

Understanding Patent Portfolio and Development Strategy of 3D Printing Technology

Yen-Tzu Chu, Hsin-Ning Su

Graduate Institute of Technology Management, National Chung Hsing University, Taichung, Taiwan

Abstract--This study aims to analyze patent portfolio of three-dimensional printing industry, future trends, as well as to explore how patent strategy could be developed. A total of 1089 patents that belong to 3D printing technologies are retrieved from the United State Patent and Trademark Office (USPTO) patent database for analysis. There are two objects in this research: first, from the patent perspective to distinguish how emerging three-dimensional printing is. The other object is using knowledge flow tool to demonstrate how diversified the 3D printing industry can be. Moreover, by analyzing the 1089 of 3D printing patents, some important implication, i.e. technology life cycle, patent citations, patented characteristics information and knowledge flow, can be uncovered to understand the overall 3D printing technology trends, in terms of (1) Country (2) Industry (3) Organization levels.

I. INTRODUCTION

In 2000s, the explosion of interest in three-dimensional printing can be observed. As President Obama very famously declared State of the Union address in 2013, “3D printing technology has the potential to revolutionize the way we make almost everything. It's going to save America!” [1]. From the speech it could figure out how three-dimensional printing technology is going to change dramatically the way human being live and the product human being use. Three-dimensional printing is a manufacturing process that builds layers of printed material to create a three-dimensional solid object from a digital model. A three-dimensional printer is a type of material design printer that designs and builds three-dimensional prototypes as models by using computer-aided design program or software. As three-dimensional printing technique was developed, the way of manufacturing products has been influenced. Table 1 shows the brief history of three-dimensional printing from 1986 to 2012.

Table 1 demonstrates the continuously advanced three-dimensional printing technique. In this knowledge-based society, it has been a critical issue to understand technological trends not only to avoid

unnecessary investment but also to gain the seeds for technological development. Many methods have been proposed to understand technological development, and one of them is through analysis of patent information. Patents are useful for competitive and technological trend analysis [2][3]. Patent analysis is also a valuable approach that uses patent data to understand the developed technology in industry in order to foresee future scenario. In the early stage of a technological development, the number of issued patents is very limited. Empirical observation shows that patent number growth usually follows a S-shaped curve. The observed fast-growing period, which is due to the increasing issued patents, is followed by a plateau on the top of the S-curve [2]. Patent analysis has been shown to be valuable in planning technology development for analyzing national level strategy [3] as well as for modeling the development emerging technologies[2][4][5]. Understanding the technological growth by the use of patent data can be an insightful for evaluating technology development trend. Three-dimensional printing is a technique, which can be used in variety industries. In past literatures, researchers emphasis on the method of making three-dimensional printing and the materials could be used in three-dimensional printing. There are researches focusing on finding a new method or materials for three-dimensional printing. A research integrated our indirect 3DP technique with imaging technologies and successfully created custom scaffolds mimicking human mandibular condyle using polycaprolactone and chitosan for potential osteochondral tissue engineering[6]. However, there is no study focus on through analyzing three-dimensional printing patents to discuss and find the information of three-dimensional printing technology. The purpose of this research is through analyzing and collecting patents data find critical information of three-dimensional printing field. Also, from all the patent data analysis not only demonstrated past but also forecast the future trend. Moreover, by forecasting this field, this study suggests some strategies for country, industry and organization.

TABLE 1: THE HISTORY OF THREE-DIMENSIONAL PRINTING

Year	Events
1986	Charles Hull developed the first three-dimensional printer for commercial used.
1993	Massachusetts Institute of Technology (MIT) applied three-dimensional printing technique patent successfully.
1955	Z Corporation got the only one authority from MIT to develop three-dimensional printing.
2005	The first high-resolution of colorful three-dimensional printer “Spectrum Z510” which is produced by Z corporation.
2010, Nov.	The first three-dimensional printing automobile “Urbee” was developed.
2011, Jun.	The first three-dimensional printing bikini came out in the world.
2011, July	England scholar researches and develops the first three-dimensional chocolate printing machine in the world.
2011, Aug.	The engineers of Southampton University develop the first three-dimensional printing airplane.
2012, Nov.	Scottish scientists using human cells for the first time with a 3D printer to print out artificial liver tissue.

II. METHODOLOGY

This study first downloads all USPTO utility patents issued from 1976 to 2012 (4,389,348 utility patents in total), then from these download data mining patents related to three-dimensional printing. From the figure 1 below, it is the way of this research to extract keywords from patent documents.

Figure 1 shows that the process of finding the keywords related to three-dimensional printing. The first step of this study is using the key words "three dimensional printing" or "three dimensional printer" or "3D printer" or "3D printing" or "3 D printing" or "3 D printer" or "3 dimensional printing" or "3 dimensional printer" or "three D printer" or "three D printing" or "three dimension printer" or "three dimension printing" or "3 dimension printing" or "3 dimensional printer" to use advanced patent search method to collect patents issued from 1976 to 2012 (4,389,348 utility patents in total) in USPTO. In the past study, forecasting trend or planning patent portfolio by patent analysis is common using International Patent Classification (IPC) or United States Patent Classification (UPC). However, three-dimensional printing is a technique, which is used in variety industry. Thus, if using IPC or UPC to find patents and analysis, it must neglect part of patents, which are also related three-dimensional printing technology. After mining the data, there are 1089 patents, which are not only related three-dimensional printing but also compatible with this research.

In the course of reviewing the literature [7][8][9][10][11], consulting with experts in this field, 14 important characteristics of patents are retrieved from every patent document and defined as variables of patents: 1) Patent Number, 2) Application Year, 3) Issue Year, 4) No. of Assignee, 5) No. of Assignee Country, 6) No. of Inventor, 7) No. of Inventor Country, 8) No. of Patent Reference, 9) No. of Patent Citation Received, 10) No. of IPC, 11) No. of UPC, 12) No. of Claim, 13) No. of Non-Patent Reference, 14) No. of Foreign Reference. Some variables that have nothing to do with forecasting the trend of three-dimensional printing, i.e. 1) Patent Number, 2) Application Year, 3) Issue Year 4) No. of Inventor Country, 5) No. of IPC, 6) No. of UPC, 7) No. of Non-Patent Reference, 8) No. of Foreign Reference, are not considered in the characterization work conducted in this

study, and therefore the following 6 variables remained and subsequently used in this study.

1. No. of Assignee
2. No. of Assignee Country
3. No. of Inventor
4. No. of Patent Reference
5. No. of Patent Citation Received
6. No. of Claim

By analyzing and collecting three-dimensional printing patent data this research finds out the characteristic of patents. The methodology is separate into two parts shows in the Figure 2. First part, basic patent analysis includes technology life cycle, top 10 first assignee countries, top 15 industries, first assignee type, and top 10 first assignees. Also, by finding the litigation of patents and the most cited counts patents to get key patents of three-dimensional printing. All of these data analysis is by using SQL tool.

Technology life cycle: first, find out the patent amounts of each year and the inventors amounts of each year, then the position of the inventors' amounts on the X-axis, the patent amount on Y-axis. The figure can illustrate the patent amounts each year, which can understand the patent technique life cycle. Investments in a technology have to consider its current life cycle stage[12]. This method helps organizations do the decision whether keep input the asset to invest the technique or not. From the assignee country analysis, this study choose top 10 to disclose that which country has the largest volumes of three-dimensional printing patents and also figure out how intensive or diffusion this technology is between countries. Top 15 counts patents in industries: a patent could be used in diverse industry. From arranging patents in different industries could figure out how this technique develops in each industry. First assignee type: classifying all patents into different assignee types to see which kind of type is the most active way to apply patent in three-dimensional printing industry. Top 10 patent counts of first assignee: from this analysis, it could show that which organization or individual own the most patents in the industry. Time-cited counts and patent litigation of three-dimensional printing: this research using ordering patent time cited from the highest to lowest to present which patent is the key patent in this technology field. In the

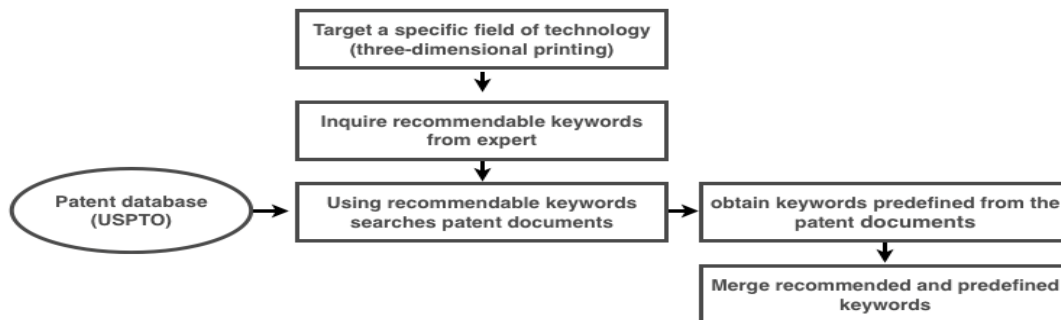


Figure 1 The process of finding the keywords related to three-dimensional printing patents

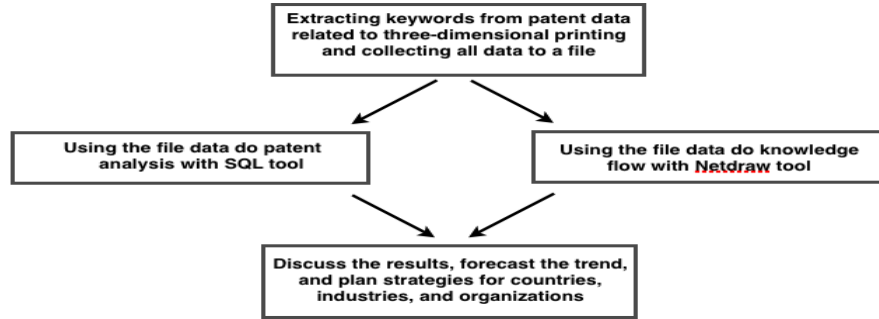


Figure 2 The framework of this research

literature review showed that highly cited patents are of greater technical importance than less frequently cited patents[13].

Second part is knowledge flow, which is finding the information analysis between citing patents (forward citation) and cited patents (backward citation). This research uses a visual method for patent analysis to let the network more clearly. In this research, using knowledge flow demonstrates the interaction between countries, industries, and companies of three-dimensional printing technique. There are three centralities can be seen as three indicators for three research evolution mechanisms: (a) degree centrality—indicator of research diffusivity, (b) betweenness centrality—indicator of research intermediacy, and (c) closeness centrality—indicator of research influence. This study associates with social network analysis and patent citation analysis for three-dimensional printing to build social network. Through the patents and its citation to understand technique developed track, and also analysis the potential path for technique development[14]. This research uses the information of patent to draw countries', industries', and organizations' social network. From the knowledge diffusion perspective, through patent citation analyzing the technique capability of countries and organizations to find the improved track of technique knowledge[15]. As times by, the degree of technique diffusion will change significantly. This study uses Netdraw as a tool to draw patent citation network. In social network theory, it uses degree centrality to measure the impact level of actor. From organizational behavior

perspective, it demonstrates that the centrality of social network is one of important factors of influence. When an actor has a high degree in centrality, it also means the one who has higher power in organization.[16] The centrality degree can show the nod with others relative degree in network; at the same time, it can also understand whether the nod is a vitally important factor or not. There are three types for the measurement of nod core degree or called the indicator of centrality degree, including degree centrality, closeness centrality, betweenness centrality[17]. This study adopts social network theory, through degree centrality to understand the country, industry, and organization interaction between each of them. The higher centrality node is, the more influence the nod is. US patents are used in this study to forecast three-dimensional printing industries because of two reasons: First, the largest and most competitive market around the world is USA. Thus, it is important for companies to get US patent protection for all their key inventions. Second, the USPTO has the largest collection of patents in the world, with extensive coverage of most technologies. As such, US patent data is one of the best available patent data to forecast three-dimensional printing industry.

III. RESULTS AND DISCUSSION

Following are descriptive analysis of three-dimensional printing patents. Figure 1 shows the technology life cycle of three-dimensional printing from 1977 to 2012.

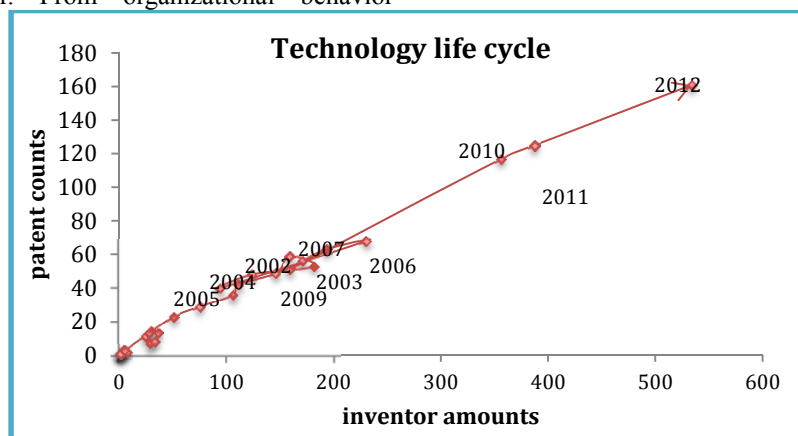


Figure 3 The technology life cycle of three-dimensional printing

Figure 3 shows the technology life cycle of three-dimensional printing. Technology life cycle illustrates the patent amounts of each year and the inventor amounts of each year, then the position of the inventor amounts on the X-axis, the patent amount on Y-axis. Technology life cycle is a concept to measure technological changes [18]. The figure can show the patent amounts each year, which can understand the patent technique life cycle. This method helps organizations do the decision whether keep input the asset to invest the technique or not. There are four stages in technology life cycle. Stage 1 is the beginning of a technique. In this stage, there are few firms want to enter into this field; also, patents counts both application and inventors are few in this stage. Most patents belong to co-owners. Second stage is that technique is growing up. In this stage, the technique has advanced and broke through the limit. In the market perspective, as technique in this stage, it also implies that this technique regard as an investable and a valuable technology industry. Moreover, a significant phenomenon in growing stage is that application amounts and inventors of patents are rising in dramatically speed. Third stage is the mature of technique. In mature stage, as the technique has been exist in

market for a long time, a few firms will maintain applying huge volume patents and build patent portfolio to prevent other potential firms to entry into this industry. Also, at this time, the patent application counts are going to have a huge increasing because of time-delay by applying patents. However, the inventor counts of patents become a stable growing in a low rate. Forth stage is technique-facing bottleneck to breakthrough. In this stage, there is no more investment to research and develop this technique; also, the resource of patents will not expand. From this table, three-dimensional printing technique is in the second stage, growing stage. As mention before, in this stage, the technique has advanced and broke through the previous limit. In the market perspective, as technique in this stage, it also implies that this technique regard as an investable and a valuable technology industry. Moreover, a significant phenomenon in growing stage is that application amounts and inventors of patents are rising in dramatically speed. Through the patent amount of each year, it can also tell the trend of three-dimensional printing is keep rising from 1977 to 2012 except 2005 and 2009. From 2010 to 2012, there is a dramatically growing both inventors and patent counts.

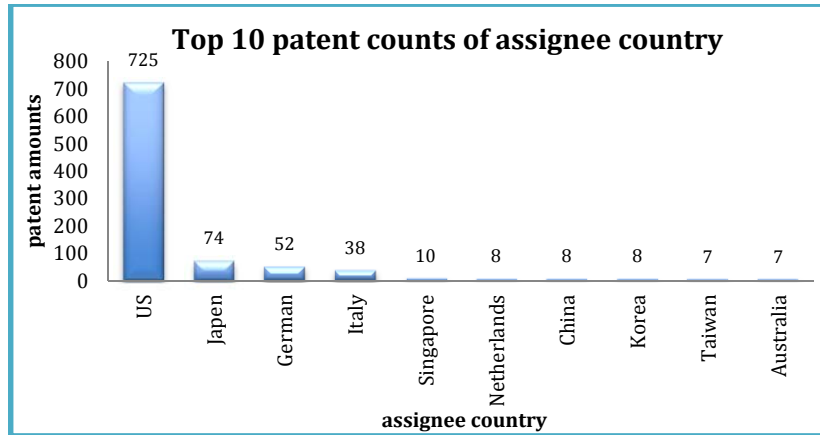


Figure 4 Top 10 patent counts of assignee country

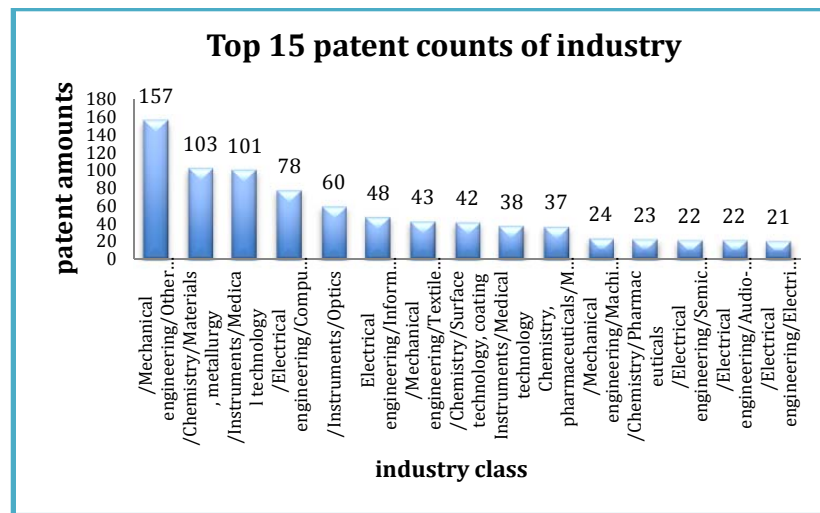


Figure 5 Top 15 patent counts of industry

Figure 4 shows that top 10 patent counts of assignee country. Assignee country, in other words, is a patent belongs to which country. Figure shows the top 10 countries with the largest volumes of patents. The position of the countries on the X-axis follows the number of three-dimensional printing patents owned by each country, where the US is positioned on the left end and ranked as No. 1 and Australia is on the right end and ranked as No. 10 in terms of number of patents. There is a big gap between No.1 (US) and No.2 (AU). It implies that most three-dimensional printing patents are in the United States. From this figure, it could also illustrate that the developing of three-dimensional printing industry is intensive for specific country, not a worldwide common industry. Thus, United States is the largest amounts of three-dimensional printing patents and also it focuses on this technique industry and is willing to develop this industry.

Figure 5 shows the top 15 industries with most volume patents of three-dimensional printing technique. The position of the countries on the X-axis follows the number of three-dimensional printing patents owned by each country. This figure demonstrated that the Mechanical engineering/other special has the most volume patents industry. In Mechanical engineering/other special industry class, it occupies 14.28% of total three-dimensional printing

patents. In other words, it shows that Mechanical engineering/other special industry is the main three-dimensional printing techniques developed. From the other perspective to see this figure, electrical engineering occupies the highest percentage is top 15 patent counts of industry.

Figure 6 shows that top 10 patents counts of organizations. The position of the countries on the X-axis follows the number of three-dimensional printing patents owned by each country. There are 4,389,348 utility patents in total issued by USPTO from 1976 to 2012 and 1,099 patents relative to three-dimensional printing field. Calculating all top 10 patents, there are 287 patents. After calculating, all top 10 organizations patent counts have about 26% of total three-dimensional printing patents. 3D System, Inc. has most patent counts in the three-dimensional printing field. It has about 25% in total top 10 organizations patent counts. The top 1 (3D Systems, Inc.) and top 2 (Massachusetts Institute of Technology) have similar patent counts; however, from top 2 (Massachusetts Institute of Technology) to top 3 (Object Geometries), there is a big gap in patent counts. It could tell that in early of 2010s, the main organizations of three-dimensional printing patents are 3D Systems, Inc. and Massachusetts Institute of Technology.

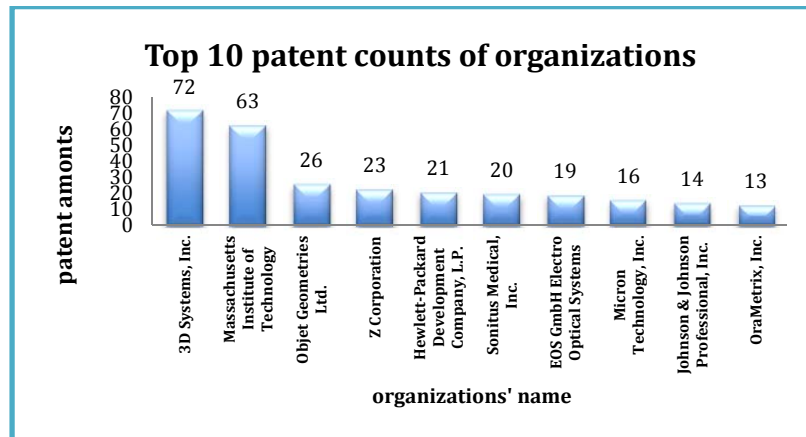


Figure 6 Top 10 patent counts of organizations

TABLE 2 TOP 15 FORWARD CITATION COUNTS IN THREE-DIMENSIONAL PRINTING

PN	Forward citation	Reference	Claim	Assignee	Country	Type
5204055	317	11	42	MIT	US	4 University
5797898	267	23	29	MIT	US	4 University
6503831	185	22	23	Patterning Technologies Limited	GB	2 Company
5387380	180	7	58	MIT		1 Individual
5490962	179	10	19	MIT	US	4 University
6259962	162	11	8	Objet Geometries Ltd.	IL	2 Company
5518680	147	8	18	MIT	US	4 University
5278442	143	12	6			1 Individual
5340656	143	12	21	MIT	US	4 University
6123861	142	42	13	MIT	US	4 University
6520996	142	133	28	DePuy AcroMed, Incorporated	US	2 Company
5943235	125	29	36	3D Systems, Inc.	US	2 Company
6696073	125	22	23	Osteotech, Inc.	US	2 Company
5594652	110	2	5	Texas Instruments Incorporated	US	2 Company
5902537	108	70	82	3D Systems, Inc.	US	2 Company

The main purpose of table 2 is through ordering forward citation to find the key patent in three-dimensional printing industry. In the table, there are 15 patents and all of them are ordered by the forward citation counts from the top 1 to top 15. Through arranging top 15 patent cited numbers, it can tell that which patent is vitally important to three-dimensional printing industry. By doing so, the research finds that the patent number 5204055 whose title is “Three-dimensional printing techniques” has the most time cited. There are 317 patents citing patent number 5204055. Thus, from this table results, patent 5204055 is one of the key patents in this industry. However, the assignee type of Patent Number 5204055 is university not company that is the most volume patent counts for assignee type. In other words, the most cited counts patents is belonging to MIT University. There is no company has the right of this patent. There are seven patents, which first assignee is Massachusetts Institute of Technology, and two patents from 3D system, Inc. Massachusetts Institute of Technology is a university from US. It can tell that the university focus on three-dimensional printing and has a good quality patents. There are eleven patents are assigned from United States. From the assignee type, table 1, there are 6 patents assignee in university, 2 patents assignee in individuals, and 7 patents assignee in company.

Litigated patents

There are only 7 patents, patent number are 5370692, 5345391, 5184307, 5137662, 5059359, 6942830, and 7735542 in three-dimensional printing field have been litigated till 2012. 3D Systems, Inc. owns four litigated patents. Moreover, Envisiontec GmbH, GeoDigm Corporation, Guild Associates, Inc. each of company own one litigated patent. Although the litigated patents are few in 2010s, as the trend of three-dimensional printing is coming, there will be more and more patents which are going to be litigated. Thus, for these litigated patents, it must be more valuable in the future. The most amount patent litigation is 3D system, Inc. even though there are only 4 patents. The total three-dimensional patents amounts belong to 3D System, Inc. are 72 patents. Thus, after calculating the proportion, there is only 5.556% of patents in 3D System, Inc.

Knowledge flow

As three-dimensional printing technique starts to develop in a fast speed way, this research would like to use knowledge flow to figure out the network between countries, industries and organizations.

Figure 7 shows knowledge flow between countries. The bigger the circle size is, the more influence of countries is in three-dimensional printing industry. The thicker the line is, the more interaction and connection is. From this figure, United States is the most influence country in three-dimensional printing industry. In the figure, most countries have the interaction with United States. Moreover, United States has a good technique diffusion and knowledge flow with Italy and German. Thus, through the diffusion and

knowledge flow, it implies that United States stands on the top of three-dimensional printing industry.

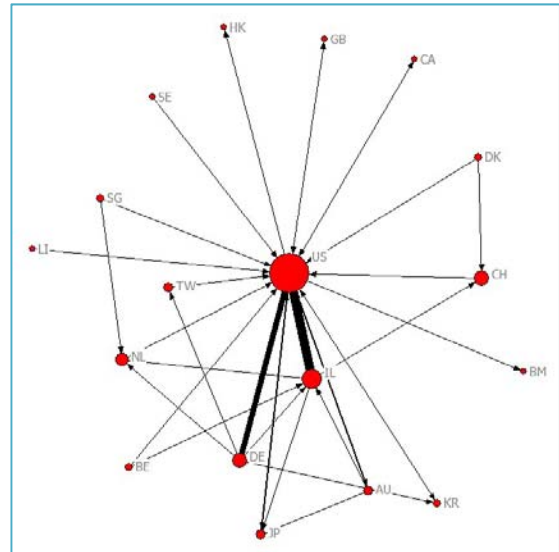


Figure 7 Knowledge flow between countries

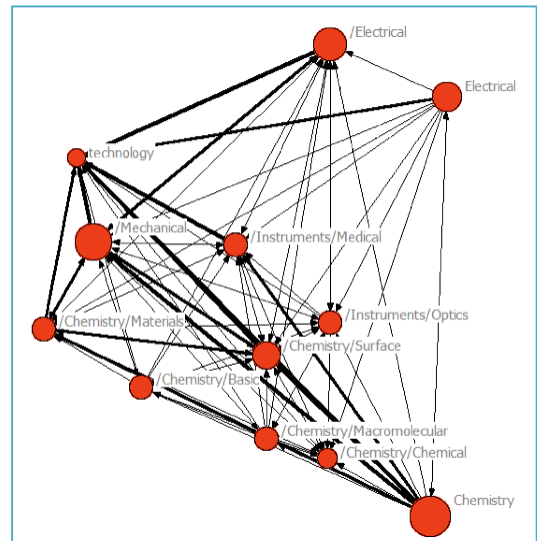


Figure 8 Knowledge flow between industries

Figure 8 shows that knowledge flow between industries. The bigger the circle size is, the more influence of industry classes in three-dimensional printing industry. The thicker the line is, the more interaction and connection is. The more degrees between industries imply the more connection between each other. In this figure, it only shows that the degree more than 20 between each other. From figure 6, it illustrates that chemistry, mechanical and electrical engineering are main industries for three-dimensional printing technique. Also, by this figure, it can tell that three-dimensional printing technique has a wide knowledge flow between industries. In other words, it is a technique which can be used in variety industries.

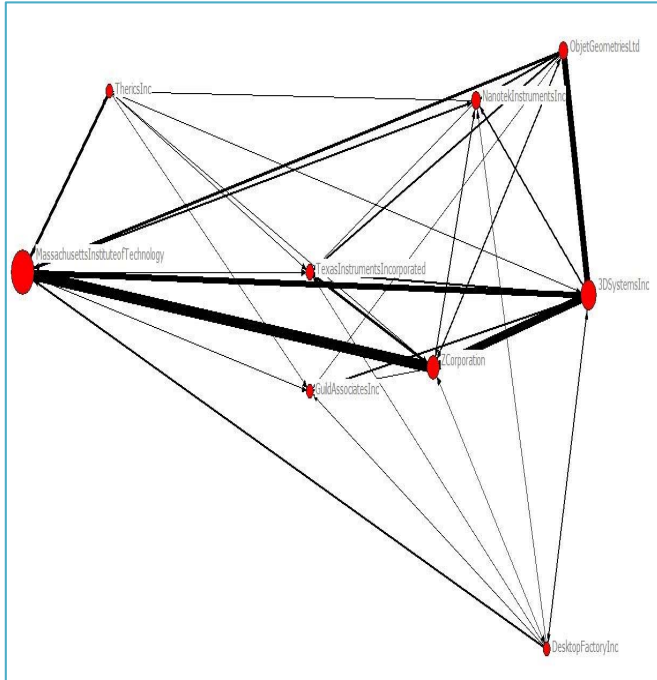


Figure 9 Knowledge flow between organizations

Figure 9 shows knowledge flow between organizations. In this figure, it only shows the interaction degree more than 20 between patent owners. The bigger the circle size is, the more influence of organization is in three-dimensional printing industry. The thicker the line is, the more interaction and connection is. Thus, MIT is the most influence organization in this industry; also it has a good relationship between 3D system Inc. and Z Corporation. The second one of influence degree is 3D systems Inc. which is the top 1 patent counts of first assignee. This figure could tell that which organization is one of the main dominates in three-dimensional industry. Moreover, it could also illustrate the interaction and connection between organizations. The most interacted between organizations are MIT, 3D systems Inc., and Z Corporation. It may imply three of them have a nice knowledge flow between each other.

IV. CONCLUSION

The new technologies have led to the creation of new business models and the emergence of new industries. The purpose of this research is that through analyzing three-dimensional printing patents to understand the trend of three-dimensional printing industry. From above patent statistic results, here is going to conclude those results to several sentences. First, from figure 4 Top 10 patent counts of assignee country, figure 7 Knowledge flow between countries, and table 2 Top 15 forward citation counts in three-dimensional printing, all of these results tell that U.S is the leader of three-dimensional printing industry in 2010s. Second, through Figure 5 Top 15 patent counts of industry, Figure 8 Knowledge flow between industries, and table 2 Top

15 forward citation counts in three-dimensional printing, combine these results, it shows that there is a strong connection between mechanism and chemistry industry. Also both industries are the top two industries in three-dimensional printing industry. From Figure 9 Knowledge flow between organizations, Figure 6 Top 10 patent counts of organizations, and table 2 Top 15 forward citation counts in three-dimensional printing, all these results tell that in three-dimensional printing industry, MIT, 3D Systems, and Z corporation has a strong connection and lead this industry. Moreover, this research is expected to help the industry forecast quality patents in the future and do patent portfolio early. Patent is one of the measure tools to evaluate the capability of innovative.

Strategies for country, industry, and company

As the technology life cycle illustrates that three-dimensional printing technique is in a growing stage, this research provide some suggestions and strategies in different perspectives. In the dynamic environment and unstable competitive market, companies should consider about how to control and manage core competencies, key patent with their own resource. When is the timing to enter into the industry? Where or which country is the main market of new product or technique? Organization requires long-term view to forecast market and how to create its own competitive advantage, how to build differential innovation compared to competitors. Moreover, it's vitally important to understand what do exist and potential customers need and transfer companies' weakness to be opportunities. Company should consider all the factors. Of course, firms have to plan their own direction first then to know where it should be achieve and implement patent strategy. A technology comes out; normally it could not only impact particular companies, industries but also countries and global interaction. Thus, the following suggestions are separate into three parts, namely strategies for country, for industry, and for organization.

Strategies for country

This research uses USPTO to collect and analysis three-dimensional printing patents data on which is this research emphasis. In this growing stage, what countries should concern about is whether this technique is valuable for country to keep investing or not and is there any potential economic effect stimulate country have a better life by this new technique. Here is going to use United States as a country example. There are two reasons as follow. First, from the USPTO data, the most volume patent counts country is certainly United State. Second, United State is also the first mover in three-dimensional printing markets. For United States in early of 2010s, it has already stood in a high level in three-dimensional printing industry, because of the first-mover and strong resources provide by United States. Thus, the disputes for United States are how to maintain this top one position and what should From results of the top 10 patent counts of assignee country analysis, it can tell that the

three-dimensional printing patent counts rank of Taiwan is No.9. There is no any litigated patent belong to Taiwan. It can imply that the innovative capability and developing and researching of Taiwan have a huge room to improve in three-dimensional industry. Although it is hard for Taiwan to compare with United States directly, it could find the Asia benchmarks which are Japan and Korea to learn their strategies. From results of the top 10 patent counts of assignee country analysis, Japan is on the rank of No.2 and Korea is on the rank of No.7, thus it could figure out that both countries take attention in the three-dimensional printing industry and are willing to have good positions in this industry.

Strategies for industry

From the technology life cycle figure, it shows that three-dimensional printing is in the growing stage. The technique of three-dimensional printing is still advancing and become more and more mature and professional. In the growing stage, there will be many potential competitors want to entry into this industry. It is a good situation for industry to have more organization competing. It can stimulate each firms spend time on researching and developing this technology. Through the positive competition this technique industry is going to be much stronger. Moreover, in the growing stage, new technique industry would have more opportunity to combine with other industry technique to create more innovative products.

Strategies for organization

In the growing stage, it is vitally important for company to increase their own core competence and competitive advantage by applying patent and doing patent portfolio. All in all, as technology keep advancing, the growth rate of three-dimensional printing keeps rising. In the competitive market, the sustainable development is a vitally important issue in an organization. Patent is becoming one of the critical things for all of countries, industries, and organizations. Moreover, this situation will keep it and become more and more obviously in the future. Here is going to use 3D systems, Inc. as an example to demonstrate company because it is one of the main three-dimensional printing companies. Also, it is a leading provider of 3D printing centric design-to-manufacturing solutions including 3D printers, print materials and cloud sourced on-demand custom parts for professionals and consumers alike in materials including plastics, metals, ceramics and edibles. Its products and services replace and complement traditional methods and reduce the time and cost of designing new products by printing real parts directly from digital input. These solutions are used to rapidly design, create, communicate, prototype or produce real parts, empowering customers to manufacture the future. In the growing stage, organizations would like to expand the market share and try to raise revenue and profits. Thus, it has to make a decision to plan a strategy or define target market.

V. FUTURE WORKS

There are several limitations in this research. In this research, the main methodology is using patent analysis to try to forecast three-dimensional printing technology future trend. By using patent analysis, research could get a lot of results of a specific industry. Moreover, patent analysis is collecting all patent information and try to put the information in a systematically way to help reader easy to understand. The common way is using by patent statistically. However, it is hard for users to make all the results narrow down from convergence to divergence. Griliches provided a theory of the main advantages and disadvantages of using patent statistics[19]. When forecasting the technology, it is common to use the degree of innovation to discuss the new tech trend. However, patent statistics are an output indicator of innovation rather than an input indicator (such as R&D expenditures). The main advantage is that patent statistics circumvent the issue of R&D productivity ('the number of innovations per unit of R&D'). The main disadvantages is that simple patent counts do not take into account differences in the quality of innovations, that many patents do not lead to innovations, and that the propensities to patent an innovation may differ between sectors[20]. Thus, it cannot just use one methodology, patent analysis to directly forecast a new technology. In the future work, it can try to find another method to let the forecast more accuracy. Another limit of this research is that using keywords to find out all the patents related to three-dimensional printing from USPTO may not be completed. Also, there is no adequate patent amount in three-dimensional printing field, and it would cause the data analysis be uncertainty and not reliability enough. The suggestions are that in the future work it could find a better systematic method to collecting all patents related to three-dimensional printing instead of using keywords, and as times by there is going to be huge amounts of three-dimensional printing patents. At that time, do the research again is more reliability with adequate patents. Moreover, it could study broader impact of three-dimensional industry instead of just analyzing patent information.

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