Information Synergy of Industrial Symbiosis

An open data approach to build an industrial symbiosis data repository

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Abstract

Purpose: This paper tries to review the exiting literature on Information and Communication Technologies for Industrial Symbiosis. And it presents an open data approach to the Industrial Symbiosis research.

Method: Literature reviews and data mining are used to achieve the research purposes.

Results: Four insights can be gained from an explorative open data approach on E-PRTR data sets:

1. We can get an overview of how waste flows transfer within Europe Union.
2. Match-making possibilities can be facilitated by integrating industrial production data sets with the investigated open data.
3. This register is created for the purpose of contributing to transparency and public participation in environmental decision-making within in EU. As it was not designed to support the research of IS in the beginning, we demonstrate that we can use it for the research of IS research.
4. We believe that there are other open data base online, with certain efforts and skills to clean these tedious data sets, we can integrate more and more cleaned-up open data sets and finally form IS data repository.

Conclusions: By providing a framework of the functions of ICTs for IS practices, the exiting tools are reviewed in this paper. The different interpretations of tacit information of IS from different authors in the field are discussed. We think the ontological framework provided by eSymbiosis project addresses the gap by providing taxonomical classifications of resources and IS processing technologies.

We argue that a wiki-based platform documenting IS cases and research results might create know-how knowledge in the field by strengthening the community communication and interactions. A trial case of exploring open data for the IS research has been presented.

Keywords: industrial symbiosis, open data, data repository, literature review, ICT for industrial symbiosis

1. Introduction

Industrial ecology is the field of combining natural, technical and social sciences in a systematic view at scale levels from the global to the local, learning the concepts from nature and implementing them in the society, by means of which sustainability can be approached and maintained.

Industrial symbiosis (IS) is one of the implementations of industrial ecology concept in a local/ regional level. The concept of symbiosis is taken from nature, where both species benefit from the short and long term interactions, which results a higher chance of survival in the environment.

An example of symbiosis from the ecology world would be bees help the pollination of the flowers but also get honey for themselves. A widely cited definition of IS by Chertow is : “engaging traditionally separate companies in a collective approach to competitive advantage by involving physical exchanges of materials, energy, water, and by-products together with collaboration of assets, logistics, expertise, and knowledge [1]. Though from practices in NISP, a new definition of IS has been proposed, focusing on eco-innovation and knowledge-sharing, of which geographic proximity are argued not to be the condition of IS activities [2].

The importance of Information and Communication Technology (ICT) on the Industrial Ecology research has been featured in the 2010 special issue on “Exploring environmental applications and benefits of Information and Communication Technology” of Journal of Industrial Ecology. As one of the key concepts of Industrial Ecology, Industrial Symbiosis is considered as a knowledge-intensive discipline [3]–[5]. The retrieving, exchanging and recycling of information are becoming important in the research of IS. Different stakeholders of IS (e.g. facilitator, participants and research institutes) can all benefit from the use of ICT. The paper by Grant eta al. summarized ICT tools for IS before 2009 and analysed them from the five development phases of IS [6]. While the second section of this paper tries to investigate more recent applications of ICT for IS based on their initial efforts and presents a framework to structure their primary functions and relationships.

Crucial in finding possible synergies within industrial clusters is to know the location, magnitude, and specifications of material flows, available energy, existing permits, and economics of supply chains etc. All those data have to be brought together in a useful way. These data provide the inputs for ICT applications, either they are heuristic visualization tool for strategic facilitation of IS or they appear as models to suggest synergetic material/energy match-making possibilities to policy- makers. In this sense, data is vital for the implementation of ICT for IS.

Many initiatives exist in the Industrial Symbiosis field in which a practitioner collects the data they need by a direct inventory to all the stakeholders in the cluster. The collected data then serves as inputs for ICT application. However, a lot of data is already available in datasets on European level and in that way linked to national bureaus of statistics, governmental agencies, branch organizations, etc. The third section of this paper will demonstrate a case of analysing open online database for the benefits of IS research.

This paper presents a trial case of exploring the open data approach to IS, the future outlook of this open data approach to facilitate IS will also be discussed, with possible research agenda and directions

presented. The efforts of the IE/IS research community will be appreciated to contribute to this IS data repository; therefore this paper calls for knowledge sharing on the topic of open data approach to IS.

2. ICT applications for IS

A framework has been proposed, based on a literature review of existing practices on information and communication technologies of industrial symbiosis, with emphasis on building an information system that can create synergies.

Grant eta al. summarized ICT for IS and analysed them from the five development phases of IS. Of the 17 tools they have inspected, the majority of the ICTs were used for the opportunity identification phase, which means to discover new process that can transform a by-product to a resource input for some other production process, and input-output matching of the resource provider and receiver. Some of the ICTs can also deal with opportunity assessment. That is so say, the outcome of the synergetic connection is evaluated in terms of environmental benefits or economic benefits or social benefits. Few investigated applications consider phases like “barrier remover”, “commercialization management” and “documentation”.

We listed the ICTs for IS based on their functions. And the framework we propose shows the relationships between functions. And what kind of data is needed for each function is elucidated accordingly. To make it clear, some applications can have more than one function, and only those functions are analysed below in Figure 1.

GIS stands for geographic information system interface and it needs the data of the location of the organizations (e.g. latitude and longitude) [7]. The outcomes of GIS show where the industries are and they provide the basis for match-making function and hot spots identification.

Looplocal is a heuristic visualization tool proposed by Aid et al [8]. Rather than giving specific suggestions of synergetic linkages for Swedish municipalities, this tool counts the number of potential synergies within each municipality and the total number of organizations included in each municipality, the average number of synergies per organization per municipality can thus be derived. This average number of synergies serves as an indicator and was mapped in a Google heat map to demonstrate the hot spots per of potential synergies among municipalities. An interesting thing of this tool is the way how the number of potential synergies is calculated. By manually inspecting over 800 life cycle inventory inputs material and the list of over 60 European waste codes, they came up with 191 potential substitution and exchanges. These 191 exchanges are then crossed checked with estimation of waste generation per facility and material/ fuel input facility to get the desired indicators. The authors also acknowledged the time-consuming process of manfully deriving the potential substitution and exchanges. We think that these efforts can be relieved to certain extent by introducing ontological representation of waste and processing technologies, which are in detail explained by T. Raafat et al. and will be discussed later [9].

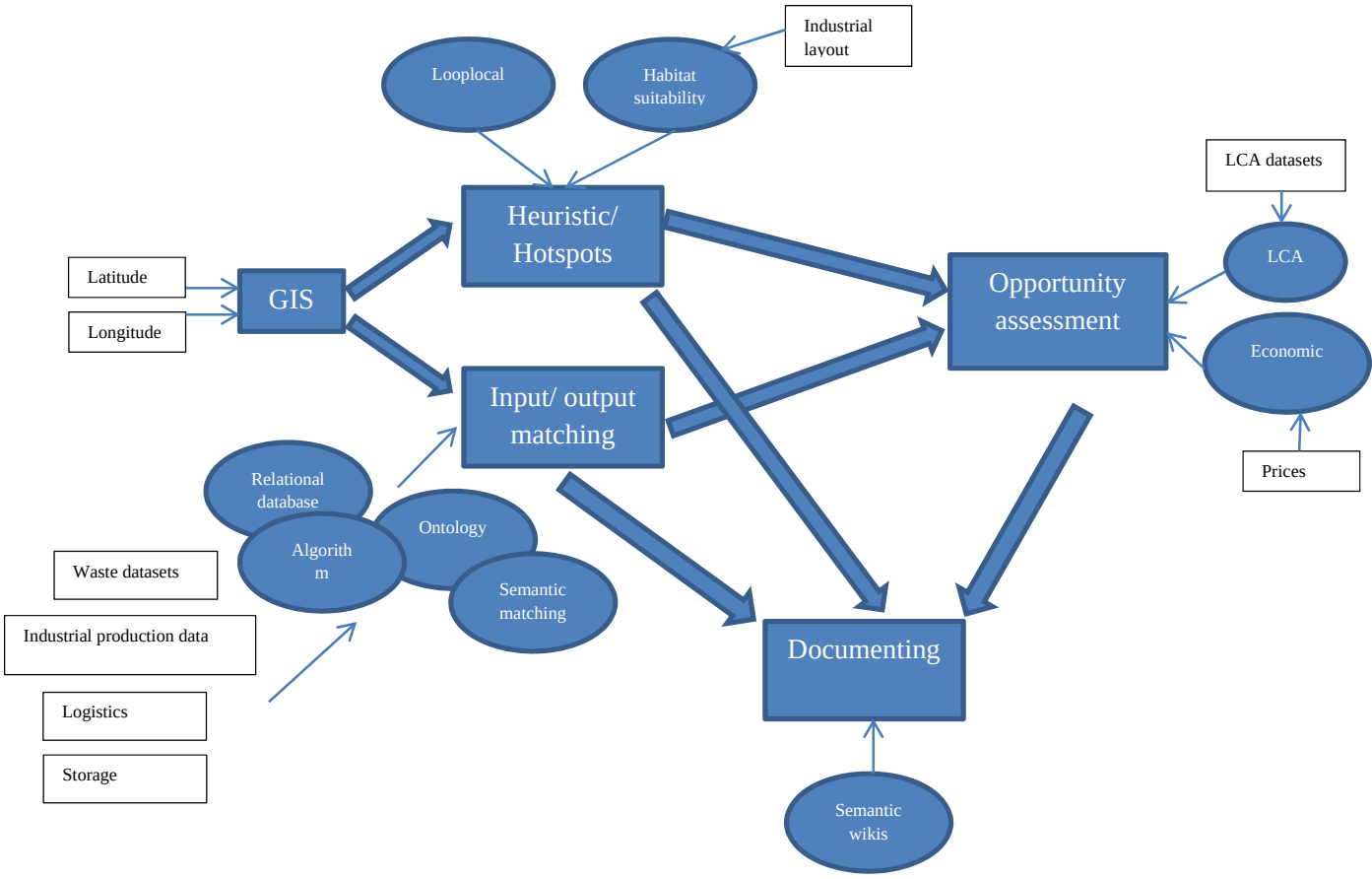

Figure 1 A framework of ICT functions for IS

Habitant suitability mapping is another tool to identify "hot spots" developed by Jesen et al. from University of Surry [10]. Their focus is on the mapping of utilities sharing rather than input/ output matching. By using the region of South Humber Bank as the bottom case, 9 variables are developed to characterise this case. The existing industrial layout of England is then checked against this bottom case. The more similarities the other industrial regions get compared to this bottom case, the more potential in establishing IS these regions will have for utility sharing. But the industrial pattern of the bottom case might not suggest the "perfect" combination of utility sharing, or whether there will be a "perfect" combination is subject to discussion as the industrial pattern differs region by region.

Another general ICT function that builds on GIS data is input/ output match-making. Grant et al. discussed most of these applications in their paper [6]. Some of these applications rely on relational database and some on linear integrated programming (cf. details can be found in the appendix of the survey of system in their paper). Grant et al. also point out that the taxonomical classifications of

resources remain a great challenge to these systems as there is a requisite of common language to produce relevant search results [6]. This challenge is similarly presented in the Looplocal tool discussed above.

The project eSymbiosis tries to solve the challenges of taxonomical classifications of resources and technologies. They present an IS ontology design in which the resource classification and technological processing are described [9]. The match-making is enabled by calculating the similarity of two resources. The similarity consists of two parts, of which they call the tacit knowledge part (the distance measurement of the ontology graph) and the explicit information which is the quantity, location, availability and pattern of supply [4]. Although weighting parameters are described by the authors as "experiential", this ontology for IS addresses the knowledge gap that was mentioned in the paper of Grant et al.

The opportunity assessment function is incorporated in the eSymbiosis project also, where there is a pre-assessment of the potential linkages. The results of this environmental assessment have an influence on the final outcome of the match-making process [11]. Other opportunity assessment can be life cycle costing, cost benefit analysis and social benefit assessment of these potential linkages.

While the tacit knowledge defined in the eSymbiosis is defined as the knowledge captured from experience in waste treatment and IS practice, the tacit knowledge presented in Grant et al.'s paper refers to know-how and can't be codified, for example, the communication and trust among companies [4], [6], [12].

Grant et al. mentioned the ability to promote explicit and tacit knowledge sharing through the creation of community and social capital. We think in terms of documenting the match-making results, IS hot-spots or the assessment outcomes, a wiki based web platform can well support the demonstration of explicit information. While in the meantime, we hope that trust can be built through the use of this platform, creating a knowledge-sharing community. More discussion can be seen in the paper by Korevaar et al [13].

3. An open data approach

As we can see in figure 1, the information of geographic location, waste data and industrial data are the inputs to ICT systems. Except the Looplocal, which integrates many data sets, many others systems adopt a closed data input approach. For example, 32 companies provided specific data to the Geneva IS project [7]. And companies in Viotia participated in the eSymbiosis project [11].

A different approach will be to look at the open datasets. Open datasets normally contains large volumes of information compared to closed data inputs. Although these data were not initially put online for the facilitation of IS, with efforts of data cleaning and curation, new insights can be shown. As Lombardi et al. advocates: "…to substantially advance theory-building for IS, and inform (if not structure) the discussion of its nature and definition, core IS hypotheses must continue to be challenged and qualified with empirical research, via both large data sets (where possible) and case studies". Below is a case that explores the open data for IS research.

The open data investigated is E-PRTR, The European Pollutant Release and Transfer Register (http://prtr.ec.europa.eu/). It provides easily accessible key environmental data from industrial facilities in European Union. The latest 2010 register contains data reported annually by more than 30,000 industrial facilities covering 65 economic activities across Europe.

For each facility, information is provided concerning the amounts of pollutant releases to air, water and land as well as off-site transfers of waste and of pollutants in waste water from a list of 91 key pollutants including heavy metals, pesticides, greenhouse gases and dioxins.

As the online data base is provided by semantic forms (rdf), SPARQL query language is used to query the information about waste transfer facilities provided in the database. Cleaning the data in R, figure 2 shows the locations of all the waste providers.

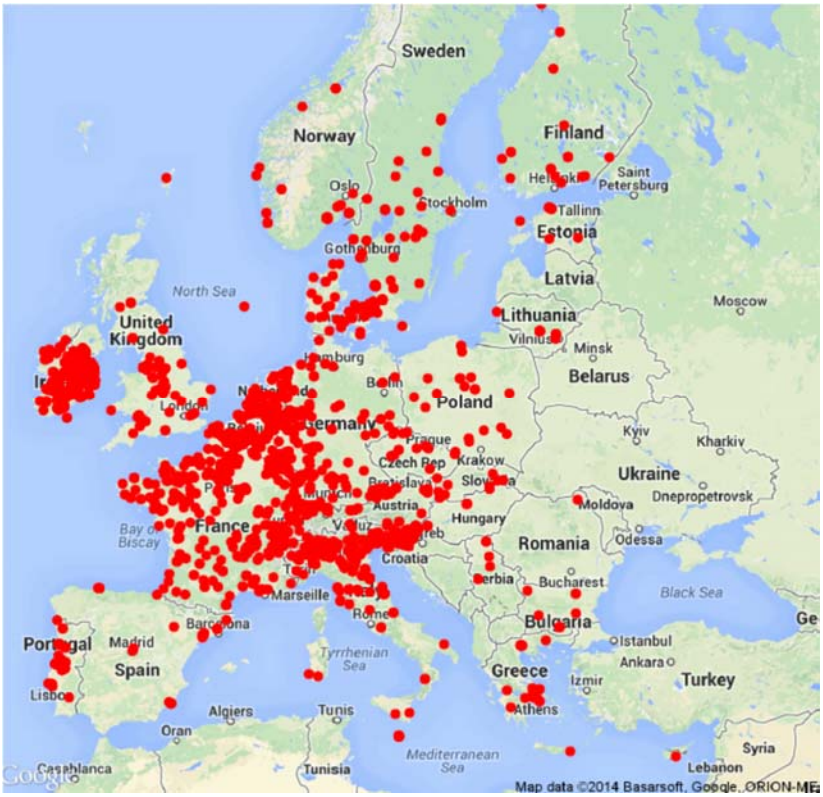

Figure 2 locations of all the waste providers

As the data base provides only the receiving address without the longitude and latitude, using google redefine (https://code.google.com/p/google-refine/) and R, we connect the waste provides and receivers with arrows. Figure 3 shows the waste transfer in Greece.

When waste providers are within Greece When waste receivers are within Greece

Figure 3 waste transfer in Greece

We can see that at least from the database, Greece provides more waste flows to other countries than receiving them. And the distance these flows travelled are mapped as well.

This is trial case gives interesting insight into how open data can assist the research of IS, we can conclude four insights:

1. Though Only one waste data base has been explored, as waste minimization constitutes one of the three dominant parts in IS research, we can still get visual overview of how waste flows transfer within Europe Union [14].
2. If further efforts can put another layer of industrial production inputs data on this map, and we include only the waste providers, match-making possibilities can be facilitated.
3. This register is created for the purpose of contributing to transparency and public participation in environmental decision-making within in EU. As it was not designed to support the research of IS in the beginning, we demonstrate that we can use it for the research of IS research with some efforts of data mining and cleaning.
4. We believe that there are other open data base online, with certain efforts and skills to clean these tedious data sets, we can integrate more and more cleaned-up open data sets and finally form IS data repository.

4. Conclusions

This paper starts to exam the exiting literature regarding ICTs for IS. By providing a framework of the functions of ICTs for IS practices, the exiting tools are reviewed. The different interpretations of tacit information of IS from different authors in the field are discussed in detail. We think the ontological framework provided by eSymbiosis project addresses the gap by providing taxonomical classifications of resources and IS processing technologies.

We argue that a wiki-based platform documenting IS cases and research results might create know-how knowledge in the field by strengthening the community communication and interactions. A trial case of

exploring open data for the IS research has been presented, we believe that an information synergy of IS can be achieved by data mining on open datasets that are not designed in the first place for IS research.

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