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A patent-based cross impact analysis for quantitative estimation of technological impact: The case of information and communication technology ☆

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Abstract

The increasing syntheses and interactions between various technologies increase the usefulness of cross impact analysis (CIA) as a method for forecasting and analyzing them. Conventional CIA depends on an expert's qualitative judgment or intuition and thus it is difficult to evaluate quantitatively the impact of one technology on another. In this study, we employ patent analysis in CIA to examine such impacts between technologies based on multiple patent classifications. Patent information is used for facilitating quantitative and systematic approach in CIA. The distinctive feature and main contribution of the proposed approach is the overcoming of the limitations of conventional CIA, by employing conditional probabilities based on the patent information. The classification of patents, particularly the multiple classifications, is used to evaluate the relationships between technologies. As an illustration, a patent-based CIA with information and communication technologies (ICTs) was conducted. Firstly, the patent-based cross impact among ICTs was calculated. Secondly, the technology pairs were classified based on the cross impact score between ICTs. Thirdly, a cross impact network was constructed to identify the complex relation among ICTs. Finally, the changes in cross impact scores between technologies over time were analyzed. The results of this research are expected to help practitioners to forecast future trends and to develop better R&D strategies.

Keywords: Cross impact analysis; Technological impact analysis; Patent analysis; Information and communication technologies

☆ It is confirmed that this item has not been published nor is currently being submitted elsewhere.

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1. Introduction

Technology forecasting provides helpful information to practitioners, in both the private and public sector in developing R&D plans and policies, respectively. By its very nature, technology forecasting is a difficult process, and it becomes more difficult due to the interrelations and interdependencies between technologies. Accordingly, many studies have analyzed the relationship between technologies and evaluated the overall impacts of technologies on other technologies [1,2]. Among these studies on technology forecasting, cross impact analysis (CIA) has been used as a practical methodology to forecast the emergence of new technologies and to identify the interrelations between technologies by defining the emergence of new technologies as event occurrences. This involved estimating the occurrence of events (technologies) and the impact of each event of interest on other events [1,3,4]. In essence, CIA is an analytical approach for consistently estimating the probabilities of a set of events. Probabilities are adjusted according to the judgments concerning potential interactions between the forecasted events. The fundamental assumption of CIA is that most events are related to other events. The occurrence and interactions are evaluated by estimating the initial probabilities of each event and the conditional probabilities between two events. The estimation is performed by literature survey and interviews with experts in the specific field.

In order to forecast the occurrence of technologies and impact between technologies, a cross impact matrix is constructed with the probabilities estimated by the technology experts and a calibration run of the cross impact matrix is performed to obtain the consistence of probabilities. This approach is widely used in CIA, but it has some limitations. First, requesting subjective and intuitive estimates of initial and conditional probabilities may result in inconsistent estimates because there are mostly likely discrepancies in the subjective estimates depending on the background and the knowledge level of the experts. Further, as the number of technologies to be forecasted increases, the data collection requirements increase geometrically. When we construct the cross impact matrix with N technologies, experts should estimate N occurrence probabilities and $N(N-1)$ conditional probabilities. A 10-by-10 matrix requires 90 conditional probability judgments and a 40-by-40 matrix requires 1560 estimations. This restricts the size of the problem.

In this research, we suggest a modified CIA to evaluate the relationship between technologies and how these relationships change. The distinctive feature and main contribution of the proposed approach is the overcoming of shortcomings of conventional CIA, by using a quantitative and systematic method for estimating conditional probabilities. This approach focuses on the evaluation of relationship, that is, the impact between technologies. Specifically, the conditional probabilities are not obtained from experts, but rather, are measured using patent data in order to perform a more quantitative CIA. The technology classification of patents, especially the multiple classifications of patents, can be used to evaluate the relationship or impact between technologies. For the case study, the relationships between different information and communication technologies (ICTs) are identified and, the changes of these relationships between technologies over time are analyzed from the years 2000 to 2004. These changes are the basic information that can reflect the technologies for the near future.

2. Literature review

2.1. Cross impact analysis

The general notion of CIA was first suggested by Gordon and Helmer with the game futures created for the Kaiser Corporation [5], and later expanded to a number of forecasting areas [5–8]; however, it