Combining scientometrics with patent-metrics analysis for CTI service in R&D decision-makings: practices of National Science Library of CAS

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Abstract: Scientometirc analysis and text-mining method has been applied into the scientific and technological tendency tracking and relevant scientific performance evaluations for several years in China. Since 2012, NSL-CAS began to provide the CTI (Competitive technical intelligence) services based on the metrics for supporting the R&D decision-making and set the services into the decision processes. Upon the specific customer requirements, NSL is engaged to help the technology-based firms to improve its technological innovation capabilities via CTI like novelty review or checkup for technology development, selection for technological innovation paths, proofing for decision-making technology project, evaluating for technology development of product, competitors monitoring, identification of R&D partnership, and supporting for strategy-making of industrial technology and development. The scientometric methods have established many indicators for the technology analysis, they can be applied in either independent or mixed ways, whereas composite index is also a useful option, which relies on specific requirement of services and needs. For CTI services, we could choose or customize various layer or level indexes schema for different purposes. For the supporting for the industrial technological strategy decision-making and technology innovation path identification (or selection), the scientometirc indicators could play the right roles for R&D trend analysis. Specifically, in meso-technology-analysis, bibliometrics and patent analysis indicators should be mixed in accordance of different subjects or stages of the emerging technology whose characteristics could then be indicated by these mixed indicators, since the scientometric indicators could profile the framework for research subjects and patent analysis could describe the technology development trends. Whereas in a micro-technology-analysis, technology trends analysis is mainly used for the new technological product development for the strategy-making of the technology-based firms, and the bibliometric indicators could be reflexed directions of scientific subjects or the layout of researches. In fact, when a client proposed a CTI need, they would imply to include the meso- and micro-technology-analysis, even the macro-. So when we execute a CTI service for the client, we should run an iteration and loop analysis by the bibliometric and patent analysis, especially the theme tracing or subject analysis by the tech-

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mining and co-wording. For the macro analysis, such as the competitiveness of the institutions or countries and regions, we should pay more attentions for the combination of scientometric and patent indicators and the set-up the schema for CTI services.

Keywords: CTI for industrial technology; iteration analysis; scientometric indicators; patent technology analysis; National Science Library of CAS (NSL-CAS)

1 Introduction

The National Science Library of Chinese Academy of Sciences (NSL-CAS) was established in 1949, and it is the biggest academic library and information institution among China's numerous scientific and technological information institutions. The integration of traditional library functions and information consulting services has become its fundamental strategy of NSL-CAS for a long time. Generally, NSL-CAS mainly provides three types of information consulting services, which include: information and technology intelligence analysis at different levels, such as, technology forecasting, technology evaluations, policy-making supports for the S&T administration, and traditional library services for the end-users (for the researchers and scientists). Even then in 1978, the NSL-CAS has established a new Information Analysis Department for handling the increasing intelligence service needs, its main task is to serve the needs of R&D management, supporting the service need of relevant policy-making, and explore the intelligence service model for needs that be drawn from the scientific disciplines.

Since 1985, NSL-CAS is constantly and actively working on scientific and technological information and intelligence analysis, which closely followed the needs of S&T management, decision-making, technology commercialization, in-house R&D of firms, and R&D research projects, etc. In 2001, NSL-CAS experienced a significant transformation in which it began to exploit the ICT and digital content technology to meet the universal needs to scientific research literatures. However, the change was not only just limited in upgrading the traditional services with new technology. NSL-CAS began to turn main tasks on the services of trend analysis of scientific fields, technology development and the services of competitive technical intelligence for industrial sectors. In those services, NSL-CAS has applied the scientometric indicators and text-mining techniques into the technological trend analysis, and provide the professional analytic reports of scientific fields and R&D trends supervised by scientists in those scientific fields and technology specialists intensively.

So far, NSL-CAS's scientific and technological trends analysis and dynamic monitoring services have focused on the 13 key scientific fields, and could provide the situation analysis and monitoring of scientific fields, monitoring and profiling of technology, planning and strategy of science and technology, and industrial technology development etc. And its customers now expand to policy-makers, R&D

institutions, R&D firms, and technological innovation teams. Totally, the services and products of NSL-CAS are primarily technology dynamic monitoring reports, technology (or technical area) subject analysis and scanning, analysis reports for technology development trend, and strategy and planning consulting report, etc.

In recent decade years, NSL-CAS has introduced the concept of CTI into its services and have meshed up the logistics, analysis method and data in the technology, market, and business intelligence, aiming to provide the improved services to strategical decision-making related to S&T, R&D management, technology commercialization, technology transfer and competitive technical intelligence for enterprises. In short, NSL-CAS is trying to change its self-identity, and intent to realize the stragetic transformation, from a traditional library which primarily plays a role as an information or literature provider, to be an information hub, whose job is more about providing knowledge, rather than just raw information.

Methodologically, NSL-CAS has been exploring to apply the scientometric indicators into the decision-making support and scientific subject monitoring. What's more, it also combines different methods like bibliometrics, patents-metrics, text-mining, and experts review together, for improving the quality of its competitive technical intelligence services. So, the purpose of this article is to explain how those methods be applied into the CTI service in NSL-CAS.

2 Practices of CTI in NSL-CAS

In practices, NSL-CAS has primarily three types of CTI services for the clients ---- novelty review for the development of a specific technology or scientific subject, CTI for the development of particular technology theme, and that for an industry. They respectively face the needs of three different types, which are micro level, meso level, and macro level. We will introduce them with three specific examples for the three types of services.

Example 1: Novelty checkup service for Development of a Specific Technology Topics[2]. For a specific technology topics, as we thought, which belongs to micro level services, our CTI services are provided mainly in form of novelty search and review report for the technology research and development. There are two kinds of novelty review services in NSL-CAS, one is for evaluating the novelty and necessity of a R&D project proposal before it is formally started and funded, we could call it proposal's checkup service, and another one aims to assess a finished project's performance and achievements, we could call it as the novelty checkup service for project acceptance. As its term and name indicates, the novelty review serves the purpose of scientific project evaluation predominantly through the indi-

[2] Source: NSL-CAS novelty review report of project for funding, The Application of Hydrodynamic Cavitation Technique in the Wastewater Processing, 2014

cators of novelty, and is primarily for researchers of universities, research institutes, and firms. The first kind of novelty service for the project proposals is essential to the projects management, because it related the funding allocations. But proposal's novelty checkup services are not prevalence in the past twenty years, because that the huge scientific budget of government be poured into the S&T projects and the efficiency be neglected, and the S&T management departments have paid more attention to project acceptance and checkup. In the past two decades, NSL-CAS kept improving its work and has obtained the ability to complete about 300 novelty review reports per year, most of them are the novelty checkup for project acceptance. In this paper, we would focus on the novelty checkup service for the project proposals.

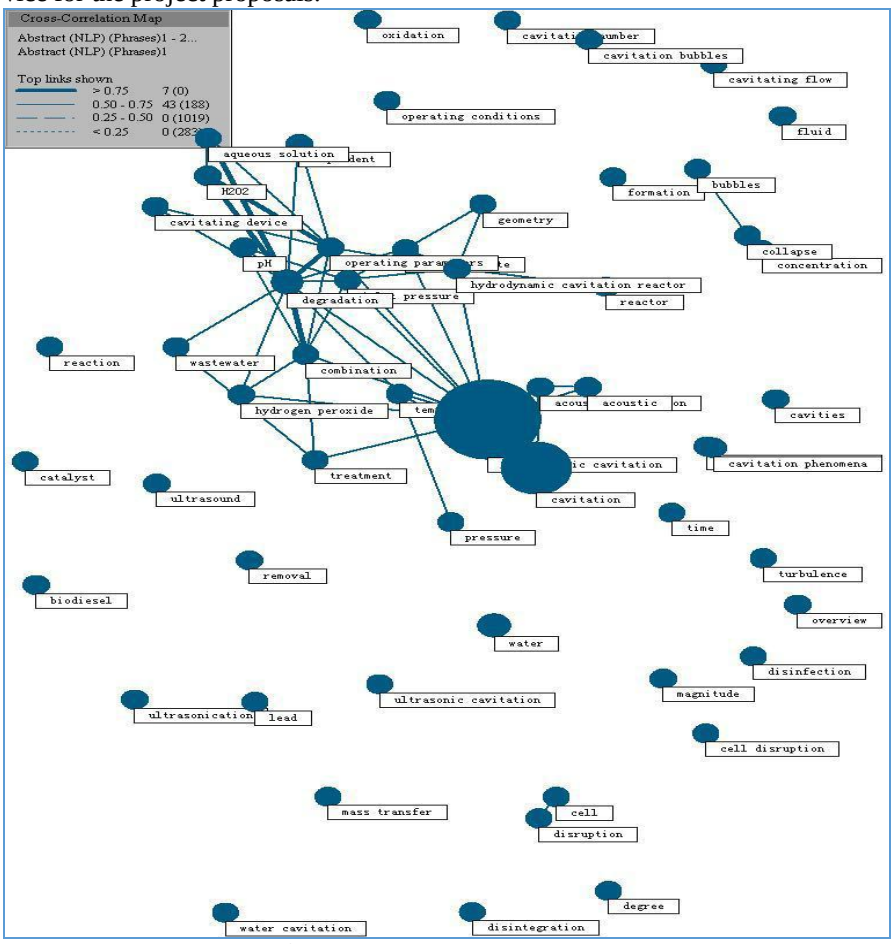

Figure1: Relationship of Research Subjects in Hydrodynamic Cavitation Technology

For instance, the A company plans to develop the hydrodynamic cavitation technology for the wastewater processing, which is for environment protection purpose. The company entrusted NSL-CAS to provide the novelty checkup service

for the proposal. NSL-CAS would then create a novelty review report for the technology project proposal with the bibliometrics and patent data from WOS database or others, and it will serve as a reference material with the project proposal for funding and technology development strategies. In the report, we found that the research points and topics of hydraulic cavitation technology's application in sewage treatment mainly concentrate on the hydraulic cavitation mechanism, processing methods and devices, and the key factors of cavitation property by the technology topics mapping and profiling. What's more, hydrodynamic cavitation technology can also be applied into biological cell broken, sterilization, and biodiesel preparation.

We achieve these findings primarily by means of keywords clustering of articles and patent themes mapping. The first step is to search relevant scientific papers and form a research article dataset[3]. With the help of TDA, we picked up some key words from those research articles about hydrodynamic cavitation technology, and then cluster them and obtained a result as the Figure 1 shows, the domains networks.

The second step is to create a patent applications or document dataset, which we get by means of searching patent data of hydrodynamic cavitation innovation and applications. We identify more than 290 active patent assignees in this area, and individual amount 129, account 44.48% in all applicants. Also, we find that in the top 8 assignees, 4 of them are American ones. And the countries who ranked as top 5 of the largest patent applicants are Russia, US, China, Canada, and Japan. In accordance of the titles and key words of these patents, with the help of TDA again, we achieved a patent theme map as Figure 2. It is apparent to see that the majority of patents' themes concentrated on the field of hydrodynamic cavitation reactor.

[3] Search formula = ("water cavitation*" or "hydrodynamic cavitation*") in WOK database.

Figure2: Patent Technology Subjects Layout [4]

By the scientometric methods, in figure1, we could count up the frequencies of keywords in the research papers and cluster the research subjects and then draw out the keyword-relations visually. Other than usage of the scientometric indicators to analyze the development of hydrodynamic cavitation technology, we also use the PCT of patent to pattern the technology fields and important points, and draw the payout of patents, in the figure 2, shown that the hot field or subject of

[4] Source: NSL-CAS project novelty review report, The Application of Hydrodynamic Cavitation Technique in the Wastewater Processing, 2014. In the figure, the yellow points represent the Russian patents' subject distribution, which concentrate on reactors; the green points reflect the American ones, no apparent concentration; while the red points are Chinese ones, mainly focus on applying the hydrodynamic cavitation techniques in wastewater processing.

patent applying is the hydrodynamic cavitation reactor. By checking the map of patent subjects layout, we found the major patents of hydraulic cavitation devices be designed with more porous plate and venturi tube, and hydraulic cavitation should be coupled with oxidation reagents to strengthen the quantity of free-radicals via which the effectiveness of removing organic pollutants could be improved. In the conclusion, as an emerging technology, the hydrodynamic cavitation, with its relevant technology, has been applied in organic wastewater treatment. It is a valuable technology and actually worthy further development.

Example 2: Competitive technical intelligence (CTI) for the technology subjects or fields[5]. When facing a broader technology area rather than a relatively narrow "technology topics", which is at meso level that we define, we also would execute the competitive intelligence service for the clients, particularly for the industrial clients. Contrasted to the novelty checkup service for the specific technology, CTI reports should comprise the full range analysis of the related technology topics, in which the reports should integrate the scientometric index, patent technology analysis and professional reviews of technological development. All these reports are organized in a systematic way.

B Company is a medical technology company whose main products are the vaccines for pig. In 2014, upon the company's request, we took the task to analyze the development of swine vaccine technologies, including pig pseudorabies vaccine, swine fever virus vaccine, swine Japanese encephalitis vaccine, and pig transmissible gastroenteritis vaccine. What need to note is, this subject's range is broader than the example A, which is a relatively narrow and about only one specific technology (hydrodynamic cavitation technology). In contrast, this one is about an area that composed by several sub-techniques, so the outputs of our work will be a series of reports rather than merely one.

In the example of B company, one sub-report of the serial analysis report is about researches and technology development of the swine fever virus vaccine, we analyze the R&D advancement in this subfield with the help of bibliometric indicators like article publications and citation data. We describe (past) evolutions, current situations and predict the (future) tendency of the swine fever virus vaccine technology's development, perform a cluster analysis to identify the key techniques and their distribution, and indicate the main competitions and R&D cooperation in this area. After the analysis based on academic articles, we begin to operate the patent analysis, which includes the patent application and development tendency, the patent distribution among different countries (regions), patentee and technology subject distribution analysis, competition and cooperation between patent assignees.

[5] Source: NSL-CAS project novelty review report, Serial Reports of Swine Vaccine Technology Analysis, 2014.

Specifically, to produce the analysis of pig pseudorabies vaccine, which is one sub-report of the series, we firstly collect relevant research papers. By searching the databases of ISI Web of Science and ISI Medline[6], we form our dataset. Then we identify the topics of these papers roughly and index the subject words, which now mainly rely on reading artificially. Through a simple statistics, we find the most popular research subjects about the pig pseudorabies vaccines are: the effectiveness of vaccine, the preparation of vaccine, the effects of maternal antibodies, vaccine immunity pathway, vaccine immunogen, vaccine immunity adjuvant, passive immunity, immune modulator, security of the vaccine, vaccine carrier, nasal cavity immunity, and so on. And further, based on those subject words analysis, most researches currently concentrate on immune effectiveness, the preparation of the vaccine, and maternal antibodies.

Then, we use the database of ISI Derwent Innovations Index to create a patent dataset, and obtain approximate 164 results relevant to our subject of pig pseudorabies vaccine. China and the US are two predominant patent applying countries. After scanning and selecting these data artificially, we get a dataset with 89 patents that closely associated with the technology of pig pseudorabies vaccine. These data indicates that the primary patent topics also include: the preparation of vaccine, vaccine's immune effectiveness, vaccine carrier, vaccine immunity adjuvant, testing methods for the vaccine's immune response effectiveness, vaccine immunogen, and passive immunity. Similar with what has shown in the article dataset, the most frequently appeared study themes are vaccine preparation, immune effectiveness, and vaccine carriers as well.

Example3: CTI for the industry sector's strategy decision research[7]: Apart from CTI services at micro (a particular technology topics) and meso (a technology subject) levels, NSL-CAS also could do analysis service for the entire industry, which we call it as the macro level service. In these years, we keep providing the consulting services to local government agencies and support their decision-making process for which we produce several consulting reports like *Strategic Intelligence of Ionic Rare Earth Industry, Technical Intelligence Analysis of Effective Development and Utilization of Tungsten Resources Industry, Industry Technology and Economic Analysis of Coal Glycol* etc. In these works, we combine different analysis methods and tools, such as the literature review (tertiary information or document), scientometric indicators, patent analysis, and text-mining, together to make our report as comprehensive and referable as possible. To finish such works, we organize an operation team, construct the key intelligence topics (KIT) according to our discussions with the researchers, and perform the bibliometric analysis and patent technology theme (or core-tech) analysis.

Here we cite the report of Ionic Rare Earth Industry as an instance. We first identi-

[6] Search formula=(porcine or pig or swine) and ((pseudorabies or aujeszky disease) near vaccine*)
[7] Source: NSL-CAS Industry Analysis Report, 2014.

fy and review the key technology fields or topics of ionic rare earth industry, and find it mainly associates with extractions and separations, Nd-Fe-B magnetic material, white LED rare earth phosphor powder, rare earth hydrogen storage materials, rare earth ceramics etc. And we can do analysis for each of these fields. For example, in rare earth extraction and separation, based on the academic article and patent publication data from WOS, via scientometric indicators which have been mentioned above, we can identify the most important countries and top 5 organizations that perform well in relevant research and development. And we can also figure out the hot topics and find core-tech patentees. More specific analysis are following:

(1) Research organization analysis: for those organizations that involve in the researches of rare earth extraction and separation techniques, we do a statistical analysis about the top 5's publications. The results show that they are most interested in following topics: solvent extraction, liquid-liquid extraction, synergistic extraction, ion exchange, Cyanex 272 and 923, crown ethers, fractionated extraction, rare earth element extraction (cerium, scandium, yttrium, ytterbium, lanthanum, samarium, erbium, phosphate). When focusing on four organizations, Chinese Academy of Sciences, Russian Academy of Sciences, India's Bhanha Atomic Research Center, and Japan Atomic Energy Research Institute, the key words frequency statistics tell us their research emphases respectively. Chinese Academy of Sciences focus on trace analysis, europium, neodymium, lanthanum, film, carboxylic acid, nitric acid, and nitric acid; differently, Russian Academy of Sciences mainly pays more attention to nitrate, yttrium, europium, cerium, lanthanum, nitrate molten salt, Cyanex272, and crown ethers; while Bhanha Atomic Research Center prefers to do more researches over liquid-liquid extraction, selective extraction, thenoyl trifluoroacetone (TTA), TODGA, Cyanex923, nitrate, yttrium, terbium, ytterbium, solvent extraction, luminescence, and circulation; and Japan Atomic Energy Research Institute emphasizes researching circulation and rare earth elements like europium, neodymium, yttrium, lanthanum, erbium, and dysprosium.

(2) Cluster analysis of subfields of the current research areas: Based on the ontology and knowledge of the rare earth science, the rare earth extraction and separation technique is primarily consists following subfields: ore decomposition (with different acids, like nitric acid, hydrochloric acid, and sulfuric acid), extraction of rare earth oxides and elements(extraction from the liquid or roasting, applying various reagent, P204 and TBP), extraction and solvent filter devices (including reaction devices, extraction equipment, and ion exchange devices). In the analysis process, we perform a natural language processing (NPL) for keywords of the rare earth extraction and filter technology, and cleaning and merging the thesauruses and classifications, then take the relevance analysis Ucinet software package. Finally, we could have a keywords clustering figure as below (Figure 3).

In accordance of the result of the clustering analysis, currently, the research topics

over the rare earth's extraction and separation primarily concentrate on the extraction process and methods, aids and solvent used, the extraction and separation of different elements, relevant equipment and devices, sources of rare earth elements, and wastewater treatment in the processing. As the following, the hottest topics are described.

(a) Technology of rare earth extraction and separation: The major methods: ① hydrometallurgy, including ion exchange method, solvent extraction method, and precipitation method; ②pyrometallurgy, purifying the calcined rare earth's oxides or alloys. The major process: leaching, ion exchange or precipitation separation, calcining and purifying, wastewater treatment. Sometimes heating or cooling will also be needed.

(b) Acid and solvent used in the extraction and separation: The clustering analysis indicates that the extraction and separation now mainly rely on hydrometallurgy, in which the most frequently used acid solvent are: hydrochloric acid, sulfuric acid, nitric acid, oxalic acid, and phosphoric acid. The common used extracting agents are amines compound.

(c) Rare earth elements' separation: The most important part of the extraction and separation techniques is to separate cerium, yttrium, and scandium out of the rare earth oxides or ores and purifying them.

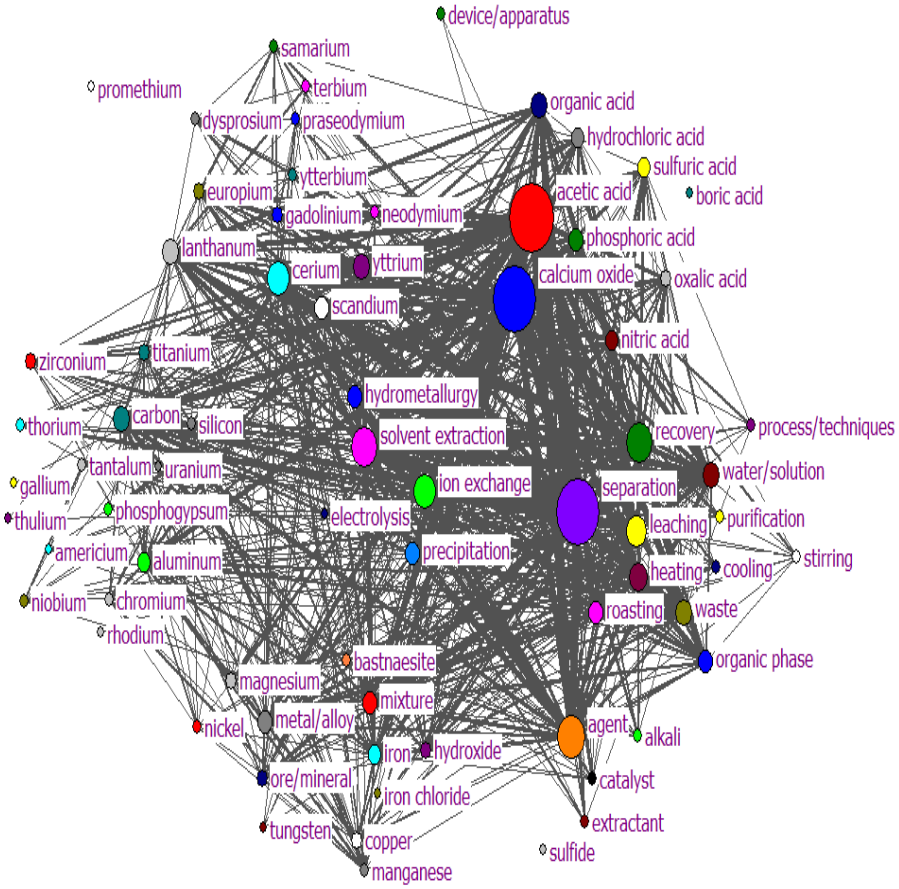

Figure 3: Patent of Technology Theme Clusters of Rare Earth Extraction and Separation

(d) Devices for extraction and separation: The primary devices and equipment include those for reacting, precipitating and washing, filtration, extracting, ion exchanging, evaporating and crystallizing, drying, and so on.
(e) Rare earth ore and sources: Specific extraction and separation processes are always up to the sources of rare earth. From those technique themes, it is apparent to see that the most frequently appeared ores are Kaolin, monazite, and Baiyuneboite mine. Other rare earth sources include wastes of phosphor powder and magnetic materials and alloys. We find most of those patents about rare earth circulation belong to Japanese organizations.
(f) Wastewater treatment in the processes of separations: Researches in this area mainly regard to the acidic, alkaline, and radiological wastewater processing. And

this also include the treatment of exhaust gas, to purify the sulfuric acid mist, chlorine gas, and hydrogen chloride gas.

3 Experiences and Discussions

In accordance of its CTI service goals and client's need, NSL-CAS defines its service objectives and clients as R&D management, research teams, research projects, technological innovation of firms, and industrial technology development (focus on firm technology innovations). In this frameworks, NSL-CAS has developed the three levels (kinds) CTI services, like R&D novelty review (checkup) for technology developing, technological innovation pathway selection, product technological advancement assessment, technology competitor monitoring, collaborator identification, and S&T strategy decision-making, and so on. To provide the best information consulting and supporting for the decision-making, we should guarantee the quality and liabilities of the intelligence analysis reports. In the following section of the article, we would discuss the experiences of NSL-CAS to have the intelligence analysis more reliable and accurate, even valuable. We try to conclude and set up some principles that could be applied to develop the high quality technology intelligence reports.

3.1 To classify the CTI services into three levels, and to create the quite different tactics for the application of scientometric indicators accordingly

Competitive technical intelligence is undertaken to monitor and interpret key events that would impact the technology strategy of the institutions and to provide a continuous awareness of science and technology trends[8]. The key events might include the scientific breakthroughs, R&D layouts, strategic initiative, advancement of key technology commercialization, etc. Thus, CTI is widely used for monitoring and interpreting scientific and technological key developments or breakthrough, and it is a useful method to track the development tendency of science and technology. Before W. Bradford Ashton first introduced competitive intelligence into the laboratories, research institutes, and government agencies, the CTI only as the part of competitive intelligence was merely for business technology strategy and firms' R&D management. So far, with helps of bibliometric or scientometric tools, a comprehensive mechanism has been developed for applying the CTI to serve different customers in order to maintain their competitive advantages[9].

[8] Jeffery Murphy (2001). Using competitive technical intelligence techniques to complement research-and-development processes. In: Managing frontiers in competitive intelligence, by Craig S. Fleisher and David L. Blenkhorn, pp136-148. ISBN: 1-56720-384-1, 2001.

[9] W. Bradford Ashton, Bonnie Hohhof (ed.), Competitive technical intelligence[C], Competitive

As being presented above in the article, upon the customer needs, NSL-CAS classifies the services as three levels:
The first one is service for the micro level. The services regards primarily a particular research or technology topic (for example, the hydrodynamic cavitation technique mentioned above). The CTI service at this level mainly serve the purposes of assessing advancement and feasibility of the technology, and identifying the key competitors, and so forth. We usually do this through novelty review for R&D project proposal and evaluation of advancement of product technology.

The second one is at the meso level. The services focus more on a technology subject or field, which might consists many different subfields or topics (for example, the swine vaccine technology mentioned above, composed by many different kind of vaccines but all for pig), rather than just a narrow "technique point". CTI services at this level are mainly for R&D management, such as the management for the R&D projects, R&D teams, and for the firm's new product development etc. Specifically, NSL-CAS would provide the service for the trends analysis of scientific research field, analysis for the core technology, trends analysis for product technology, and submit the reports individually for the clients.

The last one is at the macro level. The services mainly be related to the business intelligence and strategic intelligence, at which we aim to analyze the technology development of a particular industry (this covers an entire industry, is the most broad topic, like the rare earth instance shown above). This kind of CTI services mainly are strategic planning of research institutes and firms, technological tendency of emerging industries, science and technology dynamics or trends (of different countries and regions), and so on. The service subjects or contents include the discipline strategy and layout in the research institute, technology trends analysis of the particular industry, even the competitiveness comparison of the science and technology in the regional or countries.

For above different levels of CTI services, we employ different analysis methods of articles and patent applications.

At micro level, the CTI of the particular technology topics, we rely on precise retrieval technique to collect the information and form a database, in which the standard datasets of academic articles and patents are organized respectively. Then we would read the research paper and patent applications one by one, and classify them. With the help of clustering analysis, we can figure out the important research themes, direction, research communities (teams and individuals), collaboration, and competitive relationship or situations and so on. In those intelligence mining process, we usually employ general scientometric indicators and statistic indicators of technology related to patent to explore the state of technology devel-

opment, such as the publication, authorship, classification and category, patentee, citation. We use those indicators to reveal the layout of technology comprehensively. Then we could summarize and induce from the comprehensive review of scientific advancements (triple information) written by the specialists or scientists in related professional organizations.

At the meso level of CTI services, we seek to establish a framework for technology topic analysis firstly by discussing with the customers. We execute the retrieval actions for collecting the scientific research and patent applications information by repeatedly iteration and then form a database. According to the analysis framework, we choose the indicators of bibliometrics or scientometrics and patentmetrics to analyze the stages of technology development, to find the important research institutions (important research teams and researchers), to highlight the hottest technology subjects or topics, and to reveal the relationship of keywords. And by means of topic and key words clustering (including keywords in the title and abstracts), IPC, patent technology function analysis, and co-word analysis, we can finally identify the development stages, key and important specialists, core technology, and relationships between research themes in a given technology subjects.

Finally, for the macro level of CTI service, different indicators and methods of scientometrics and text-analysis and text-mining based on the big data should be used comprehensively. In the analysis process, we need to pay more attention on the features of the technology evolution, that of hot technology topics, relevance of technology topics, the relationship of technology with industries and technology competitive landscape. In short, according to the customers' specific requirements and service needs, we figure out different relationships via analyzing the metadata of academic articles, patents and mining the information and words relationship from the full text.

3.2 Analyzing the technology trends of an industry via the combination of bibliometric and patent-metric indicators

The achievements of scientific researches usually present as the form of academic articles and patents. The bibliometrics or scientometrics, which are based on academic articles, mainly rely on metadata of the articles to reflect the scientific research activities in outline. The amount of publications could reflex the vitalities of the research field, the amount of citations could refract the importance of the article, and more the publications or patents could show the research abilities of the countries, regions, and organizations that produce them. Whereas metadata analysis based on patents could imply the relationship between scientific researches and industry. It also shows the technology innovation capability of firms (research institutes, countries, and regions), partnership and competition between them, and the evolution or inheritance relationship of technology. Moreover, by using patent

citation, we can identify the core technology in an industry, form the patent pool, and develop the cooperation in R&D.

In CTI practice of NSL-CAS, considering the different features of scientometrics (bibliometrics) and patent-metrics, the CTI services need to construct an integrated and complex analysis framework, regarding both academic articles and patents to show the R&D situation of an entire industry. How do we could operate the service processes? Firstly, we could employ bibliometric methods to describe the research topic distribution of the scientific field, and use the citation between the articles to profile the evolution paths of research topic, and use the publication and subject layout to show the layout of research power and competitiveness of R&D institutions.

Secondly, we conduct a patent analysis in which the focus is to reveal those most significant technological topics, their current situations and layout, research capabilities of those key R&D organizations, then find the technology directions. Thirdly, we choose the technology subject which is closely related to the patent technology applying from the subject map which be graphed with the bibliometric analysis of research papers, and then we could make the patent technology analysis for the technology subject and reveal the key direction of the industrial technology. Alternately, we can also choose a reversed way by doing further bibliometric analysis with patent technology topic. We choose the technology subject from the patent technology topic map, then to make the bibliometric analysis of the research paper around the patent topic. From those analysis, we could find the hot research subject and subject layout, and more show the research power distribution and competitiveness. No matter which way we take, the main purpose of this analysis is to find the hot research topics, their distribution, and research organizations' layout and competitiveness.

Similarly, when facing the CTI service for the industrial sector's demands over technology and innovation path selection, scientometric indicators are very effective tools to display the technology development directions from a macro perspective. With the assistance of patent-metric analysis, we can find the most important technology point and industrial technology layout. For the technology analysis at micro level, integrating the bibliometric and patent-metric indicators allows us to establish different analysis frameworks over business R&D orientations for different issues in different technology development stages (which will be discussed in the next point). Such a composite index would be able to describe the basic features of the technology's development. For the meso level analysis, patent technology tendency analysis in which scientometric indicators are used for technology monitoring can be widely applied in new products' technology development.

3.3 Establishing the "iteration" CTI analysis mode for science and technology monitoring

Based on technology S-curve, M.S. Brenner (1996) employed patent applying as boundary point that contact the research and technology development and explained the relationship between technology intelligence and competitive intelligence, and he illustrated how CTI services work in products' life cycle and CTI service lines in the technology life-cycle. Jeffery Murphy (2001) classified a product's life cycle as conceptualization of new product, maturation of new techniques, commercialization of the technology, and that of the product. Accordingly, he identified the information flow of the entire process, which includes gray literatures, research articles, patent applications, the development of technical processes in enperprise, the release of new products, and their sale. The industrial technology and basic researches are naturally associated, and the patent literatures play a role of bridge between them. Thus, the CTI services are mainly consisted by two parts, the monitoring of research subject and that of technology development.

In its CTI service practices, for supporting its scientific subject analysis and technological topic analysis, NSL-CAS established an iteration mode----"bibliometric analysis + patent technology analysis". Specifically, scientific subject (domain or subject or topics) framework will be constructed by bibliometric analysis at first; and then the key industrial technology will be chosen as topics from the biliometric subject framework for following patent technology analysis. And then, core patent technology will be picked out afterward, and again the bibliometric analysis will be used again to analyze the core technology of patent. What is more, content analysis and mining will also be introduced in this process.

In many cases, consulting agencies (such as the NSL-CAS) suffer problem of lacking specific professional who have the detailed scientific and technological knowledge or subject background, which makes their CTI services not sufficiently professionalized. However, the science and technology advance so rapidly that it is very hard for intelligence analyst to found professional member for every specific subject. But the layout of research subject by scientometric method is very useful to the trends analysis of the related technology based on the patent-metrics for the R&D managers.

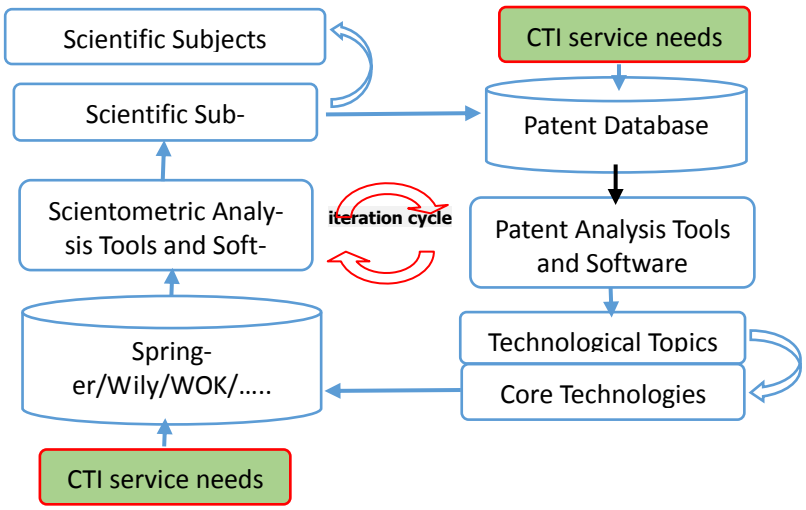

Figure 4: The iteration cycle of scientometrics and patent-metrics in the CTI service of NSL-CAS

To overcome above limitations, at the beginning of our CTI analysis work, other than merely using the bibliometric methods, we also discuss with our customers (researchers) to create a framework of retrieval word or keywords framework for technology topics, which contains the most important research themes in the research subject area. Then we choose those technology topics from the well-defined frameworks that have been developed enough to conduct patent-metric analysis, which helps to figure out the core technology in this subject. Ultimately, we could conduct the research article-based bibliometric analysis for the core technology and to find the key scientific and technological points of core technology, and have the current R&D situation in the technology subject revealed. The entire process mentioned above is an iteration cycle with both bibliometric and patent-metric methods and indicators involved (as the figure 4 shows).

3.4 Creating the CTI service procedures, ensuring the involvement of the professionals and their consulting

The core point and importance of CTI service is the high-quality reports of technology trends analysis and novelty checkup. To guarantee the reliability of our analysis reports, NSL-CAS has quality control measures and principles in the analysis processes. In the novelty checkup service, there are some principles that must be obeyed by the staffs. First, training programs for novelty review are always organized for the attenders. Such training's emphasis lies on improving the skills to use science and engineering databases, even the fact database, and staffs are required to be familiar with major databases of different subjects and obtain precise searching and retrieval ability. Second, standards for writing novelty review report are established. NSL-CAS has formulated clear rules over the novelty checking report's form, writing style, content, and way of expression, and all staffs are required to obey them strictly. Third, to maintain the independence of novelty review service, working procedures, especially about how to communicate with the clients, are also created to guarantee our work results free from customers' intervention. Fourth, to make sure the report's conclusion precise sufficiently, we also have regular communication mechanism, which allows our workers to contact with the technicians and professionals. And there are also regulations to handle the

situation whenever differences between us and customers over the report conclusions rise. Our workers must follow the regulations to reply and improve the work to ensure the checkup results as scientific and independent.

In the process of CTI services for the technology subjects, we also try to make our works enough scientific and guarantee the efficiency from four aspects. First, we set up the procedure for the requirements, which asks staffs to keep communicating with researchers and developers in the requirements collecting phase. Upon the customer needs, with the involvement of our staffs, researchers will give some key words or subject words for searching for the articles or patents. After obtaining the preliminary results, we would exchange ideas with researchers and clients, improve and optimize the preliminary searching results, and form the database of the full text article and abstracts or patent application. Then, we would do the scientific keywords-based clustering analysis, which helps us to construct a research subject or technology topic framework. We will need to constantly contact with outer researchers and professionals until we get a satisfactory enough result of information searching. Second, when we taking service for the important technology subjects, we would organize consulting meeting to form the analysis framework and if necessary, invite outer experts of the area to give suggestions and to assist us to create the technology topic framework(see figure 5, the subject frame for technology analysis), conduct clustering analysis, and even revise our final report. Third, we have setup the new kind service model, operating the CTI based on the key intelligence topics (KIT), and let the KIT be the core of technology subject analysis. We divide the client's requirements into several groups based on the technology areas of industries, such as the medicine and health sectors, agriculture and food sectors, IT and equipment manufacturing sectors, new material and energy industry, to organize specialized technology intelligence teams in form of community of practice (COP). The members of each team will learn knowledge of technology areas of which their team is in charges. These teams would also study hot technology topics, major industry technology subjects, and core technology and products of their industry. All these help our staffs to accumulate information and professional knowledge for future use. Fourth, we establish stable collaboration with some experts of many technology and industry areas to help us in CTI services constantly.

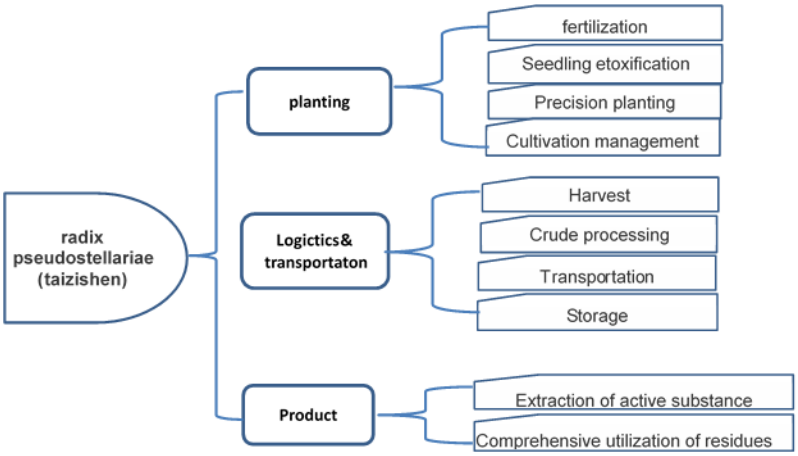

Figure 5: Subject or domain framework for technology analysis (eg. Taizishen industry Chains)

3.5 To integrate sources of business information and technology intelligence, and to provide the customized services according to the needs

NSL-CAS usually faces diversified needs, which would include from either S&T decision-makers or firms, and could serve for R&D management, specific research projects, or business R&D. With the reform of China R&D system in these years, China's research institutes increasingly be involved into the development of industrial sector and business R&D, while the firms also be engaged in the R&D activities and aim to establish the firm links between their products, marketing activities and academic researches. All these new changes and developments bring more diversified demands for technology intelligence services. Thus, it is necessary today for us to associate the trends of technology development, competitiveness of technology intelligence, industrial technology development, and business intelligence together, and to provide differentiated CTI services to meet different decision-making needs.

When we operate the technology analysis for the enterprise R&D, we should pay more attentions on the CTI deeply, such as the marketing intelligence, to collect and analyze the market capacities, productions scales, productive potentials, product upgrading. When supporting decision-making at meso or macro levels, such as the supporting to the important S&T project of government, there would have the explicit need to analyze the R&D activities and layout of the key R&D institutes, and should contain the information of project funding for the intelligence analysis, and both domestic and international R&D achievements and strategies need to be

consider. What is more, the information of potential partners and rivals remains of importance.

For a long period of time, NSL-CAS kept serving the needs of technology innovations by providing services such as the novelty review for technology development, technology innovation path selection, support for business R&D projects, product technique assessment, competitor monitoring, potential partner identification, and R&D strategy suggestions. For CTI services, we could choose or construct (customize) different indicators schema for different analysis purposes. For the industrial technological strategy support and technology innovation path identification (or selection), the scientometirc indicators could play the right roles of technology development as soon as possible. Specifically, in the meso-technology-analysis, bibliometrics and patent analysis indicators should be mixed in accordance of different subjects or stages of the emerging technology whose characteristics could then be indicated by these mixed indicators. Whereas in a micro-technology-analysis, as patent technology analysis and core technology are mainly for the new product development, thus some bibliometric indicators that indicate the technology tendency should also be added.

4 Conclusions

In the experiences of NSL-CAS CTI services that support R&D decision-making of the enterprises or scientific institutions, we should form a complex scientometric indicators schema to profile the technology topics and then select the commercial technology by patent-metrics from the topics, or set up the technology mapping which be based on the patent-metrics to analyze the core technology and trace the technology advancement by scientometrics. In the practices, a fine CTI report should include the technology topics, selection of technology innovation pathway, future technology directions, market and business intelligence, competitors' intelligence and production intelligence. In the CTI reports, the bibliometric indicators, patent metrics indicators (including the text-mining for themes or subjects), even the local investigations of competitors, should be included.

Despite we cannot 100% fulfill the needs of Chinese firms and R&D administrators so far, our exploration in CTI service still achieved many valuable experience and lessons. In the process of learning the customers' needs, we find they have very strong preference to quantitative analysis of technology trends. Yet, different customers also have their own preference. The decision-makers of R&D projects are more likely to take visualization and explicit analysis (with charts and graphs), while firms tend to associate the information of technology tendency with their products and market closely, and are more interested in potential competitors and the future development orientation of technologies. Moreover, with the Chinese economic reform and the structural adjust keep-going, more and more research and technology transformation organizations will explicitly demand CTI services

for the technology maturity, feasibility of commercialization and industrialization, and rival monitoring and so on. To meet these growing demands, with the help of bibliometric and patent-metric methods, we will keep exploring to improve our CTI services.

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