Extracting Knowledge from Technological Research Papers in Application of IoT

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Abstract— **In this paper, we have extracted knowledge about IoT based on semantic analysis of corpus data which is constructed from IoT IEEE survey papers that were published recently. For the basic understanding of research tendency, common biblio-metric approach such as tf-idf is introduced. Since 2009, the number of publication of survey papers related to IoT has been increased dramatically and there are about 6 to 7 application areas where IoT would introduce an innovative usage of network and information technologies. Upon these basic understanding, we try to construct method to extract 'knowledge' from those documents. We have introduced inference rules to the semantic relationship in sentences. Each sentence and consisting words are indexed as RDF primary nodes and are stored in triple-data-store. We have added several inference rules by looking at meaningful words and sentences. In this sense, the method is not fully machine-oriented; we applied heuristic knowledge by reading sentences and discourses about the technological issues of those survey papers. The result shows deeper understanding of an issue described in large amounts of documents in a short period of time. It is possible to apply this method for different area of expertise. This analysis has been pursued in a context of foresight activity in science and technology policy.**

I. INTRODUCTION

Internet of Things (IoT) is a term used to describe situation that 'things', not only electrical communication devices but a variety of applications that are connected to each other over the internet. Based on a survey of a research institution IDC, amount of annual sales related to IoT are indicated from $1.9 trillion in 2013 to $7.1 trillion in 2020.

There is a wide range of research areas related to IoT. In the context of science technology policy making, application fields of such an emerging technology like IoT should be recognized and understood well among stake holders.

Technology foresight is one of the tools for the above mentioned purpose, which has been studied for long in terms of methodology [23][24][25]. Technology foresight is an upstream element for science and technology development process. Technology foresight i.e. input for the formation of the technology policies and strategy that guides the development of the technological infrastructure, is gaining attention [28, 29 and 30].According to a classic statement, a foresight exercise thus involves a systematic process in which an attempt is made *"...to look into the longer-term future of science, technology, and economy and society with the aim of identifying the areas of strategic research and the emerging generic technologies likely to yield the greatest economic and social benefit*" [31] [32].

First of all, let us give the definition of the term "Internet of Things". The term Internet of Things was first introduced by Kevin Ashton in 1999 in the context of supply chain management [17]. Kevin Aston also quoted "We need an Internet for things, a standardized way for computers to understand the real world" [18]. Same notion was used by Neil Gershenfeld in 1999 in his book "When Things Start to think" [19]. He wrote "in retrospect it looks like the rapid growth of the World Wide Web may have been just the trigger charge that is now setting off the real explosion, as things start to use the Net." The Internet of things is not a result of single novel technology, but it is of several technical development provide capabilities which was given by F. Mattern [20].When we use 'ubiquitous', it rather describes the situation that devices of human users ubiquitously exist around us. On the other hand, term 'M2M' definitely means a situation that application software or computer system automatically communicates with each other to provide some kind of services. The term 'Cyber Physical' is also used for describing such situations. The term IoT has been used recently though, what the concept covers has been discussed for years in the academia and the industry. Those are how IoT has been defined so far.

Generally foresight activity is scanning of issues related to certain area of technology; this is the basic and often the starting point for various methodologies such as workshop and scenario building. Our main interest in this paper is the initial stage of such activities.

In this paper our focus is mainly placed on extracting significant issues related IoT. We apply combinations of basic text mining techniques to extract the knowledge from document database. This scheme is intended for playing a partial role in foresight activities, but the discussions about this context is out of the range in this paper. We are going to use IEEE paper data based for the purpose. We assume that the results might be utilized for the foresight activities. The paper focuses on knowledge extraction and acquisition that are the bottleneck in artificial intelligence applications. In simple words knowledge extraction is a process of creating Knowledge from Structured and Unstructured documents. So extracting knowledge from research paper is helpful for every person who wants to read the research paper of specific fields and type. By extracting knowledge we have divided the paper and various topics according to their applications and keywords.

This paper is organized in the following manner. Section 2 contrasts the Overview of IoT research in past few decades. Section 3 outlines the knowledge extraction. It is further divided into two sections which are related works and explanation of triple data storage. In section 4 we have presented our experimental results on our data-sets. We have presented the analysis and result of our method on 69 IoT research papers. Section 5 gives an overview of various

applications of IoT. And the brief evaluation about the analytical schema is given in section 6. We have outlined the conclusion for this work in section 7.

II. OVERVEW OF IOT RESEARCH

As given by Atzori [12], Internet of Things can be realized in three paradigms—internet-oriented (middleware), things oriented (sensors) and semantic-oriented (knowledge).In order to obtain overview of research trend about IoT, we look at survey papers. Fig. 1 shows the number of papers that has 'IoT' or 'Internet of Things' as key terms as well as 'survey' in abstract in IEEE paper database.

In the recent year "Internet of things" has spread rapidly- In 2005, it had been found in many books, and in 2008 the first conference was held in this research area [21].Since 2009 the number increases exponentially. We selected papers until year 2013. By the time, this trend is still going on. The numbers are continuously increasing. There are three IoT components which enables seamless ubicomp: (a) Hardware—made up of sensors. (b) Middleware—on demand storage and (c) Presentation—novel easy to understand visualization and interpretation tools which can be widely accessed on different platforms [13]. There are more specific taxonomies of each component which is addressed in [14], [15] and [16].

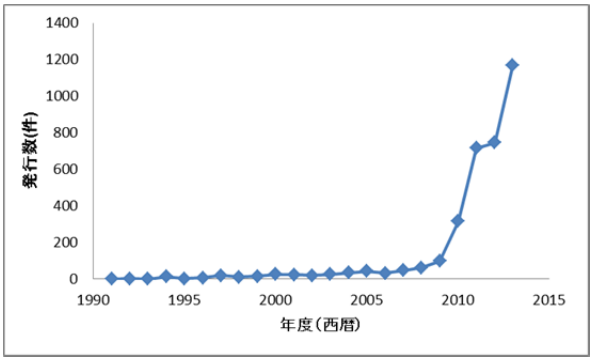

Fig.1 Number of IoT related Papers Published

III. KNOWLEDGE EXTRACTION

A. *Knowledge Extraction*

Knowledge extraction is defined as extracting knowledge from structured and unstructured sources. The technique which is used to extract knowledge from structured sources such as databases is known as "data mining", so specific technique "text mining" is introduced to extract knowledge from the unstructured sources like email, text documents, XML etc. Knowledge mining can be characterized as concerned with developing and integrating a wide range of data analysis methods that are able to derive directly or incrementally new knowledge from large or small volumes of data from the structured or unstructured sources using relevant prior knowledge [26]. The general purpose of Knowledge discovery is to "extract implicit, previously unknown, and potentially useful information from data" [27]. Some of the past research works in the field of Knowledge extraction is shown below.

Rajman and his colleagues [1] had presented an approach for knowledge extraction. They have presented example of the two algorithms - probabilistic association of keywords and prototypical document instances. They have given the importance of the Natural language processing tools for extraction. So Association method can be used for Indexed data whereas prototypical method can be used on plain documents.

Alani and his team [2] have developed knowledge extraction approach. Their approach has three structure i.e. knowledge extraction, information management and biography construction. In knowledge extraction, they used lexical database and entity recognizer for identifying knowledge fragments. After this the data is passed to the information Management stage. In this stage, the data is passed through the process of consolidation and indexing. After this the data is passed to Biography construction (Narrative Generation). The data is passed through various processes like rendering, interaction etc. They have produced acceptable results.

Pugeault and his team [3] have improved the quality of the knowledge extraction tool. They gave the approach of replacing the text with lexical semantic data. Their aim is to improve the granularity i.e. linguistics and functional. They have also used EDF thesaurus. Their semantic representation of the text has two steps i.e. General organization of text and Identification of knowledge to be extracted. They have defined three levels of knowledge representation and also Simple methods for data extraction. They have also produced good results.

Ultsch and his team [4] developed an approach using Artificial Neural networks. They have used a function called Sig*[5] for knowledge extraction. To extract, there are three steps i.e. selecting attributes for a class, Construction condition for selected attributes and Characterizing and Differentiating Rules. This method has various applications like Medical, Avalanche Forecasting and to monitor chemical process.

Maria Vargas-Vera [6] developed a Knowledge Extraction approach using Annotation tool. This method has four phases such as: Browse, Markup phase, learning phase and Information extraction phase. This first phase is for choosing the browser. They have used WebOnto [7] browser due to its advantage for creating knowledge models and visualizations. Next phase is related to the markup that is tagging phase. This Phase can be referred to annotating phase. They have given various Annotation tools. Next phase uses Crystal (Machine learning Component), it uses marked texts as training data and learns relations. Last phase is used to extract the final information after ignoring the useless data. They have produced significant results.

Beseiso and team [8] gave a new architecture for Email knowledge extraction. This proposed method is designed to handle unstructured emails. They have divided the extracted ontology from email into four components as follows: The ontology learning component, the management component, the semantic email and Client side plug-in. They have also divided the email in four domains such as Meetings and Schedules, News, Reviews and Technical support and request. They have a dataset with 1200 emails. They have produced significant results.

Peter Clark and Phil Harrison [10] worked on knowledge extraction by making database of "tuples" and thus capturing the simple word knowledge and using it in improving parsing and improving the plausibility assessment of paraphrase rules used in textual entailment. Lenhart Schubert [11] gave an approach by firstly "possibilistic" propositions from noun phrases and then they try to generalize it based on the nature and statistical distributions.

B. Triple Data store for Knowledge extraction

So far, there is no simple definition of "knowledge", so that the "extraction" covers wide range of methodology and a lot of combination possibilities for them. Here, our original intention was to understand the application area of rapidly emerging IoT researches. From science and technology policy management stand point, we assume that there are some human experts who are stand by for the foresight activities after computer centric information processing. So that the knowledge extraction in this article, target to extract significant sentence and keywords from the set of documents, so that the experts can grasp direction of technological researches.

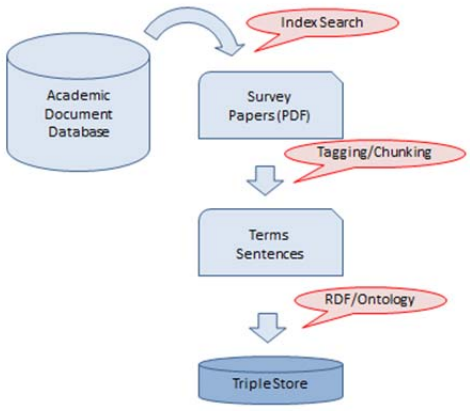

Fig.2 Triple Store of Documents

With the above purpose, we combined several fundamental text mining and artificial intelligence techniques. Recently there is a lot of useful open-source software available for the text processing, such as Natural Language Tool kit for Python. And computing power of commonly available PC is able to provide enough computing power for the basic data mining. This article provides the prospects in which a certain combination of basic methodologies over well-formed document database, good amount of knowledge can be obtained.

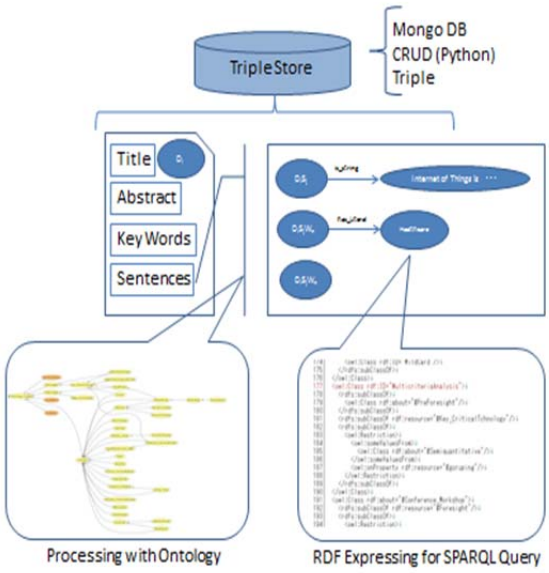

Fig.3 Structure of Triple Store

Our basic document database is academic research papers archive of IEEE conference and transaction database that is facilitated in a university. Usually research papers have structure with title, abstract, key words, sentences, and references. At first, survey papers are selected by human originally by searching through library. There are 69 articles up to year 2014, we are going to use them for analysis and knowledge extraction for further processing. Based on abstract and keywords we applied a couple of clustering method to the documents with variety of algorithm and measures of distance vectors. According to basic knowledge about application area of IoT, we decided 6 categories as the initial group.

Then triple data store is constructed for all these documents. The triple data model is related to Resource Description Framework format of data representation. Here we do not need to follow precise W3C notation since it is not necessary to share data with other data set or project. Triple format has subject, predicate, and object for each triple. The unit of data is identification of documents, sentences, and words. The Fig.3 shows the conceptual descriptions of how to form the triple store and the structure of the triple store. The database is formed with MongoDB software. With basic predicate such as "has_Literal", "is_string", a chunk of words and sentences has relationship to ID which has identification as a document, a sentence, or a word. To this triple data store we can apply various inference rule which is described in a form of either Python program or SPARQL type query of triple format.

IV. THE ANALYSYS

A. TF-IDF

Natural language processing technique has been widely used for document analysis. We apply this technique to the papers collected from IEEE paper database. Criteria keywords for choosing papers are, "IoT","Internet of Things" and "survey". We have selected 69 papers from conference and transactions of IEEE.

First we extracted frequently used technical terms from the papers. Basic procedure is as following;

1) *Data cleansing*
2) *Abstract text database*
3) *TF-IDF analysis*

Here we use TF (Term Frequency) value that is the metric to measure number of appearance of words. Highly appeared words are considered to define the characteristics of the documents. Meanwhile, IDF (Inverse Document Frequency) is usually used with TF. This value characterizes the significance of a particular word or sentence in the document in the collection of documents. The multiple of those values are often utilized to understand the characteristics of a document or to capture trend contents of several documents. In the order, to grasp the characteristics of each classified survey papers, we apply this method.

There are 786 terms appeared in the documents, and about 46% terms are chosen for later analysis after omitting very common words. Table 1 shows the example of terms that have high mark in TF (Term Frequency).

TABLE 1 RESULTS OF TERM FREQUENCY

Rank	Term	TF
1	internet	42
2	sensor	25
4	networks	20
4	wireless	20
5	management	12
6	social	10
7	protocol	9
9	data	8
9	security	8
10	energy	7

TABLE 2

Rank	Term	TF
1	internet-of-things	33
2	wireless-sensor-networks	9
3	radio-frequency-identification	7
7	6lowpan	4
7	constrained-application-protocol	4
7	smart-cities	4
7	social-network	4
10	data-mining	3
10	human-computer-interaction	3
10	Middleware	3

Some technical terms appear together. In Table 2, set terms that have high frequency are shown.

According to those high frequent technical terms, it is naturally shown that Iot related researches are closely related to internet and network technologies. Especially wireless communication technology such as CoAP(constrained-application-protocol) is important in IoT. At the same time, there are varieties of terms in the field of security, smart society/city, data-mining, application and so forth. Those words indicate that the IoT has wide range of applications in our current social life and will provide strong affects to the modern life.

B. Resaltes from Clustering Analysis

In previous section, we could capture general trend about IoT research. In the following, we configure document database and apply natural language analysis technique over the database in order to understand detail of facts described in the documents.

TABLE 3 SIGNIFICANT TECHNICAL TERMS

Group	Key Tems	Application Field
1	information security, European disasters	Security, Disaster Prevention
2	healthcare	Welfare, Health care
3	building, automation systems	Construction, Housing
4	wisdom, scenic, industrial informatics	Industry, Tourism
5	enterprise systems, device	Manufacturing, Enterprise IT system
6	benchmarking, gamification	Services, Computer Industry, IT

Clustering is the analysis method to extract and classify groups of documents, each with a common feature from the set of data. The 69 survey papers in IEEE database are used for the analysis. After performing the clustering analysis over the database, we applied natural language processing technique for each group of documents. The followings is the procedure to extract key technical terms.

1) Document Vector: Document-Term Matrix is configured based on TF value
2) Clustering documents into 6 groups
3) Term Frequency is measured in each group
4) Terms of High IDF value are extracted, namely they show the characteristics of each group

In Table 2 the high-marking terms in IDF are shown. Terms of each group characterize area of interests in each group. According to this analysis, it is obvious that IoT has wide range of applications such as healthcare and tourism.

C. Semantic Data Structure

Above processing is done without semantic structure. In this section, we explain the schema to analyze sentence data stored in cross-indexed triple store with semantic structure of data items. The explanation in this section is intended for non-computer engineers who are able to persuade similar analysis to this article with basic knowledge of data processing and programming.

There are many excellent semantic toolkits available. We have referred Python code [22]. We chose to use this programming language because it is very simple language to read and understand, it's concise enough to fit easily into short code blocks, and it has a number of useful toolkits for semantic data processing.

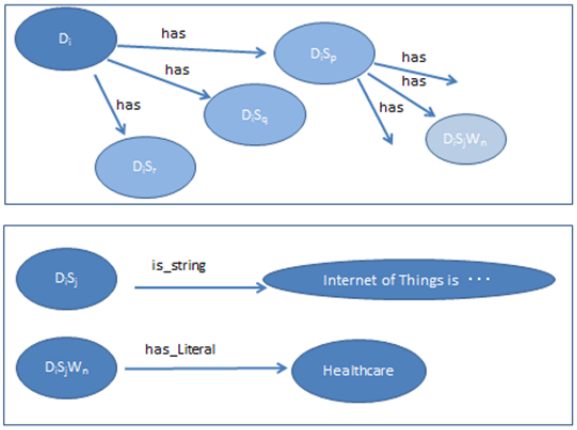

Fig. 4 Triple format of the Document Data

In Fig. 4 the triple format is shown and it forms the fundamental building block of semantic representations of each paper. As explained in previous chapter in section B, Every document is chunked into sentences and words from each sentence. Each triple is composed of a subject, a predicate, and an object.

Let us briefly give an example of "knowledge description". Figure 4 shows a triple syntax called an RDF graph. RDF, an abbreviation for "Resource Definition Framework," is a concept adopted in defining knowledge structure. Knowledge fragments are expressed in syntax consisting of three elements: the subject, the predicate, and the object. There are several notation methods for this structure.

The example in the above chart refers to a documents consist of several sentences. Each sentence has unique id such as D_iS_j which means jth sentence of the ith document. The subject is a collection of id representing document, sentence or word. The predicate defines the rule: "has" when the item belongs to a certain id. The object is string or sentence of the Document for the processing.

In the semantic data processing, ontology should be created in the field of interest. To describe ontologies; logical expressions need to be configured. This process uses a syntax called predicate logic. Ontologies are written in OWL (Web Ontology Writing Language), whose standardization has been conducted by W3C.Describing a knowledge structure in predicate logic or responds to constructing a set of elements that meet a certain condition, such as "If A, then B." The resulting set is the database fundamental to knowledge processing in the semantic data processing. Knowledge processing based on predicate logic takes the form of generating answers from a collection of fragments of knowledge, such as "*If A is true, then B is satisfied*" and "*If B, then C,*" to queries such as "*Is Z true, if A holds?*" This process is referred to as the reasoning mechanism.

Based on the triple data base, we are able to introduce variety of rules along with ontology defined in the triple store. For example, the following quasi-Python code of query represents a rule to extract an *id* of a triple that contains both "*IoT*" and "*Healthcare*" in a same sentence.

```
query([('?sentence','has','?word1'),
       ('?sentence','has','?word2'),
       ('?word1','has_Literal','IoT'),
       ('?word2,'has_Literal','Healthcare')])
```

The implementation of query is the method defined for variable binding of triples. After binding triples with a query, the new bindings or items can be added in triple store for further analysis. The task of this knowledge extraction process is formulated into scheme of writing queries in the constructed triple data store.

V. APPLICATIONS OF IOT

So far, we have explained overview of knowledge extraction scheme. Let us show some of findings from the document database.

In accordance with the contents of the six clusters of papers, we will look at each of the features. In Group 1, the relationship with the field of security and disaster is important in IoT. For the reason, as the product of the IoT is to penetrate into our daily life, this leads to security threat. In the future, while the IoT related products increases explosively, it must be urgent to ensure security accordingly.

Group 2 have strong relationships to the medical and welfare industry. By providing communication function to the medical device, IoT will determine the health status of the patient remotely. It may contribute to the improvement of individual consciousness about health. There are already commercial application products such as connected tooth brush, etc. Some application software takes care of collecting medical data of client and support doctor's diagnosis. It is very promising that IoT will be developed and progressed in medical and health care applications.

Group 3 have strong relationships to housing and construction industry. By mounting the IoT devices to housing environment, it is considered that more comfortable life is possible. By detecting personals in a housing environment, it could be helpful to prevent crime. It is possible to provide a new service by monitoring or turning on and off home appliances by remote control. There are several research projects already going on in these aspects.

In Group4, industry applications of IoT and tourism sector are shown. By networking sensors and sophisticated equipment with associated software, IoT may trigger the innovation in various industrial sectors. There is a specific term; "Industry Internet" is used to describe such a situation.

One of the examples of such a platform is “Predix” of GE in USA. By installing 10 million of sensors in the platform of medical devices, they collect and analyze daily data to operate them efficiently. It is expected that this kind of system is going to be further developed and expand in near future.

In Group5, the relationship with the enterprise business information system is discussed. It also contain new types of IT solutions in variety of business sectors. Now it is widely recognized that IoT will play an important role in the field of corporate activities in production and management.

IoT naturally has strong relation to IT and computer industry. According to the survey papers in Group6, security patches and virus type software are applied to the IoT products, so that in near future variety of new service is expected to emerge. One of the interesting keyword in which IoT might affect is “gamification”, meaning the convergence of working style.

VI. EVALUATIONS

First step of the document analysis is based on clustering. Descriptions about each cluster are given in the previous section V. In order to evaluate the feasibility of clustering, we have compared extracted words and key-words which are indicated by the author of each paper. The conformity and comprehension of the words are counted and statistically processed. Here the conformity means the ratio of key-words of the abstract to the extracted words, and the comprehension is the coverage ratio to them. The results are shown in the Table 4.

TABLE 4 CONFORMITY AND COMPREHENSION

	Conformity	**Comprehension**
Average (%)	34.6	61.6

Both variables show modest matches. This is because the number of key-words given by the authors is limited so that a few irrelevant words might distort whole data.

According to extracted words and sentence, human experts described summary of each cluster. If the procedure in this paper is considered as supervised learning process of machine learning, we need precise evaluation in these aspects. However our procedure does not assume correct answers about output. We have to work on that directions in future research. This procedure, applying semantic structure towards words and sentences can be applied in various setting for supporting expert understanding situation of a certain research field in science and technology. We believe that the potential feasibility and usability of proposed procedure have been shown in this article.

VII. CONCLUSION

Recently, academic document database is well-organized in electronically accessible form, and also open-source software for document analysis is available. In other words, the bibliographical approaches for knowledge acquisition from documents become common and effective with these technologies.

In this paper, we focus on the rapidly increasing IoT-related technologies and conducted analysis over survey papers in the fields. A set of survey papers which treat IoT related research is selected from IEEE research paper database. In our method, basic natural language processing technique with semantic annotations over words and sentences is applied.

Motivation to persuade this research is based on foresight activates about emerging technology. Above mentioned technique could be applied to and improve schematic aspect of understanding the direction of the research. Although there are variety of possible setting and scheme in foresight methodologies, it is often the case that in the initial stage of such activates, basic knowledge about the forecasting technology area should be visualized in basic classification and annotations with descriptive terms.

For the basic understanding about this field of study, the number of issued academic papers which include IoT as a key terminology had been rapidly increased. Consequently it is clear that IoT is a hot research subject and important for the science policy stake-holders to understand the research trend of this research area. For analysis it is naturally recognized that IoT has a strong relationship with technology elements in electrical communication network-related technologies. There are some application areas of ICT such as "application to the medical field", "safe and secure society”, “the foundation technology for building” and so forth, are considered to be important application of IoT. From the heavy industry to software application, there are many possibilities of innovations with IoT. Especially the IoT is expected to make advancement in the field of medical. IoT is considered important research target for future research and development.

Our analytical technique, combined common natural language processing with semantic annotations of words and sentences is presented. Our attempt is to apply them to the initial stage of foresight seems to be successful. However we could only provide simple evaluations by using abstract key-words. The evaluation of knowledge extraction is necessary task to persuade for future.

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REFERENCES

[1] Martin Rajman and Romaric Besancon,“Text mining- Knowledge extraction from unstructured textual data”.In:Proceedings of the 6th Conference of the International Federation of Classification Societies, Rome, 1998.

[2] Alani, Harith; Kim, Sanghee; Millard, David E.; Weal, Mark J.; Hall,"Automatic ontology-based knowledge extraction from web document", Wendy; Lewis, Paul H. and Shadbolt, Nigel R. IEEE Intelligent Systems, 18(1), pp. 14–21. (2003)

[3] Florence Pugeault,Patrick Saint-Dizier and Marie-Gaëlle Montei," Knowledge Extraction from Texts:a method for extracting predicate-argument structures from texts".In: Proceeding of the COLING '94 Proceedings of the 15th conference on Computational linguistics.

[4] A. Ultsch, G. Guimaraes, D. Korus, H. Li,"Knowledge Extraction from Artificial Neural Networks and Applications",In:Proc.Transputer-Anwender-Treffen TAT '93, Aachen, 20.–22. September 1993.

[5] Ultsch,A.Habilitationsschrift,"Konnektionistische Modelle und ihre Integration mit wissensbasierten Systemen",Universität Dortmund,1991.

[6] Vargas-Vera, Maria; Motta, Enrico; Domingue, John; Buckingham Shum, Simon and Lanzoni, Mattia,"Knowledge extraction by using an ontology-based annotation tool",In: Knowledge Markup and Semantic Annotation (K -CAP 2001 Workshop),2001, Victoria, B.C., Canada.

[7] J.B. Domingue,"Tadzebao and WebOnto:Discussing, Browsing and Editing Ontologies on the Web", In: Proceedings of the Knowledge Acquisition Workshop, 1998.

[8] Majdi Beseiso,Abdul Rahim Ahmad and Roslan Ismail,"A New Architecture for Email Knowledge Extraction", In: IJWesT: International journal of Web & Semantic Technology,Vol. 3. Jul 2012

[9] Akihiro FUJII,"EDI Standardization of E-Commerce in the Cloud Environment and Its Future Evolution", Science and Technology Trends - Quarterly Review, Vol. 41, Nov. 2011

[10] Peter Clark and Phil Harrison,"Large-Scale Extraction and Use of Knowledge From Text", In: Proceedings of the fifth international conference on Knowledge capture(K-CAP '09),USA, 2009.

[11] Lenhart Schubert,"Can we derive general world knowledge from texts?",In:Proceedings of the second international conference on Human Language Technology Research,2002.

[12] L. Atzori, A. Iera, G. Morabito,"The Internet of Things: a survey",Computer Networks, 54 (2010).

[13] Jayavardhana Gubbia, Rajkumar Buyyab, Slaven Marusica, Marimuthu Palaniswamia, "Internet of Things (IoT): A vision, architectural elements, and future directions", Future Generation Computer Systems,2013.

[14] Rajkumar Buyya , Chee Shin Yeo , Srikumar Venugopal , James Broberg , Ivona Brandic, "Cloud computing and emerging IT platforms: Vision, hype, and reality for delivering computing as the 5th utility", Future Generation Computer Systems,2009.

[15] Sameer Tilak, Nael B.Abu-Ghazaleh,Wendi Heinzelman,"A taxonomy of wireless micro-sensor network models", ACM SIGMOBILE Mobile Computing and Communications Review ,2002.

[16] Melanie Tory ,Torsten Moller,"Rethinking Visualization: A High-Level Taxonomy", Proceedings of the IEEE Symposium on Information Visualization,2004.

[17] Ashton, K., " That "Internet of Things" thing". RFiD Journal.

[18] Schoenberger, C.R," The internet of things. Forbes Magazine",2002.

[19] Gershenfeld, N.: When Things Start to Think. Henry Holt and Company,1999.

[20] Friedemann Mattern and Christian Floerkemeier,"From the Internet of Computers to the Internet of Things",In: Book :From active data management to event-based systems and more, Pages 242-259 ,2010.

[21] Floerkemeier, C., Langheinrich, M., Fleisch, E., Mattern, F., Sarma, S.E.: (eds.) The Internet of Things. First International Conference, IOT 2008, LNCS 4952, Springer (2008).

[22] Toby Segaran, 'Semantic Web Programming', O'reilly, 2009

[23] Georghiou, L.'The UK technology foresight program', *Futures,*Vol. 28, No. 4, pp.359-377,1996

[24] United Nations Industrial Development Organization(UNIDO),'Technology Foresight Manual', Vienna, Vol.1, pp.7-10

[25] Kanama, D.,'A Japan's experience of a mission-oriented multi-methodology technology foresight process', Int. J. Technology Intelligence and Planning, pp.253-267, 2010.

[26] Michalski, R.S.: *Knowledge Mining: A Proposed New Direction, In:* Invited talk at the Sanken Symposium on Data Mining and Semantic Web, Osaka University, Japan, March 10-11, 2003.

[27] W. Frawley and G. Piatetsky-Shapiro and C. Matheus, Knowledge Discovery in Databases: An Overview. AI Magazine, 1992,213-228.

[28] Third Foresight Conference 2015, By Centre for Strategic Futures (Singapore), Raffles City Convention Centre, June 2015.

[29] The 6th International Conference On Foresight Foresight: Its Impacts And Possible Contribution For Policy Making, 2nd to 5th March 2015 in Tokyo, Japan.

[30] 5th International Conference on Future-Oriented Technology Analysis (FTA), 27-28 November 2014, Brussels.

[31] Irvine, J. and Martin, B.R. 1984. Foresight in Science: Picking the Winners. London: Pinter Publishers.

[32] Annele Eerola and Birte Holst Jørgensen," Technology Foresight in the Nordic Countries", Risø National Laboratory, Roskilde September 2002.