Detection of paradigm shifts and emerging fields using scientific network: A case study of Information Technology for Engineering

Thara Prabhakaran [1], Hiran H. Lathabai, Manoj Changat *

Department of Futures Studies, University of Kerala, Thiruvananthapuram, Kerala, India

ARTICLE INFO

ABSTRACT

Detection of emerging fields in any industry is of great importance to the industrialists, engineers and policy makers of business as well as state administration. Exact awareness of the paradigm which governs current research activities and chances of likely paradigm shifts which could redefine the research approaches, is very crucial for the actors of scientific community and policy makers. Excellent technologies in IT, even accelerated the scientific and applied ontological pursuit in both academia as well as industry. In this work, network approach is advocated for the identification of innovations, new paradigms and emerging fields in the IT industry in the research area 'engineering'. The network is a scientific network of research publications which reflects the volume and flow of scientific activities. Centrality analysis, path analysis, cluster analysis, etc. are used to identify the key papers of paradigm shifts, emerging fields, relatively important clusters and works respectively. A new metric, flow vergence index is devised for cluster analysis. The paradigm shift identified from this network is RFID technology, related with the supply chain management. With proper economic and policy supports, there are some good reasons to look forward for more wonders from the industry.

© 2014 Elsevier Inc. All rights reserved.

1. Introduction

Almost all the industries ranging from healthcare, medicine and pharmaceuticals, banking, biotechnology and biomedical engineering, automotive, operations and manufacturing, building and construction, distribution, food processing, space sciences, weather monitoring, and disaster management are directly or indirectly using the advancements in IT for their daily and strategic functioning. It renders a ubiquitous presence in the life of people through technologies embedded in various devices of different levels of sophistication and applications. Information technology industry being one of the sub-industries of the engineering industry, also have almost the same spread and reach. Detection of emerging fields, paradigms [1] associated with the scientific researches which directly or indirectly affect any industry is very important for industrialists, academic researchers, engineers, policy makers in business organisations as well as in state administration. Mulkay et al. [2] argued that emergence of a new research network occurs through the invasion of other research areas over one which holds room for development where theories and techniques of the former are readily transferable for answering the unsolved questions in the latter. Whitley [3] argued that Kuhn's model of dynamics of science fails to provide an insight about the creation of different sorts of knowledge in different social contexts. Perry and Rice [4] favoured evolutionary branching theory of Mulkay over Kuhnian model as their evidence points to divergence of research areas instead of convergence. In this work instead of considering the research areas, the flow of knowledge at individual work level is considered and the concept of flow vergence (divergence or convergence) is introduced. The flow divergence tendency of a work within a cluster indicates its cohesive potential to other

research clusters. While convergence and passive flow indicate the tendency to grow incrementally within the confinement of the research area addressed by the cluster. Thus divergence indicates the radical nature of work and convergence indicates incremental flavour. Results point out that most of the works and research fields (clusters) in an evolved network show a convergence dominant mode of growth and thus agree to Mulkay model. The occurrence of paradigm shifts is also identified in this work and hence the evidence towards Kuhnian model with the advantage of identification of the emerging fields is presented.

Economic growth of most of the industries depends largely on the development of operating technologies within the industries. A lot of works were concentrated on the high technology industries, viewing an industry as a collection of its relevant technologies [5]. Many methods can be found from the literature, which were either intended to identify the technologies of good performance via clustering based on growth curves [6,7] or predict their development so as to help in planning. Clustering based on growth curves, a parametric method, attempts to fit a common growth curve model to all the technologies and then those showing similar patterns are grouped together by comparing their parameter values. However, their disadvantage lies in the fact that all the technological growths can't be explained by one predetermined growth model. They are more of a quantitative approach and fail to capture the qualitative aspects of the works. The importance of network of publications analysis lies in the fact that, being a knowledge flow based approach, direct relationships between the intellectual works are reflected. Indirect relationships can also be modelled by using derived networks such as collaboration networks and co-citation networks [8]. Various tools are available for complex network analysis and visualisation. Popular software packages are PAJEK [9] and GEPHI [10]. Histcite [11], an online bibliometric analysis and visualisation tool by Eugene Garfield can visualise the networks of publications as historiographs [12], which shows the historical evolution of the networks. Large network visualisation and analysis can also be done in a lot of other bibliographic management software packages.

In this work, we intend to identify important innovations (radical) and paradigm shifts that occurred in the IT for engineering during the early years of 21st century (the span of our research is from Jan. 1st 1999 to Feb. 28th 2013). This period is important because it has witnessed the downswing of the 5th Kondratieff cycle of development (K-cycle) [30], driven by information technology, networking and communication technologies. Interestingly, the growth of IT in developing countries (like India) during this period was remarkable [45] and might have far reaching impacts. Therefore, the developments in the industry during this period of the current cycle might be crucial for the future of industry, especially in the 6th K-cycle. Our research goal also includes the identification of different important fields (research clusters) in the industry. The evaluation of their performance (based on the knowledge flow characteristics) and ranking based on their performance is the main concern of this work. The identification of emerging fields in the industry is another important aim of our work. All these identifications: i.e., radical innovations, paradigm shifts, different fields of research, relatively more important fields among those research clusters, emerging research clusters, etc.

is very much handy for the scientific community, other researchers, investors, policy makers, etc. Plausible implications of these identifications to various target groups are given in discussions (Section 4).

1.1. Organisation of the work

Detailed literature review about the analysis of scientific publications using network approach is given in Section 2. Section 3 specifies about the data collection, important concepts for networks and the methods used for this investigation. Results of the analysis and the discussions are given in Section 4, which includes identification of important network characteristics. The important analyses include centrality analysis, path analysis and cluster analysis. Centrality analyses helps to identify the innovations (both radical and incremental) and also the key papers of paradigm shift. Path analyses reveal the historical development of the main and critical theme of the network. Cluster analysis using FV model identifies emerging fields and the relative importance of clusters as well as the works. Discussions, findings and implications are also covered in this section. This section is followed by Section 5 which consists of conclusion. Limitations of current work, directions for future works, etc. are given in Section 6.

2. Network approach

In many scientific fields, the advancement of the field through accumulation of knowledge is tremendous so that the researchers are forced to depend on comprehensive surveys and literature reviews to remain updated about the field [13]. Several approaches can be found in the literature to study about the progress of science. Being rewards for introducing novel design, method or solution to certain problems or set of problems, patents are well regarded as proxy measures of technological advancements [31]. Hence they are widely used for evaluation of developments in research areas and even prediction of progress. Apart from patents, other intellectual properties like trademarks are used as indicators of technological growth (especially in high technology industries) by agencies like WIPO (World Intellectual Properties Organization) [32]. Business always plays an important role in delivering value of innovations and even controls the diffusion of innovations. Radical innovations often forces players in the market to forge suitable business model innovations. A recent study with the case of music industry also affirms this observation [33]. It can be found that the concept of 'business models' needs more thorough understanding by the researchers. An attempt to provide more clarity about business models had been done by Osterwalder et al. [34]. After an exhaustive research on the literature about the comparatively young concept of 'business models' they proposed the definition of business model — "A business model is a conceptual tool that contains a set of elements and their relationships and allows expressing the business logic of a specific firm. It is a description of the value a company offers to one or several segments of customers and of the architecture of the firm and its network of partners for creating, marketing, and delivering this value and relationship capital, to generate profitable and sustainable revenue streams". Works exploring the methods of value creation from business models (especially in e-commerce) which are patentable [35]