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Abstract

Today, the increasingly faster technological advances make the competition ever-fiercer in the business environment. This situation has laid emphasis on the importance of technology foresight for corporations to plan and even shape their futures for a long term. However, the conventional methods do not overcome the problems with the overload and heterogeneity of information in the current information society. In this study, scenario agents, as an intelligent information system and part of the Foresight Support System, are used to help corporate people to deal with large amount of information efficiently, systematically and intelligently. This system combines the advantages of scenario building and storyline approaches and embeds the foresight models formed by these two approaches. The scenario agents supported foresight system is now being implemented in an industrial corporation and is expected to provide weak signals or early warnings of the future developments and trends of key technologies. This study investigates how scenario agents can effectively assist key technology foresight research and further strengthen corporate competence.

Keywords: Technology foresight, Scenario agents, Scenario, Storyline

1. Introduction

The impact of constantly emerging technologies on the economy and society is significant both at national level and for individual corporations. Our society relies on science and technology to drive the economy and to improve the standard of living. Corporations need to have a comprehensive or holistic overview of long-term trends in technology and innovation. However, as the global economic competition and dynamic developing situations are on the increase, decision-makers are faced with more and more complex problems. From the Triple-Helix perspective (that is, the interacting spheres of the government, industry and academia), the importance and the priority of technology foresight research is becoming apparent in strategic decision-making. Therefore, the purposes of this research are to put the future vision of a company to be a leader or an industrial shaper in technology by improving sustainable competitive advantage and to improve the substance, precision, and scope of strategic management with support of systematic models and numerous and extensive data sources.

Technology foresight is intended to put the envisioning and planning of the futures to a long-term perspective. The time span can be from 5 to 15 years or even longer. The attention is chiefly focused on the extrapolation of the trends of technological invention, innovation and evolution. Further exploration focuses on how to use the technology foresight research on the operational decision support for more effective technology knowledge learning, management and strategic planning.

Based on research literature studies, it can be seen that, to date, although technology foresight has a methodological repertoire of its own, there are limitations for each of them. It appears that there is a need for intelligent system technology solutions to work with methods and models to create, to modify, to adapt and to update reliable and good quality foresight. This study intends to explore the use of scenario agents as an approach to key technology foresight research, because scenario agents have made information scanning more systematic in the collection of information, have assisted system users to manage technical knowledge and have supported strategic decision-making.

This study carries three tasks: (1) to locate a theoretical framework which can explain the substance of technology foresight; (2) to introduce the operating theories of the fast, effective value-adding intelligent systems; (3) to supply ways to improve the substance, precision and scope of technology management and further corporate competence. These tasks have already been undertaken and will be discussed below.

In the next section, a brief review of foresight and technology foresight is given, especially, focusing on the key technology from the competitive value perspective. In section 3, a summary of the use of an intelligent software agent and the knowledge of scenarios and storyline is presented. The functionality and the operating theory of scenario agents are illustrated. The fourth section presents an empirical study of how the scenario agents handle the distributed and increasing amount of information. This intends to provide an approach for considering foresight as an essential part of the strategic planning programme. Section 5 analyzes a survey conducted to evaluate the performance of the system. The evaluation contains the users' feedback of the successful functions and shortcomings for future development. Section 6 summarizes my study and offers some comments.

2. Technology Foresight

2.1 Foresight in General

Foresight has had a strong global revival in the past decade. It has normally been established at national level for policy-making to strengthen the national systems of innovation. Foresight is an ongoing and evolutionary process of thinking about the future, which is different from forecasting in the sense that there is not much use of time series analysis and mathematical modelling (Carlsson and Kjellman, 2000). It is knowledge based, uses basic research and combines the developments in science and technology to provide possible visions of the future and to explore alternative futures in order to help economic development, even to ensure effective strategies for countries and corporations (Martin, 1995, p. 140).

The objectives of foresight exist widely between economics and social criteria. Martin (1995, p. 158) categorised foresight in terms of its intermediate functions: (1) direction setting, (2) determining priorities, (3) anticipatory intelligence, (4) consensus generation, (5) advocacies for a new research initiative and (6) communication and education within the research community concerning promising research opportunities and approaches. These functions are attributes and competences in the ways of assessing actions, formulating pro-active strategy, guiding, and envisioning future scenarios, which attempt to broader the vision and scope of perceptions (Major et al., 2001).

A number of practical cases can be used to prove the importance of technology foresight. One of the most famous examples is Japan's developing strategy. Since 1970, there is a series of long-term forecasts by the Science and Technology Agency in Japan aiming to innovate in

technology. These have been carried out every 5 years with the attempt of looking into the future of science, technology and innovation by up to 30 years. Today, the results of their strategy are apparent that Japan has become the leader in the technological field, constantly proclaiming new innovations. Exploring foresight research is also one of the reasons for Japan's post-war global competition success (Major et al., 2001). Currently, most governments in industrialised countries believe that an explicit, coherent technology policy is essential for economic and social development. Nowadays, foresight is becoming a trend and is likely to be widely used in corporations.

2.2 Technology Foresight for Corporate Competence

For corporate technology strategy, competence building requires a "strategic architecture", a kind of roadmap that identifies the core competence for building constituent technologies to reach the objectives (Chiesa and Barbeschi, 1994, p. 293). Competence building can, therefore, be viewed as a guided process of resource accumulation. An analysis of research literature on this topic suggests that the blocks for competence building are (1) committing the organisation to long-term objectives (Hamel and Prahalad, 1989, 1993), (2) accumulating resources and (3) enhancing the bases of knowledge and skills through learning cycles (Dodgson, 1991; Pavitt, 1991).

Furthermore, in order to remain competitive in the fierce competition, innovation and the necessary evolution of technology will be the solutions to achieve competitive advantages. This, to some extent, would result in the use of foresight for commercial purposes. Technology foresight focusing on the impact of new technologies has emerged in corporate strategy, with an emphasis on the management of emerging technologies and on the future strategic environment of firms. In this tradition, Slaughter (1998) defines technology foresight as follows:

> The ability to create and maintain high-quality, coherent and functional forward views and to use the insights arising in organizationally useful ways, for example, to detect adverse conditions, guide policy and shape strategy and to explore new market products and services.

The main point of this definition is that in order to survive, have a standpoint, be competitive, or even to be the shaper of a certain field, a firm needs to prepare for the emerging technologies, be adapted for new changes, or be creative enough for creating leading innovations.

According to Martin (1994, p. 76), in practice, in terms of the competitive importance and competitive values of technologies and technology innovation, technologies can be categorised as base technologies, key technologies, pacing technologies and emerging technologies at the embryonic stage. Among them, key technologies are the know-how that can provide a significant competitive advantage. This is the uncommon and often tacit inventive knowledge possessed by the creative R&D that generates the new generation products.

The conclusion can be drawn that a corporation, in order to win in the commercial society, should not only be good at producing saleable products at present, but also be innovative and adapt well to different kinds of changes in their environment (Peters and Waterman, 1982), because the benefits of key technology foresight in the business sector are significant for helping the corporation to (1) reduce risk and offer better rates of return for shareholders, (2) bring new opportunities, (3) have more effective management and (4) plan a better strategy

(Walden et al., 2000, p. 171). Therefore, a company can no longer simply set a benchmark to a competitor's products and processes; instead, the core action will point to create targets for future development, since the competition should create and dominate new technologies. For instance, if Nokia only focused on its core business in the 1980s, there would not be a world's leading telecommunication corporation. Foresight research focuses on tracing trends, future uncertainties to produce possible foresight visions, develop scenarios and define directions.

3. Technology Foresight Methods

Foresight is equivalent to a set of systematic efforts to look ahead, in order to plan the future more effectively. In addition, to become more systematic and more comprehensive, a foresight process must be able to accommodate a wide range of information, be public and avoid prediction (Martin, 1995).

In an information society, the valuable and speedy information with a better cost/benefits ratio is very important for corporations, because it will provide "intelligence" – a prime requirement for successful technology foresight. However, traditional methods are often characterised as iterative, costly and time-consuming, such as Delphi surveys and expert panels. However, these conventional research methods have not been totally discarded; instead, they have been integrated with competitive technological intelligence techniques (Ashton and Klavens, 1997), technology and innovation audits and market analysis (Du Preez and Pistorius, 1999). In order to support technology foresight and explore for new methods, in our experiment, agent technology has been used as solutions to help users to work with methods and models to create, maintain, modify, adapt and update reliable and good quality foresights. The scenario agents are pointed out combining the abilities in the right behaviour to play a given role. The reason for calling the application "scenario agent" is that it not only contains the functionalities of agent technology, but also involves scenario planning/writing and technology storylines.

3.1 Scenarios as a Support for Foresight

The theory of scenario agents is based on the orientation of scenarios. Scenario has been defined as:

> [a] series of consecutive, logically proceeding, justifiable, and possible images of the future; a story presented with the help of images of the future, can be understood as a functional manuscript stating the conditions for achieving the aim. A scenario includes a description of the actors, activities and a description of the sequence of events, decisions and consequences. This sequence of events leads from the present to the chosen image of the future, which can be the vision, strategic objective or opportunistic aim. (Finland Futures Academy)

Enterprises need to identify and develop success potentials earlier than their competitors. Therefore, it is not enough to look for one vision that is most likely to correspond with the expected view. Instead, it is necessary to try to acquire various views (trends, potential opportunities, new driving forces or threats) that describe the whole "window of opportunities and challenges". Alternative views of the future are a promising way to cope with the growing uncertainties.

The word "scenario" was adapted to economics from Futurology and from the work of the futurist Herman Kahn in particular. He developed scenario writing in cooperation with Anthony J. Wiener, which can be seen as the first method for the creation of scenario (Kahn

and Wiener, 1968). These scenarios were hypothetical sequences of events, through which possible future developments were made visible.

There are two kinds of attitudes toward the future. A passive attitude toward the future means that a range of scenarios are developed to embrace the range of future possibilities, after which organizational plans and decisions are modified in light of the future that actually unfolds. However, Gabor (1964) postulated a proactive stance toward the future. He introduced the idea that a social group should invent the future that it has selected for itself. Once a firm has developed a number of alternative scenarios, it can pursue technological plans or strategies that it seeks to invent the alternative future or the preferred scenarios. The second one is implemented in this study.

Except studying the alternative scenarios, what is required in creating a scenario is a study of the relationships between the influencing factors, such as price (economic factor) and new technologies (technology innovation factor). In addition, specific focuses must be taken into account. One focus is the prompt identification and assessment of emerging technologies, for instance, the technologies whose exploitation will yield benefits for the economy or society. Another focus is strategic research, i.e., the basic research carried out with the expectation that it will produce a broad base of knowledge likely to form the background for the solution of the current or future practical problems.

In order to form the scenarios through these two aspects, there are two generic modes of scanning undertaken by the agent system: reactive and proactive. In the reactive mode, the scanning search is stimulated by a problem and directed toward supporting strategic decisions. The proactive mode does not point to any predefined problem, but keeps the company itself vigilant and aware of the developments and early warning signs in its external environment (Rouibah and Ould, 2002, p.133). The proactiveness brings up-to-date information and important signals to the users' attention in a proactive way.

Thus, the goal of creating scenarios is not to define future events, but to show the different forces that signal the future in different ways. Scenario development aims at making these forces visible. In this case, if they do occur, the planner and his or her organisation will be able to recognise the forces and also be on firmer ground in the decision-making process.

3.2 Storyline as Foresight Models

In the agent system, besides the theory of scenarios planning, an effective approach is to build storylines as foresight models. Storylines are formed and employed in the system with the purpose of systematically laying out prospects for the development of related technologies of several generations. Constructing the framework of a storyline is the most important step in the development process, because accurately identifying the specific nodes and appropriate placement of these nodes will influence the quality and reliability of the foresight model (Saritas and Oner, 2003, p.15).

A storyline contains the current state and the future development of one technology and the potential changes in an interdisciplinary area. It can define the paths to meet future requirements and assist to find nodes for which more information is required. In our study, we have used a time-based framework. A framework can also be created to follow contemporary economical trends to develop, represent and communicate strategic plans in terms of the present market, products and technologies to predict the evolution and development of future technologies, products and markets. This represents the schematic

technology storyline, showing how technology can be aligned with product and service developments, business strategies and market opportunities (Phaal et al., 2003, p. 6).

Storylines are used as a tool to decrease the complexity in foresight processes by manipulating and managing information and constructing a certain kind of list that maps the developing procedures of technologies. On the other hand, storyline can also overcome human beings' limited capacity of information processing (Saritas and Oner, 2003, p.15). The use of storylines is a flexible approach, because it enables a framework to be adjusted according to the different conditions in each technology. This approach also comprises a brief review of the technology and knowledge management foundations of the techniques in the contexts of fields of technology strategy and technology transitions. From a company's perspective, the storyline of technology development can integrate with business planning and assess the impact of new technologies and market development. From a multiorganisational perspective, storylines seek to capture the environmental landscape, threats, and opportunities in a technology or application area (Phaal et al., 2003, p.16). In our research, the storylines are embedded in the agent system, which appears to be a more useful and meaningful method, because an agent can search the latest information frequently to discover changes and fill in the empty nodes of the storyline. In addition, users can also update the storylines in the system.

3.3 Scenario Agents

A technology strategy should be viewed as a trajectory of technological resource acquisition and internalization (Chiesa and Barbeschi, 1994, p. 306). Despite the fact that there are many tools (e.g. groupware, collaborative system) that can help the organisations to be more effective in accessing and sharing their knowledge, O'Leary (1996, p. 31) identified the use of intelligent agents is a promising solution to assist and facilitate in the whole management processes. The reason to conclude this statement is that the Web allows various kinds of knowledge to be disseminated across time and space barriers.

An agent is defined to a computational programme or a problem solving entity for accomplishing a specific task. It is situated in an environment to employ some knowledge or representation of the users' goals or desires (Liu, 1998, p. 363; Jennings, 2000, p. 280). In this research, the agent approach is employed to perform the foresight tasks, as well as to act as a paradigm to manipulate symbolic knowledge.

Sycara (1998a, p. 11) underlines that the agent is a computer software system whose main characteristics are situatedness, autonomy, adaptivity and sociability. *Situatedness* means that the agent receives some form of sensory input from its environment (the physical world and the Internet) and performs actions that change its environment. *Autonomy* means that the agent can take the initiative to solve a problem without direct intervention by people. *Adaptivity* means that an agent is capable of reacting flexibly to changes in its environment and taking goal-directed initiative when appropriate. *Sociability* means that an agent is capable of interacting in a peer-to-peer manner with other agents or people. The characteristics in the previous definitions are based on the abilities which are finally tightly dependent on the actual role of the agents and, by extension, on the specifications of a particular problem.

When encountering more complex, realistic and large-scale problems, the capabilities of an intelligent agent will appear to be limited in knowledge, computing resources and in perspective. To be more powerful, the problem-solving scope of a system lies firmly in the

domain of Multi-Agent Systems (MAS) (Sycara, 1998b, p. 79). A MAS is defined as a loosely coupled network of agents that work together as a society to find answers and solve problems that would exceed the capabilities or knowledge of any individual agent (Durfee et al., 1989). Large-scale networked environments and the increasing complexity and size of information resources available online are rapidly overloading the manual browsing and the search for solutions. Software agents mitigate the heterogeneity of the information environment by interacting through common protocols. A number of considerations justify that the system should also be as intelligent as possible to collect the distributed information and built on distributed architecture.

The scenario agent is in fact an intelligent MAS that can fulfil the requirements in the information society. As for the scenario agents named as iTracer that we have used in the technology foresight research project, the overall design of the scenario agents follows two major principles: (i) support for open world scenarios, (ii) support for model-based scenario building (Metal IT Project, 2001). According to the former principle, scenarios are built as support for independent scenario planning and as a basis and input for the foresight models (the scenario material being stored in a database). In the latter case, the model-based scenarios are built to direct the foresight database. The agents inside the system will form a group and work collaboratively to maintain an ongoing interaction with the environment and to react to the changes in the environment. The scenario agents are used as a wrapper around foresight models to accomplish open world scenarios and model-based scenarios. The functionalities of the scenario agents are summarised as follows (ibid): (1) to provide help and support for building open world scenarios, (2) to support model-based scenarios, (3) to automatic search data sources in the Internet and the Intranet and (4) to collect many kinds of hyper-knowledge supporting for different categories of scenario builders.

To present the structure of the MAS more clearly, a framework of the scenario agents for carrying out the task is shown in Figure 1. As it can be seen from the figure, there are parallel scenario agents both in the system parts I and II. The core part of the system is the main information source: appointed search engines including password protected sources (e.g. Factiva), through which scenario agents will search for sources (mostly commercial data) on the Internet. At the same time, information will be distributed to different scenario bases according to the predefined foresight models. System part I is to search and scan for information, that is, to collect information and put it into the databases of each search engine. The processing programmes are retrieval systems, which control the accuracy and correlation of the information, so that the irrelevant information such as advertisement or non-technical information will be deleted. The service base works in the background and has the duty to maintain the operation on a 24/7/365 basis. Information will be sorted not only according to the search engines, but also through different scenario bases in system part two. The actual work is done within the whole system at the same time. In part II, once relevant information has been found, a duplicate file will be collected and stored up by a specific scenario agent according to predefined search phases. Based on these two kinds of organising methods, the scenario agents input the extracted information from the open world into the corresponding nodes in the storylines. The user can process information, manage and update knowledge toward accumulated and collaborative knowledge bases. In addition, these agents differ from conventional information retrieval solutions due to the fact that they interact with the users and defeat the dynamic nature of the information they deal with. Users can update the foresight models and assign new tasks to the agent at any time. It can be seen the MAS controls the heterogeneity and dynamic nature of the fast growing information landscapes.

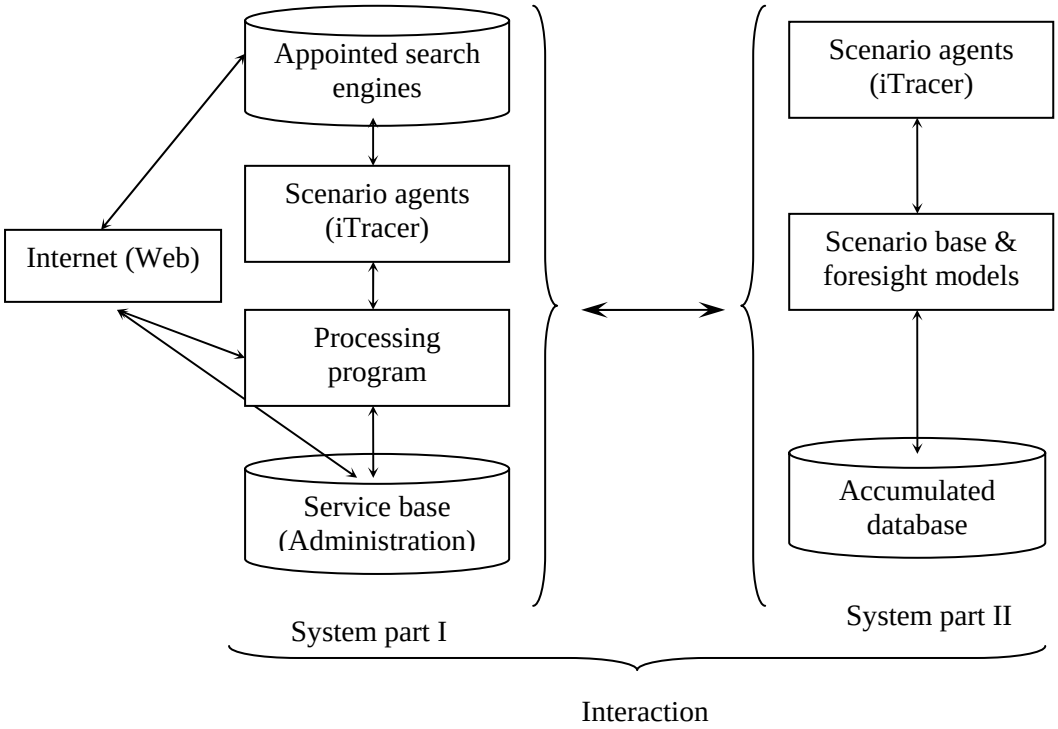

Figure 1. The framework of scenario agents

Merging the characteristics of scenario writing and storylines, scenario agents applied in the empirical study are intended to map the current situations from an open world scenario perspective, build up technology storylines, use agents to scan scientific developing trends, and moreover, to search a broader range of information to discover weak signals, hints or trends which intend to impact on development, and finally, to synthesise all the results to form model-based scenarios.

The reason for such a comprehensive combination of the three methods as above mentioned is that the limitations of each methodology can be remedied by another one and the functions can overlap and complement each other. Scenarios are pictures of several possible future situations, but stay at the level of broad generalities lacking structural frameworks to outline all the information for systematic analysis (Gavigan, et al., 2001, p.111). The storyline can organize the outline in proper order based on different criteria for specific technologies, but it is short of information to constantly enrich the whole structure. The implementation of the agent system can substantiate information demand supporting the scenarios and storylines for building foresight models. Through the combination of these methods, the limitations of each method can be reduced by other methods. The comprehensiveness and appropriateness can be seen, since the whole module not only can present many possible scenarios covering (a) production technology, products and productivity, (b) competitors and competition, (c) markets and customers, (d) profitability, capital structure, investments and financing, but also structure well with substantial information as support.

Moreover, the system is a combination of objective and subjective methods of the future studies and does not only use the data and information for extrapolating from the historical analogies and building scenarios, but also takes advantage of the users' knowledge, experience and talent (Masini, 1993, p. 78). A company will benefit from this kind of knowledge management, since technology does not create value, except that collected

knowledge in both an internal and external context can be used by relevant people or processes and be distributed broadly.

4. Scenario Agents in Practice

Scenario agent system is employed in an industrial corporation for exploring the developing trends of emerging key technologies and is intended to strengthen the strategic competitiveness of the corporation.

There are two kinds of user interfaces to present the search results. Firstly, scenario agents can conduct multiple web searching and organise the found files according to the time sequence under each search engine. The other kind of user interface is that the found news releases can be stored in the nodes to sort out information according to different search targets (the topics). The second kind of user interface plays a more important role in sorting information. Figure 2 represents the user interface.

As shown in the figure, the bottom of left side is the storyline slot, where contains the folders of several open world scenarios. The left side represent a general framework of a storyline, which has an essential role in scanning, since a major issue in the foresight research is to develop a framework to identify, evaluate and synthesise information, visions, viewpoints, controversies and so forth from different sources. The central part displays the search results from different search engines. The upper section of the central part is a knowledge base and can also be regarded as a "notebook" for the users to manage and accumulate knowledge, and each technology has own storing space.

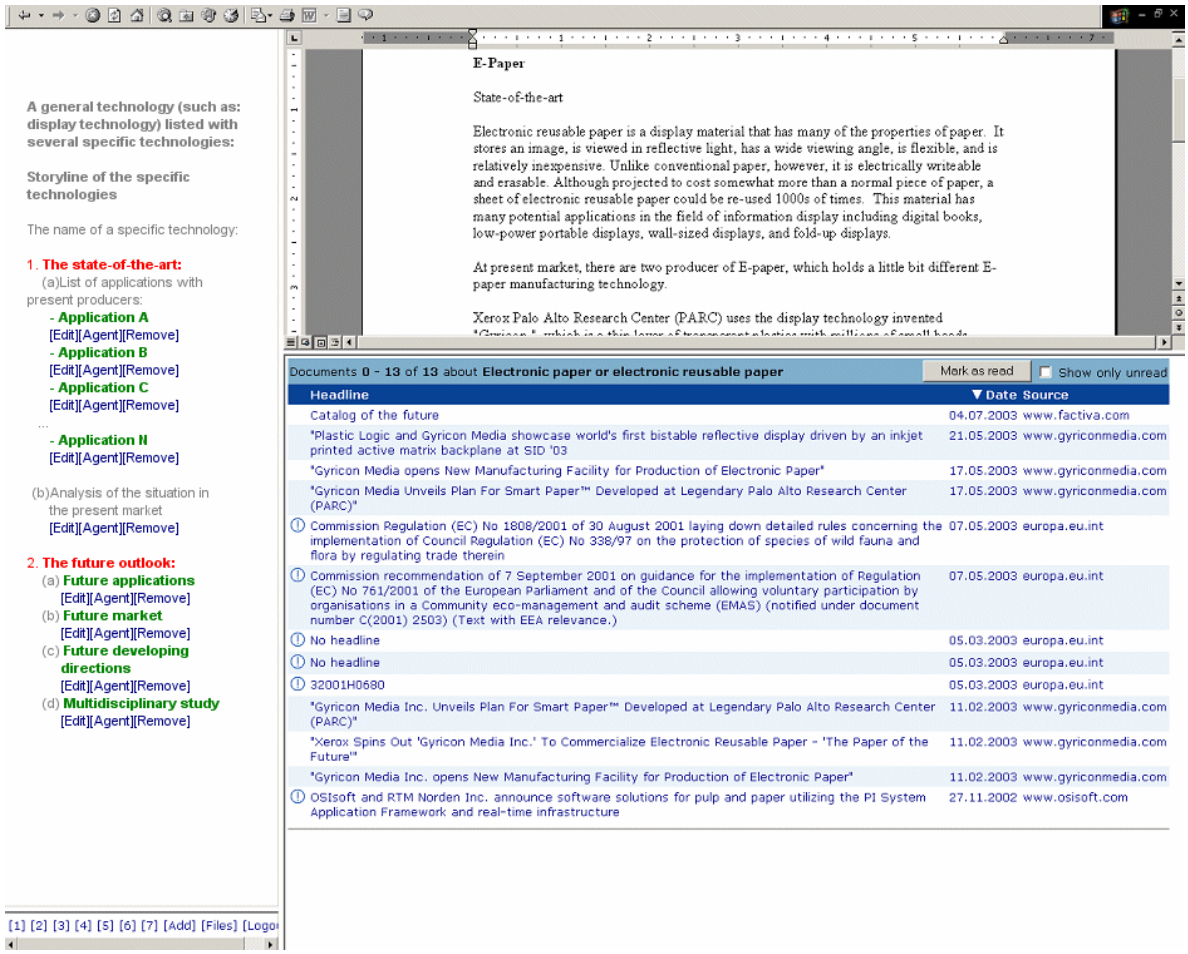

Figure 2. A scenario in the agent system

Users need to assign tasks to the agents in the following four steps. First, users should outline the open world scenarios in the storyline slot at the bottom of left side with general major technological fields, which represent different developing trends that the corporation concerns about.

The second task is to build storyline. The storyline of each technology basically contain (1) the state-of-the-art of the technology (definition and advantage analysis), (2) the present progress of relevant research organisations or corporation with possible spin-offs in the future, (3) the users of technology and areas of applications on the present markets and possibly the outlook for future markets, (4) the future outlook for both technology developing trends with a corresponding time frame and future market situations or barriers and (5) the multidisciplinary study combining the developments of other cross technologies. The storyline in Figure 2 is just an example and is established as a formulated model for agents to extract information. In practice, users need to input search phrases (e.g. the name of the technology or some known applications) of the given technologies by Boolean operators into several agents in the state-of-the-art section, so that the agents can trace the relevant operators from the most pertinent sources (about 20 or so). The search results will depend on the configuration of the search query. From the search results in the central part, users can click on the headlines to read the contents. Those do not have exclamation marks in the front of the headlines means the contents have been read. Through the information, users can find some definitions, theoretical foundations and other operators with different applications either in the current market or in the laboratories. The contents of the storylines could be changed by users repetitively according to the material that the agents find or according to the users' decisions.

The third step is to map basic technology outlook by scanning information to uncover weak signals which reveal societal and scientific developing trends. In this stage, agents are assigned to trace the market information of various applications, which can reveal potential customers, market acceptability and consumption. The system can also support monitoring the vendors or competitors by adding and inserting these companies' websites into the search engine base through another user interface, then the agents can collect the results of domain-specific scanning and periodically search messages or sense "signals" from the external environment. Through that, the agents can trace more precise information such as new outcomes, breakthroughs or investment decisions from that company or in that industrial field.

Finally, users can grasp almost all the relevant results and can periodically review new findings stored in the information base in the system to synthesise, discuss or report to the knowledge base in the upper section of the central part, which maintained by the system administration.

This kind of information processing can be regarded as a cognitive flow, since users can manage the information, edit or remove the storyline or search targets on the left and share the knowledge with the other users in the group. Searching for unknown facts may also prove predictions, to establish new or update the predefined structures and to maintain consistent domain models as well as frames of references.

With the agent system, the scanning activities will be carried out on behalf of the users, whether they are present or absent. The users only need to define the tasks, since the agent

has the responsibility for delegating the search task. Taking advantage of the Web, the users can validate and maintain the knowledge bases at any time. Moreover, the system conveniently recalls information and encourages the sharing and communicating of different views and perspectives between other users within a corporation. All the effects can also enable virtual collaborative work.

The use of software agents can assist and facilitate the processes of updating and learning the knowledge in a timely manner. The benefits of these issues are becoming more significant as the costs and complexity decrease, the rate of change increase and competition and the sources of technology become globalised. The development of agent technologies makes it easier to construct a knowledge base, receive updated information immediately and further to comprehend "raw information" and transform it into "processed information". Therefore, the users, especially the executives, can obtain the external references merging with the corporate internal information to have a broad and comprehensive understanding of the possible environmental trends or the new driving forces in technology sector which would cause changes and opportunities in the next decade in the market.

5. An Evaluation of Technology Foresight Methods

A survey has been conducted to investigate the comments and responses of the users. The survey was held online and the questionnaire was divided into four sections: demographic information, quantitative questions, qualitative questions and other comments. There were ten users of the system within the industrial corporation at the time, and eight people (80%) gave feedback. The respondents' occupational titles mainly include development engineer, director, business intelligence manager and senior manager. The age-range was from 23 to 60.

Table 1 shows the means and standard deviations of the general system evaluation, system searching function, foresight function and further effort of the system. According to the statistics, there were general positive comments and suggestions concerning the system. In general, the majority of the users considered the system necessary and useful, because it definitely helps to reduce the quantity of personal work and increases work efficiency. Based on the analysis of the mean value and standard deviations in the following, it can be seen, at first, the information scanning and search functions were confirmed. Secondly, the foresight function of the system was satisfied in testing the assumptions, structuring personalized information models and accumulating knowledge.

Quantitative Questions	Mean	Standard Deviation
(A) General system evaluation		
1. I find the system useful.	4.375	0.48412
2. I am satisfied with the system's performance.	3.5	0.86603
3. The system is easy to use.	3.375	1.11102
4. The system can be easily customized.	3.25	1.19896
(B) System searching function		
5. The use of the system makes the search for information and data faster and easier.	4.25	0.66144
6. The use of the system makes the scanning process more systematic.	4.625	0.69597
7. The system helps to reduce an overload of information.	4	0.50000
8. The information provided by the system supplements the information from other sources.	3.25	0.96825
9. I can always get access to needed information faster than those who do not have access to the Foresight Support System.	3	0.70711

(C) Foresight function		
10. The system helps to put pieces of information into a general picture and forms the scenarios for future technologies.	3.125	0.92702
11. The system helps to look at the same information from different perspectives.	3	0.70711
12. The use of the system helps me to test assumptions.	3.5	1.00000
13. The use of the system helps me to validate assumptions.	3.25	0.82916
14. The use of the system helps me to clarify ambiguous relationships.	2.75	0.82916
15. The use of the system helps me to better make sense of data.	2.875	1.05327
16. The use of the system helps me to accumulate new knowledge quickly.	3.875	0.59948
17. The use of the system tends to overload my capability to absorb new information.	2.125	0.92702
18. The information quality depends mostly on the system.	2.625	1.11102
19. The information quality depends mostly on my own efforts.	3.5	1.32288
20. The use of the system reduces my role in the analysis of information.	1.625	0.99216
21. The capacity of the information can reduce uncertainty and resolve ambiguity.	3.125	0.92702
22. The system facilitates tracing fast and unpredictable changes.	2.875	1.26861
23. The system facilitates future key technology foresight.	3.5	1.00000
(D) Further effects of the system		
24. The system facilitates corporate decision-making.	3.625	0.69597
25. The system can save the time spent on scanning.	4.5	0.50000
26. The operating cost of the system is low.	3.875	0.59948
27. The system helps to save manpower.	4.25	0.43301
28. The cost / benefits ratio of the system is low.	3.375	0.48412

Scale: 5 = Strongly Agree, 4 = Agree, 3 = Unknown, 2 = Disagree, 1 = Strongly Disagree.

Table 1. The mean and standard deviation of closed-ended questions

Open questions in the survey present positive comments, criticism and also future expectations. Generally, respondents thought the FSS has fast information update, a suitable amount of information and variety of sources, systematic documents searching and good effects on foresight research. There were also many higher requirements of information reliability and sufficiency, summarization and explanation functions and friendlier user interface. This is the firsthand information and opens up many opportunities for further studies. Many future scenarios of intelligent systems have been drawn, which is expected to bring new innovations to our society in the future studies.

6. Summary and Conclusions

In this study, there are mainly three research issues that have been addressed. (1) The importance of technology foresight as support for a technology-based corporation committing to long-term objectives has been discussed. (2) Based on the problem and the requirements in foresight research practice, the scenario agents are implemented to overcome the limitations of the conventional foresight approaches, to trace technology developing trends and to make the foresight study easily, systematically and efficiently. (3) The effect of agent technology in accumulating useful “information resources” for technology management has been examined and evaluated. With the help of agent technology, a corporation could become competitive when facing the highly dynamic information society.

This study combines the theories of agent technology, scenario writing and technology storylines to form scenario agents to support technology foresight research, with the purpose of overcoming the limitations of conventional research methods. The scenario agents

represent a new paradigm, a new interfacing approach, and a new design to the support systems. Such a foresight support approach has more capability in regulating and controlling the work process, shorten the response times and reduce workload for the users, which emphasises flexibility, systematization, efficiency, effort saving and brings competitive benefits to corporations. Moreover, scenario agents cannot be recognized as a value system, except the users work with the agents and define their personalized profiles, provide tasks to the agents from time to time. In addition, the system forms the technology storylines with mental models and cognitive recognition inside the system to promote knowledge learning and sharing through collaborative work.

The technology foresight is a complex process, which includes both systematic information and the thorough understanding by the executives. The agent technology is a means for the management to broaden their visions, views and goals for long-term development and to help the decision-makers to enhance the quality of the decisions.

The results of both the study of research literature and the survey indicate that Foresight Support System is a good option for corporations. It is clear that there is a strong demand for the use of intellectual information management system in corporations. This study serves as a step toward a better functionality of applications and services in the near future.

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