investigated intellectual structures of IoT, and its technological trends. However, there is no research that explored plausible social issues where IoT can be applied. This study was the first trial to computationally discover the linkages between social issues and IoT-related technologies that can be used to solve social issues. The result showed that healthcare issues have the highest opportunities and potentials to be solved. Semantic linkages between IoT-related technologies and social issues (i.e., water, energy, health, agriculture, and biodiversity) were investigated computationally. The result showed that healthcare issues have the highest opportunities and potentials to be solved, both in terms of number of linkages (SN contributed the most), and the percentage of linkages (NFC contributed the most). Extracted linkages were evaluated by its newness and opportunities for being realized. Demonstration of extracted linkages having the highest semantic similarity value was conducted for each social issue.

The limitations of this study are four-fold: First, we neglected clusters whose sizes were quite small, thus we might have missed important information even though their cluster sizes are small. Second, clusters of social issues were not recursively divided into sub-clusters. Therefore, there is a possibility that it was not able to extract enough concrete information. Third, we focused only on text information, and thus context was neglected. This may lead to contain noisy linkages. Last, there are several demonstration target selection criteria, but the best one has not been determined. Linkages with the highest semantic similarity were selected in this study because we considered that these linkages tend to have high potential to solve the issue.

Future works will include finding what are the best criteria for selecting linkages between technology as a solution to social issues, in addition to evaluation and validation of combination patterns of linkages. For instance, area D in Table 3 has interesting characteristics in that the cluster of social issues will be very important in the near future, which is analogous to area B in Fig. 4.

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