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Patent Portfolio Strength Analysis of LiDAR by Patent Map and Linear Regression

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Abstract— A study of patent portfolio strength analysis of competitors by patent maps and linear regression are presented in this paper. A worldwide popular and hot technology, LiDAR system, was selected to demonstrate the analysis. Patent portfolios of top sixteen competitors are collected first, then calculate the total patent strength summed by the eight traditional indicators.

Analysis results show on patent indicator 2D diagrams, linear regressions on the positions of assignees to explore the relationship of two indicators. For patent portfolios of competitors, an assignee has average claims less than 20 has low number of citations, low number of classifications, and low international applications. The patent maps recommended in this study is very suitable for industry use to quickly understand the patent quality of competitors.

Keywords— patent strength; patent portfolio; patent indicators; patent map; LiDAR.

I. INTRODUCTION

According to statistics from the World Intellectual Property Organization (WIPO), the total number of patent applications worldwide in 2020 reached 3.276 million [1]. Large-scale enterprises have a huge number of applications and hold thousands of patents at every turn. There are 23 applicants file over 1,000 PCT (Patent Cooperation Treaty) applications in 2021[2]. The value of a single patent varies greatly, the value of patent portfolios held by companies also varies widely.

Patent strength, patent value, patent quality, patent scope, and patent novelty, are all terms often used to assess the importance, impact, value, or significance of a patent. Any quantitative indicator is to extract the data on patent bulletin, no anyone indicator can fully express the value of a patent, to add up multiple indicators from different aspects to total strength is normal in industrial evaluation. So many indicators can be roughly divided into two categories. One is the value related to patent applications, which based on the cost of the applicant's patent application, or the quality of the patented document itself, mainly including number of claims, scope of claim, and size of patent family. Another is the value of invented technology, which is the quality of patented technology itself, mainly including patent forward and backward citation, and broadness of patent classification. The former related to the subjective investment in patent fees of the applicant, and the latter is an objective technical value. This article will explore the relationship of subjective value and objective value by linear regression and 2D map.

Many studies use patent indicator as coordinate axis, by displaying patent portfolios held by companies or research institutes on a two dimensional map, to learn the outline of their portfolios from the locations on the map, and further forecasting future trend from the strength or weakness of competitors in various aspects. This study will use 2D maps to display patent portfolios of competitors, and the objective is to find the most suitable graph for industrial use from the relationship between various indicators.

A hot technical topic, light detection and ranging, or LiDAR, is the subject of this study. In response to the rapid technological evolution and the expected rapid growth of the market, 3D laser scanning technology has been a hot research topic in recent years.

II. LITERATURE REVIEW

The number of patent citations is most often used to evaluate the strength or quality of a patent from a technical point of view. Important inventions are usually developed on more prior technical documents and are also cited by more patent applications. Any invention is based on prior arts, and patent citations in the patent gazette show high relevance prior patents or technical papers of the issued patents. The use of citation documents to evaluate patent strength has been around since the 1990s, long literature will not be discussed here. Tseng (2011) [3] has divided the patent indicators developed by previous scholars in 13 papers into different types according to attribution and purpose, and classified these indicators into three stages according to purpose, including motives, technological strategy, and value-produced. It has been validated by empirical study that more frequently cited patents have higher technological and economic impacts (Fisher, 2014) [4]. Patent strength analysis can be applied to the strength of patent cases, and the strength of patent portfolios held by competing companies and Institutes. Alvarez-Meaza (2019)[6] evaluated patent value and impact on further developments of additive manufacturing technology of competitors by forward citation and the size of patent family. In general, more valuable patents are cited more, but using novel revenue data held by non-practicing entities (NPEs), Abrams (2018)[6] found that the relationship between citations and value forms an inverted-U, with fewer citations at the high end of value than in the middle.

In addition to serving as an indicator of patent strength, patent citations become data sources of powerful tool to analyze a lot of technical information in recent years, because forward and backward citations construct development rout and whole map of technology. Yoon (2018) [7] suggests a systematic approach to conducting technology opportunity analysis by visualizing patent information, such as patent documents and citation relationships. Patents are visualized in a two-dimensional space, and vacant cells are identified with their estimated keyword vectors by generative topographic mapping. The results can help R&D managers plan and evaluate R&D projects for technology development. Shubbak (2019) [8] studies the development of the solar photovoltaics technological system using patent indicators, a patent impact factor based on forward citations is calculated for the purpose of identifying the most influential solar PV cell patents, and contributes with an accurate inventory of international patent classes, the geographical, organizational and technical trends over the past six decades are analyzed along with a review of the most influential inventions.

By the 2020s, relevant research has become more developed. Kuhn (2020) [9] reexamined patent citations and indicated that a small minority of patent applications are generating a large majority of patent citations, and the mean technological similarity between citing and cited patents has fallen considerably. Gazni (2020) [10] analyzes citing scientific papers of USPTO patents in the period 1998-2017, the number of science-related patents has increased twice as fast as the number of patents and scientific publications, and the number of cited papers per one patent has almost doubled. And show the innovators' references to scientific papers by the countries during 2008-2017, both including and excluding US patents. Choi (2020)[11] performs qualitative and quantitative analysis using both structured and unstructured patent data, and provides evolving detailed trends in nanomedicine fields from a scientific point of view. Patent citation-based analysis was performed, and the results are shown each country on a coordinate plan with patent family size and forward citations per patent as the coordinate axis. Kim (2021) [12] introduced a model of innovation pollination across technology and design. The author looks at the degree of innovation effect corresponding to the number of forward citations of utility and design patents, and used Dyson's 432 utility and 192 design patents to show its product categories on four quadrants.

Patent classification is another important source for patent strength evaluation. International Patent Classification (IPC) is a classification system widely used by Patent Offices. Where a complete classification symbol comprises the stringed symbols representing the section, class, subclass and main group or subgroup. For example, G01S 17/08, the most often appears in the patent pool of this study, the first letter is the section symbol consisting of a letter, followed by a two-digit number to give a class symbol. The final letter makes up the subclass, and then followed by a 1- to 3-digit group number, an oblique stroke and a number of at least two digits representing a main group "00" or subgroup.

The number of patent classifications on the level of subclass is the most commonly used in research and also adopted in the paper, covered by a portfolio of an assignee, can be evaluated patent strength and has many applications. Altuntas (2015) [13] computes the total number of different IPC codes as a measurement of expansion potential, it also indicate commercialized potential of the technology indirectly, and a high possibility of marketing potential. Lee (2020) [14] empirically analyzes the effects of artificial intelligence (AI) on electric vehicle (EV) technology innovation by employing a machine learning-based text mining model and the IPC co-occurrence network analysis, using patent data filed from 1980 to 2017. IPC co-occurrence network map demonstrated the dynamic pattern of the convergence of AI and EV technology and identified major elementary technology areas and presented interrelations between technologies in each period. Perez-Molina (2021) [15] made the acoustic frequency spectrograms to visualize the dynamics of a technology showing the evolution of its technological components, which represented by the whole set of IPC codes.

The Cooperative Patent Classification (CPC) was initiated in 2010 as a joint partnership between the USPTO and EPO, where the Offices have agreed to harmonize their existing classification systems and migrate towards a common classification scheme. The CPC system has over 250,000 categories. Shorter literature and limited offices, less research used CPC. Karvonen (2019) [16] evaluate the tagging schemes for patent documents related to low carbon technologies and provide a patent analysis of bioethanol with PCT patent publications between 2010 and 2016. The IPC and CPC based queries were optimized to find grain bioethanol, cellulosic bioethanol and patents belonging to grain and cellulosic bioethanol trajectories. This study will use CPC and IPC to have common codes on subclasses as the basis for calculating patent strength.

The size of patent family is another indicator of patent strength, a patent family is a set of patents taken in various countries to protect a single invention. The larger size of family, the higher value of the patent, because the applicant attaches great importance to the invention and is willing to spend the cost to obtain more national patents. A family could be a simple family, complex family, or extended family, depend on the priority documents share[17], the definition of patent family has to clarify to determine the patent strength (Liu, 2014) [13]. Dechezlepretre (2017) [19] provides an in-depth analysis of the characteristics of international patent families, including their domestic component. While the literature has extensively used family size as a measure of patent value, the author suggest that the number of patent filings in the priority country within a patent family as well as the timespan between the first and last filings within a family are other insightful indicators of the value of patented innovations. Alvarez-Meaza (2019) [5] evaluated patent value and impact on further developments of additive manufacturing technology of competitors by forward citation and the size of patent family.

The broadness of patent scope is one kind of patent strength, and the scope of patent rights is claim. A patent examiner compares the claimed invention and prior arts, to determine whether it has novelty and inventive step requirements for granting a patent. Verhoeven (2016) [20] provides a new measurement of technological novelty, and proposes an operationalization using patent classification and citation information. The “Novelty in Recombination” indicator is constructed using the IPC groups assigned to the patent applications in the family. The author performed a series of analyses to assess the validity of the proposed measures and compare them with other indicators used in the literature. Yang (2019) [21] investigated the technology competition of graphene biomedical technology of top countries and top assignees, and sums up patents, citations and classifications as total strength.

The broadness of the patent scope is usually evaluated by claims. The patent specification shall contain a written description of the invention, and one or more claims particularly pointing out and distinctly claiming the subject matter which the inventor regards as the invention. A claim may be written in independent or in dependent or multiple dependent form. A claim in dependent form shall contain a reference to a claim previously set forth and then specify a further limitation of the subject matter claimed. (Excerpted from 35 U.S.C. §112)

Lee (2015) [22] developed a novelty-focused patent identification map by combining the novelty indicator together with the number of patent citations and the number of patent claims. A case study of the patents about thermal management technology of light emitting diode is exemplified. The patents having higher citation counts are classified as influential, having higher number of patent claims are categorized inimitable. Sven (2019) [23] defined a normalized technological patent scope indicator through a semantic patent analysis of patent claims. The linear regressions between the patent scope and several indicators of the three technologies DVD, HD-DVD and Blu-ray disc are provided.

In addition to using the official patent classification, there are also patent strength indicators by manual classifications, for example, technology-function matrix, which is very useful to visualize patent comprehensive of competitors for technical developer, Liu (2014,2016)[24][25] used it to analysis worldwide patent strength of competitors on advanced driver assistance system and autonomous parking. Wang (2021)[26] conducted cross-domain function analysis and trend forecasting in China’s construction industry by matrix heap map, which is 2D coordinate map composed of IPC subclasses and functions. Li (2020) [27] built the Patent Portfolio Model to assess the advantages and disadvantages of an organization, to identify the opportunities of development potentials and optimal distribution, to support the decision-making for optimizing resource allocation. The author used the Revealed Patent Advantage (Schmoch 1995) [28] to calculate the relative global protection advantage and relative technology integration capability of an institute to visualize the portfolio strategy.

Patent portfolios owned by companies, institutes, and countries, can be used two indicators as coordinate axes to draw on a 2D patent map and divided into four quadrants, to visualize some valuable information by their locations. Grimaldi (2015) [29] compares and contrasts the management of patents to the company’s technologic and innovative strategy, the framework employs determinants of patent values that are elicited from patent databases, such as claims, citations, and market coverage, and judgements achieved by interviewing involved managers, such as strategic relevance and economic relevance, illustrated in a patenting strategy and economic relevance map. Yang (2019) [21] shows competitive position of top assignees in graphene biomedical technology on vision (including patents, classifications, and citations) and resources (including revenue, locations, and litigation) map. Choi (2020) [11] shows patent portfolios of applicants of different nationalities on patent family size and forward citations per patent map, to get the national distribution. Kim (2021) [12] shows Dyson’s patent products on design innovation and technology innovation map, to get whether innovation design or technology driven. Liu (2020) [30] has ever collected them as total strength to get leaders of LiDAR competitors, and visualize different aspects on 2D diagrams.

It can be seen from the above literature that there are many patent strength indicators for various aspects, simple indicators are taken directly from bibliographic information. All simple indicators commonly used in the past will be collected as traditional indicators and sum up as total strength in this study. It is a reasonable presumption that the total strength is more representative than a single indicator or a few indicators. Furthermore, this article will explore the results from a legal point of view that was rarely used in the past, and the aforementioned important literature results or conflicts also be reviewed and discussed.

III. Data Collection and Methodology

A. *Selected indicators of patent strength*

There are eight common indicators were selected to evaluate a patent portfolio by an assignee in the following, and sum them after normalization to get traditional total patent strength for competitors:

A1 Published patent families: equivalent to the number of inventions completed by an assignee.

A2 Issued patent families: equivalent to the number of patented inventions by an assignee.

A3 Average independent claims of a patent families: equivalent to number of inventions defined by Patent Acts in one patent application.

A4 Average member of a patent family: equivalent to average number of countries covered of one claimed invention.

A5 Number of sub-technologies: total completed inventions coverage in the six sub-technologies guided by experts.

A6 Number of IPC subclasses: total completed inventions coverage in IPC subclasses.

A7 Average number of cited documents of one family: equivalent to how important of the invention cited by the following inventions.

A8 Average number of citations of one family: equivalent to how wide of prior arts of an invention.

Where A1 and A2 represent completed R&D projects and patented inventions. A3 and A4 are scope of claimed inventions and coverage countries. A5 and A6 are technical broadness in view of experts and IPC subclasses. A7 and A8 are backward and forward citations. All indicators are normalize by the maximum value and sum to total strength.

The secondary indicator in this study is Revealed Patent Advantage (RPA), which definition is

$$\text{Revealed Patent Advantage (RPA) RPA} = \frac{\frac{P_{ij}}{\sum_i P_{ij}}}{\frac{\sum_j P_{ij}}{\sum_{ij} P_{ij}}}$$

Where RPA shows the related quantity advantage of the j research institute in i characteristic; $P_{ij}/\sum_i P_{ij}$ is the proportion of the number of patents of j organization in i characteristic to total patents of all characteristics; $\sum_j P_{ij}/\sum_{ij} P_{ij}$ is the ratio between the numbers of all organization in i characteristic and all organization in all characteristics.

All traditional indicators are absolute, but RPA is relative, representing the relative strength between competitors.

B. *Patent pool and overview of LiDAR technology*

Under the expert opinion, LiDAR technology including six sub-technologies: Solid State LiDAR, Optical Phase Array, Optical Beam Steering, Tunable Laser, Hybrid Laser, and Silicon Photonics Optical Coupling. The search strategy is six topics separately in the USPTO official database (USPTO AppFT) and combine them. Using these six technical themes as keywords in title or abstract, publication date between January 1, 2001 and December 31, 2020. The search quires and results are shown in Table 1. Number of documents obtained from 41 to 778.

Table 1 Search quires of this study (PD/20010101-20201231)

Topics	Search string	hits
Solid state LiDAR	((TTL/"solid state$" OR ABST/"solid state$") OR (TTL/"solid-state$" OR ABST/"solid-state$")) AND (TTL/"LIDAR" OR ABST/"LIDAR")	41
Silicon photonics optical coupling	((((TTL/"Silicon photonics$" OR TTL/"optical coupling$") OR (ABST/"Silicon photonics$" OR ABST/"optical coupling$") OR (SPEC/"Silicon photonics$" OR SPEC/"optical coupling$")) AND (TTL/"LIDAR" OR ABST/"LIDAR")) OR ((TTL/"optical coupling" OR ABST/"optical coupling") AND (TTL/"photonics" OR ABST/"photonics"))) AND PD/20010101->20201231	121
Hybrid laser	((((TTL/"hybrid laser$") OR (ABST/"hybrid laser$") OR (SPEC/"hybrid laser$")) AND ((TTL/"LIDAR") OR (ABST/"LIDAR") OR (SPEC/"LIDAR"))) OR (TTL/"hybrid laser" OR ABST/"hybrid laser"))	105
Optical beam steering	((((TTL/"beam steering$") OR (ABST/"beam steering$") OR (SPEC/"beam steering$")) AND (TTL/"LIDAR" OR ABST/"LIDAR")) OR (TTL/"beam steering$" AND ABST/"beam steering$" AND (SPEC/"LIDAR" OR SPEC/"light detection and ranging" OR SPEC/"light")))	471
Optical phase array	((((TTL/"optical phase array$" OR TTL/"optical phased array$") OR (ABST/"optical phase array$" OR ABST/"optical phased array$") OR (SPEC/"optical phase array$" OR SPEC/"optical phased array$")) AND (TTL/"LIDAR" OR ABST/"LIDAR")) OR (SPEC/"optical phase array" OR SPEC/"optical phased array"))	650
Tunable laser	((((TTL/"Tunable Laser$") OR (ABST/"Tunable Laser$") OR (SPEC/"Tunable Laser$")) AND (TTL/"LIDAR" OR ABST/"LIDAR")) OR (TTL/"Tunable Laser" OR ABST/"Tunable Laser"))	778

We combined them to get 1923 documents in total, some documents are appeared in multiple topics, as LiDAR patent pool Ⅰ.

The number of Applicants and the number of applications can form a technology life cycle. Fig.1 is technology life cycle of LiDAR in the U.S. in the past two decades. It can be observed that technical developed trend is still in the growth stage. Although the number of applications has not grown much before 2015, the number of applicants who have invested has grown significantly. More applicants invest and produce more research achievements to apply for patents, especially from 2015 to 2018, and 2019 is expected to grow.

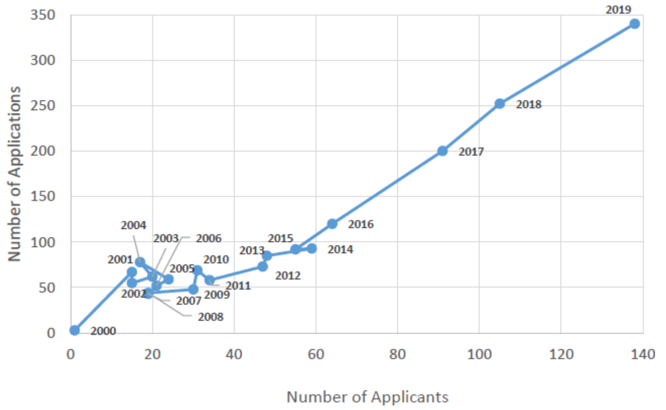


Fig.1 Technology life cycle of LiDAR in the U.S.

Fig.2 is the patent pool of six-sub-technologies, each distribution in IPC or CPC subclasses.

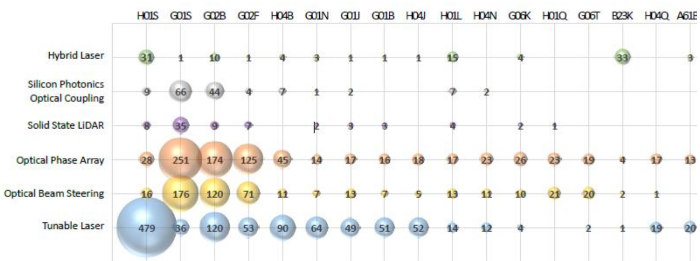


Fig.2 IPC subclasses in six technical topics

The title and brief description of all IPC codes are as following:

H01S Devices using the process of light amplification by stimulated emission of radiation (laser) to amplify or generate light.

G01S Radio direction-finding; radio navigation; determining distance or velocity by use of radio waves; locating or presence-detecting by use of the reflection or radiation of radio waves.

G02B Optical elements, systems, or apparatus.

G02F Devices or arrangements, the optical operation of which is modified by changing the optical properties of the medium of the devices or arrangements for the control of the intensity, color, phase, polarization or direction of light, e.g. switching, gating, modulating or demodulating; frequency-changing; non-linear optics; optical logic elements; optical analogue/digital converters.

H04B Transmission.

G01N Investigating or analyzing materials by determining their chemical or physical properties.

G01J Measurement of intensity, velocity, spectral content, polarization, phase or pulse characteristics of infra-red, visible or ultra-violet light;

G01B Measuring length, thickness or similar linear dimensions; measuring angles; measuring areas; measuring irregularities of surfaces or contours.

H04N Pictorial communication, e.g. television.

G06K Recognition of data; presentation of data; record carriers; handling record carriers.

H01Q Antennas, i.e. radio aerials.

G06T Image data processing or generation, in general.

B23K Soldering or unsoldering; working by laser beam.

H04Q Selecting (switches, relays).

A61B Diagnosis; surgery; identification.

C. Selected assignee and patent strength calculation

The next step we selected 16 main assignees who have over 17 patents in USPTO, the total number owned by main assignees as pool Ⅱ is 421. LiDAR's owners are scattered, there were already more than 100 applicants in 2018 as shown in Table 2, no applicant has accumulated more than 100 patents, and this phenomena is consistent with different search queries in USPTO, JPO, EPO, CNIPA, and WIPO (Liu 2020) [45]. They are SAMSUNG, SUMITOMO (consolidated NEC), RAYTHEON, INNOVIZ, ANALOG, TOYOTA, OUSTER, GM, AURORA (consolidated OURS, Blackmore Sensors and Analytics), ALPHABET (consolidated Google and Waymo), PANASONIC, HUAWEI, LUMINAR, ETRI (Electronics and Telecommunication Research Institute), FUJITSU, and INTEL. Table 1 is the traditional patent strength of the main assignees, all indicators are calculated on the patent portfolio of assignee. The data collection is based on simple family, the number of families (A1) may be less than the US applications, for example, INNOVIZ, that owns a family consists of many continuous patents, they share the same description but different claims.

Table 2 Traditional patent strength of main assignees (A0 is number of patents)

No	Assignee	A0	A1	A2	A3	A4	A5	A6	A7	A8
1	SAMSUNG(KR)	61	56	34	2.38	2.98	4	2	9.02	2.26
2	SUMITOMO(JP)	49	42	36	1.94	3.06	2	1.24	13.27	8.41
3	RAYTHEON(US)	32	33	25	3	3.16	2	1.69	15.84	10.38
4	INNOVIZ(IL)	30	6	2	3.23	15.87	1	1.47	40.37	62.1
5	ANALOG(US)	29	22	9	2.72	3.52	2	1.62	15.34	4.07
6	TOYOTA(JP)	25	25	13	2.68	1.44	1	2.36	7.92	1.08
7	OUSTER(US)	22	10	7	2.86	8.73	3	2.18	71.45	12.45
8	GM(US)	22	18	6	2.95	8.82	2	1.32	19.09	5.55
9	AURORA(US)	21	16	11	3.1	3.75	4	2.05	20.57	3.48
10	ALPHABET(US)	19	15	5	2.79	5	3	2.09	37.58	41.84
11	PANASONIC(JP)	19	17	7	2.16	3.63	2	2	8.00	3.16
12	HUAWEI(CN)	19	19	15	2.58	3.74	4	1.68	17.58	2.63
13	LUMINAR(US)	19	9	6	1.84	10.13	4	1.8	126.63	95
14	ETRI(KR)	19	18	14	1.72	1.78	5	1.39	7.33	5.56
15	FUJITSU(JP)	18	18	16	2.11	2.39	2	1.5	12.83	11
16	INTEL(US)	17	15	14	4.35	4.06	6	1.59	17.41	20.35

Three kinds of Revealed Patent Advantage of all assignees are calculated. The first is six sub-technologies advantage shown in Fig.3, the second is IPC advantage shown in Fig.4, and the third is international application advantage shown in Table 3. These are the comparative advantage of the sixteen companies in three aspects.

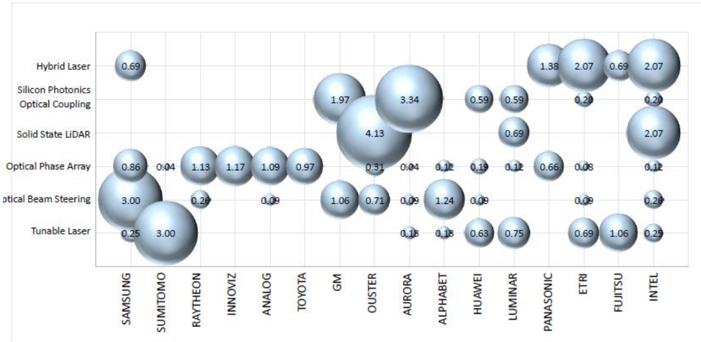


Fig.3 Revealed Patent Advantage of six sub-technologies

Almost all companies have investment in Optical Phase Array, SUMITOMO has the most advantage in Tunable Laser, but very weak in other aspects, SANSUMG is the strongest in Optical Beam Steering, OUSTER has the most advantage in solid state LiDAR, AURORA is the top of Silicon Photonics Optical Coupling, and INTEL has the least total number of patents, but is the only company covering six technologies.

Fig. 4 presents sixteen IPC subclasses, which are more detail and have different perspectives. The INTEL with the most extensive coverage in expert opinion is not prominent here. The top three companies that cover more IPC subclasses are RAYTHEON, GM, and ALPHABET. No company owns RPA more than 2 in more than two subclasses.

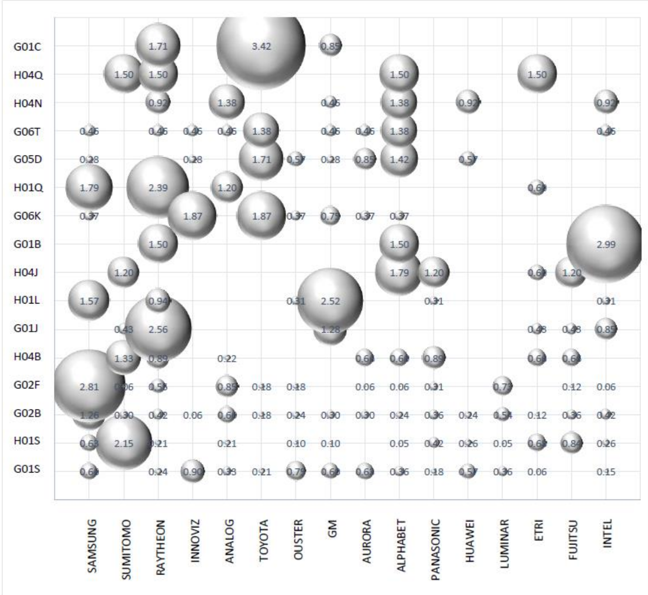


Fig.4 Revealed Patent Advantage of IPC sub-classes

Table 3 is a hot map of international application of assignees. Not surprisingly, almost all companies file into US, CN, EP, and JP. In some countries, like Brazil (BR), Honkong (HK), New Zealand (NZ), and Israel (IL), only one company has a patent application. Only ETRI applies for only one national patent KR outside the US.

Table 3 Revealed Patent Advantage of international applications (WO is PCT application)

Assignee	WO	AU	BR	CA	CN	DE	EP	HK	JP	KR	NZ	SG	TW	IL	US	SUM
SAMSUNG	0.18				0.92		1.78		0.28	5.21					0.78	9.15
SUMITOMO	0.37	2.35		2.23	0.66		0.46		3.05	0.36			2.23		0.68	12.39
RAYTHEON	1.42	1.17		1.67	0.04		1.63		0.35	0.27	11.2			11.2	0.36	29.21
INNOVIZ	1.79				2.45		2.25		2.35	1.44					3.35	13.63
ANALOG	1.23				0.17	2.31			0.07	0.18					0.74	4.7
TOYOTA	0.06				0.22		0.08		0.28						0.27	0.91
OUSTER	0.99	5.28		5.02	0.83		1.08		0.76	0.99		8.67	6.13		0.91	30.66
GM	0.31				3.24	7.69	0.39		0.28						0.91	12.82
AURORA	1.17			1.11	0.22		0.54		0.14	0.63					0.34	4.15
ALPHABET	0.62	2.35		1.11	0.13		0.23		0.14	0.27		2.48			0.35	7.68
PANASONIC	0.43				0.83		0.46		0.9						0.26	2.88
HUAWEI	1.05				0.7		1.01		0.42						0.2	3.38
LUMINAR	0.8				0.44		0.77		0.69						1.26	3.96
ETRI										1.26					0.19	1.45
FUJITSU	0.18				0.09	0.38	0.23		1.11						0.19	2.18
INTEL	0.55		11.2		0.22	0.77	0.23	11.2	0.35	0.54			2.23		0.34	27.53

D. *Correlation analysis tool*

During study, we used linear regression analysis and 2D map to get the correlation between interested patent strength indicators. Linear regression can obtain statistical significance, but the distribution state can only be seen in a 2D map. Assuming that the total strength summed up by multiple indicators is the most representative, the bubble size on 2D map is proportional to the total strength, both individual patent and patent portfolios. We can also observe whether there is a positive correlation between the total strength and the selected indicator.

For individual patents, after studying many 2D maps composed of any two indicators, we selected number of claims and citations as two axes to illustrate interesting results. On the other hand, the coordinate axes of the patent portfolio are Revealed Patent Advantages, to observe the relationship between relative and absolute strength.

IV. ILLUSTRATION

A. *Claims and citations*

It is the independent claims that determine the legal scope of the patent. Because a claim in dependent form shall be construed to incorporate by reference all the limitations of the claim to which it refers. (35 U.S.C. §112(d)) Here, the number of independent claims will be presented first. Fig. 5 is a correlation map of total claims and independent claims for competitors, the bubble size is proportional to total strength. The map is divided into four quadrants with 20 total claims and 3 independent claims, the critical number of excess fee. Five companies in the third quadrant, they did not make full use of the exemption-free, it must be said that they do no attach importance to the quality of claim drafting, or their invented technologies without many varieties cannot write more claims, so hard to say has high technical value. Those with more than 3 independent claims all have a total of more 20 claims, and INTEL is the one farthest from the origin in the first quadrant. In the fourth quadrant where most companies are located, the number of independent claims rather the total claims affects the scope of patent rights. It is interesting that no one in the second quadrant.

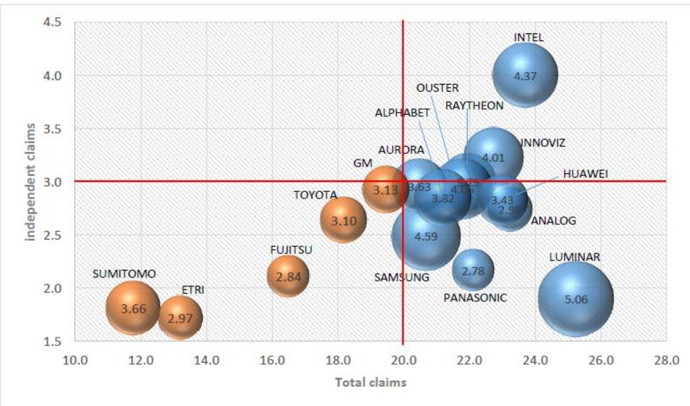


Fig.5 Correlation map of total claims and independent claims

Fig. 6 is a correlation map of total claims and citations. The positively relationship between the total strength and claims and citations may not exist in the patent portfolios. The number of citations of the five companies with a total claims less than 20 is also not high, far behind the average as well, and no one is in the higher citations, the second quadrant. LUMINAR and OUSTER with the highest number of citations have more than 20 claims, which means that those with higher technical value can easily draft more claims, and the applicant is also willing to pay excess fee for them. It should be noted that LUMINAR has highest number of citations and high claims, but independent claims less than 2.

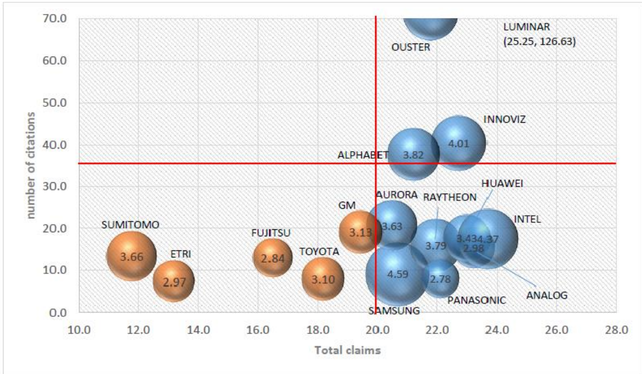
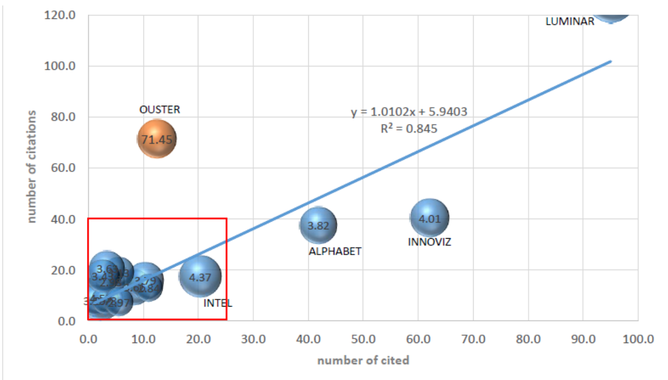


Fig.6 Correlation map of total claims and citations (LUMINAR not shown)

Fig. 7 is a correlation map of number of citations and cited, most competitors gather near the origin, Fig. 8 is a partially enlarged map.



	coefficient	Standard err.	T statistics	P value
Intercept	5.9403	3.8524	1.5420	0.1471
X variable 1	1.0102	0.12	8.4184	1.27E-6

Fig.7 Correlation map of number of citations and cited

We can see that there is roughly a linear relationship, equation y=1.0102x+5.9403, except for OUSTER and sort out. Forward citation can better represent the value of patents than backward citation, but forward citation takes time to accumulate. The hot technology patent pool must have newly published patents, and few forward citations cannot represent their real value. If forward and backward citation have a near linear relationship, the backward citation can be used instead of forward citation. There are lots of researches for forward and backward citations to show their characteristics. Although this study shows a certain linear relationship, this result may not be inferred more broadly without further evidences.

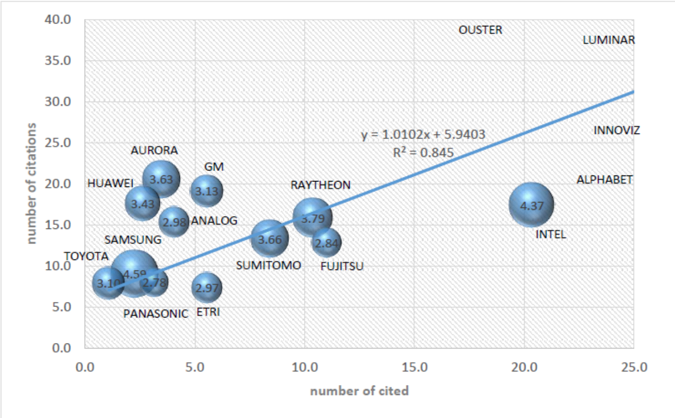


Fig.8 partially enlarged map of Fig. 7

B. Claims and RPA of IPC subclasses

Let's explore the relationship between total claims and Revealed Patent Advantage. Fig.9 is a correlation map of total claims and RPA of IPC subclasses, which higher means its patent portfolio covers broader technology and has high technical value. There are still four companies with less than 20 claims have narrower coverage technologies and are located in the third quadrant, only TOYOTA has RPA of IPC subclasses above average and in the second quadrant. There are three companies, RAYTHEON, ALPHABET, and SAMSUNG, located in the first quadrant.

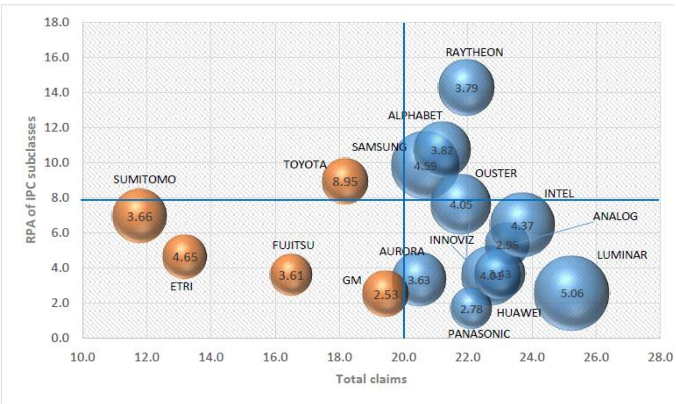
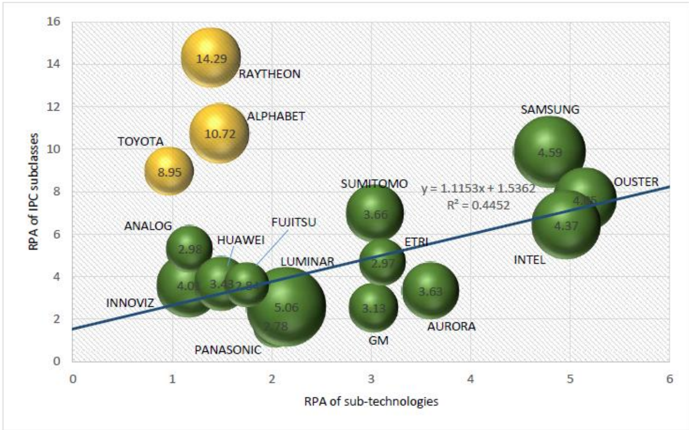


Fig.9 Correlation map of total claims and RPA of IPC subclasses

IPC subclasses coverage could be an indicator of patent strength, but not necessarily in line with the opinions of R&D experts. Fig.10 shows the correlation between RPA of sub-technologies and IPC subclasses. It can be divided into two zones to discuss. Green bubbles are in the first zone with a regression line y=1.1153x+1.5362, we can say the RPA indicators are roughly proportional in this zone. Only three yellow bubbles in the second zone, TOYOTA, ALPHABET, and RAYTHEON, they are high RPA of IPC subclasses but low under the experts' view, and it is interesting that they are three of the four above average as shown in Fig.9.



	coefficient	Standard err.	T statistics	P value
Intercept	1.5362	1.1963	1.2842	0.2255
X variable 1	1.1153	0.3754	2.9708	0.0127

Fig.10 Correlation map of total claims and citations

C. Claims and PRA of International applications

The third step is to observe the correlation between total claims and RPA of international application as shown in Fig.11. The five companies with less than 20 claims have lower RPA of international application are all located in the third quadrant, and the empty second quadrant reappears. There are three companies in the first quadrant, INTEL, OUSTER, and RAYTHEON, they invest the highest cost in patent claim drafting and international application.

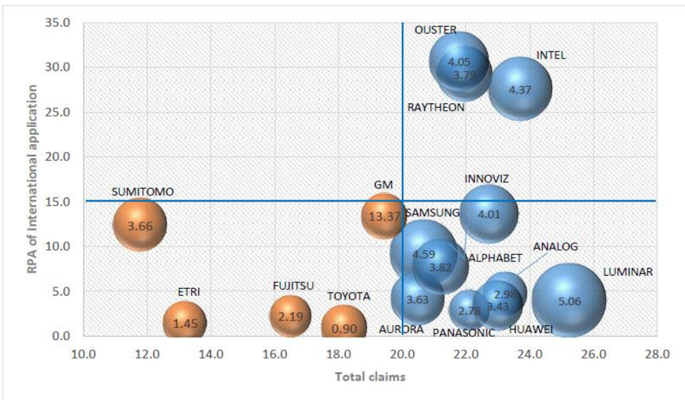
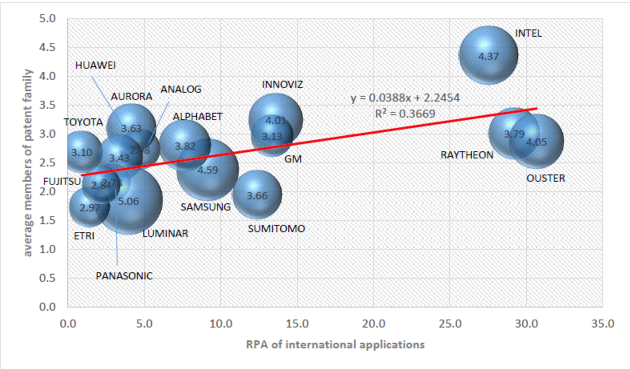


Fig.11 Correlation map of total claims and RPA of international applications

Family size is a common indicator for patent strength in literature, the relationship between it and RPA of international application is worth understanding, and shown in Fig. 12. It can be observed that highly positive correlation between them, Pearson correlation coefficient is 0.606, a liner regression line is y=0.0388x+2.2454.



	coefficient	Standard err.	T statistics	P value
Intercept	2.2454	0.1956	11.4778	1.65E-08
X variable 1	0.0388	0.0136	2.8487	0.01288

Fig.12 Correlation between RPA of international applications and family size

D. *Summary*

The number of claims is a subjective patent value of the applicant, and the number of citations is an objective technical value, there is no necessary relationship between the two. The above evidences show that the two seemingly independent variables still have a relationship with each other. For those inventions with higher technical value, more varied embodiments require more dependent claims, and the applicant is also willing to spend more cost even if excess fees needed. We can use number of claims to evaluate patented technology.

The threshold value is 20 claims in patent portfolio, which is affected by excess fees for each claim in excess of 20 charged 100USD, and each independent claim in excess of three charged 480USD (USPTO fee schedule, effective January 2, 2021). The applications with 20~30 claims which occupy 60% of pool I, and exactly 20 of them is 38%.

A patent portfolio has less 20 claims, we can assert that its technical value is not high, all of them have not varieties and are mostly improved inventions. A portfolio has more 20 claims but less than 30, it can only be said to be normal situation and need high citations to be considered high value. A patent portfolio more than 30 claims, it can be asserted that it also has high technical value without looking at the number of citations, which is indeed higher and confirmed in this study.

V. CONCLUSIONS

On the patent portfolio of competitors, there were many researches on how to present the business strategy, its performance in various aspects, or forecasting future development based on 2D maps. Among the various 2D patent maps composed of two indicators, the results of this research suggest that three bubble maps can quickly know the strength of the patent portfolios of companies and could be the most fundamental patent analysis map. The bubble size can be proportional to total strength, the number of patent applications or grant numbers. All three maps can be obtained quickly and at low cost, so it is very practical and automatically generated on patent database. The first is number of claims and citations map, this map visualizes patent legal value and technical value in depth. The two indicators are the most representative and easy to obtain in patent itself and technical value, respectively. The second is number of claims and IPC subclasses, this map visualizes patent legal value and technical value in broadness. The third is number of claims and size of family, this map visualizes patent legal value and geographical coverage value.

REFERENCES

[1] World Intellectual Property Indicators 2021, WIPO, available at www.wipo.int/edocs/pubdocs/en/wipo_pub_941_2021.pdf

[2] Patent Cooperation Treaty Yearly Review 2021, WIPO, available at https://www.wipo.int/edocs/pubdocs/en/wipo_pub_901_2021.pdf

[3] F-M. Tseng, C-H. Hsieh, Y-N. Peng, Y-W. Chu, 2011, Using patent data to analyze trends and technological strategies of the amorphous silicon thin-film solar cell industry, Technology Forecasting & Social Change, 78 332-345. https://doi.org/10.1016/j.techfore.2010.10.010.

[4] T. Fisher, J. Leidinger, 2014, Testing patent value indicators on directly observed patent value-an empirical analysis of Ocean Tomo patent auctions, Research Policy, 43(3) 519-529. https://doi.org/10.1016/j.respol.2013.07.013

[5] I. Alvarez-Meaza, E. Zarrabeitia-Bilbao, R.M. Rio-Belver, I. Martinez de Alegria, and I. Bildosola, 2019, Patentometric: monitoring the scientific and technological trends of additive manufacturing in medical applications, International J. of Production Management and engineering, special issue, 65-72. Polipapers.upv.es/index.php/IJPME

[6] D. Abrams, U. Akcigit, J. Grennan, 2018, Patent value and citations: creative destruction or strategic disruption? National Bureau of Economic Research, Working Paper 19647. https://www.nber.org/papers/w19647.

[7] B. Yoon, C.L. Magee, 2019, Exploring technology opportunities by visualizing patent information based on generative topographic mapping and link prediction, Technological Forecasting & Social Change, 132 105-117. https://doi.org/10.1016/j.techfore.2018.01.019.

[8] M.H. Shubbak, 2019, Advances in solar photovoltaics: Technology review and patent trends. Renew. Sustain. Energy Rev. 115 109383. https://doi.org/10.1016/j.rser.2019.109383.

[9] J. Kuhn, K. Younge, A. Marco, 2020, Patent citations reexamined, RAND Journal of Economics, 51(1) 109-132.
https://doi.org/10.1111/1756-2171.12307

[10] A. Gazni, 2020, The growing number of patent citations to scientific papers: Changes in the world, nations, and fields, Technology in Society, 62 101276.
https://doi.org/10.1016/2020.101276.

[11] Y. Choi, S. Hong, 2020, Qualitative and quantitative analysis of patent data in nanomedicine for bridging the gap between research activities and practical applications, World Patent Information, 60 101943.
https://doi.org/10.1016/j.wpi.2019.101943.

[12] D. Kim, J. Kim, 2021, Is innovation design- or technology- driven? Citation as a measure of innovation pollination, World Patent Information, 64 102010.
https://doi.org/10.1016/j.wpi.2020.102010

[13] S. Altuntas, T. Dereli, A. Kusiak, 2015, Forecasting technology success based on patent data, Technology Forecasting & Social Change. 96 202-214.
https://dx.doi.org/10.1016/j.techfore.2015.03.011

[14] M. Lee, 2020, An analysis of the effects of artificial intelligence on electric vehicle technology innovation using patent data, World Patent Information, 63 102002.
https://doi.org/10.1016/j.wpi.2020.102002

[15] E. Perez-Molina, F. Loizides, 2021, Novel data structure and visualization tool for studying technology evolution based on patent information: The DTFootprint and the TechSpectrogram, World Patent Information, 64 102009.
https://doi.org/10.1016/j.epi.2020.102009

[16] M. Karvonen, K. Klemola, 2019, Identifying bioethanol technology generations from the patent data, World Patent Information, 57 25-34.

[17] L. Mailander, L., Topic 3: Patent Families, WIPO, retrievals from www.wipo.int › aspac › wipo_ip_bkk_12 › wipo_ip_bkk_12_www_238983.

[18] K-T. Liu, M-S. Lin, 2014, A study of patent family definition and building strategy on GaN patterning technology, European International Journal Science and Technology, 3(7) 301-313.
https://eijst.org.uk/images/frontImages/gallery/Vol._3_No._7/29.pdf

[19] A. Dechezlepretre, Y. Ménière, M. Mohnen, 2017, International patent families: from application strategies to statistical indicators, Scientometrics, 111 793-828.
https://doi.org/10.1007/s11192-017-2311-4

[20] D. Verhoeven, J. Bakker, R. Veugelers, 2016, Measuring technological novelty with patent-based indicators, Research Policy, 45 707-723.
https://dx.doi.org/10.1016/j.respol.2015.11.010

[21] X. Yang, X. Liu, J. Song, 2019, A study on technology competition of graphene biomedical technology based on patent analysis, Applied sciences, 9 2613.
https://doi.org/10.3390/app9132613

[22] C. Lee, B. Kang, J. Shin, 2015, Novelty-focused patent mapping for technology opportunity analysis, Technological Forecasting & social change, 90 355-365.
https://dx.doi.org/10.1016/j.techfore.2014.05.010

[23] Sven Wittfoth, 2019, Measuring technological patent scope by semantic analysis of patent claims – An indicator for valuating patents, World Patent Information, 58 101906.
https://doi.org/10.1016/j.wpi.2019.101906

[24] K-T. Liu, H-Y. Hsu, 2016, A study of worldwide patent strength of competitors on advanced driver assistance system, Journal of Multidisciplinary Engineering Science and Technology, 3(8) 5437-5442.
https://www.jmest.org/wp-content/uploads/JMESTN42351738.pdf

[25] K-T Liu, Y-T. Chen, 2020, A study of worldwide patent strength of competitors on autonomous parking, Journal of Multidisciplinary Engineering Science Studies, 6(2) 3051-3056.
http://www.jmess.org/wp-content/uploads/2020/02/JMESSP13420616.pdf

[26] L-Y. Wang, D. Zhao, 2021, Cross-domain function analysis and trend study in Chinese construction industry based on patent semantic analysis, Technological Forecasting & Social Change, 162 120331.
https://doi.org/10.1016/j.techfore.2020.120331

[27] S-Y Li, X. Zhang, H-Y. Xu, S. Fang, E. Garces, T. Daim, 2020, Measuring strategic technological strength: Patent Portfolio Model, Technological Forecasting & Social Change, 157 120119.
https://doi.org/10.1016/j.techfore.2020.120119

[28] U. Schmoch, 1995, Evaluation of technological strategies of company by means of MDS maps, International Journal of Technology Management, 10 426-440.
https://doi.org/10.1504/IJTM.1995.025635

[29] M. Grimaldi, L. Cricelli, M. DiGiovanni, F. Rogo, 2015, The patent portfolio value analysis: A new framework to leverage patent information for strategic technology planning, Technological Forecasting & Social Change, 94 286-302.
http://dx.doi.org/10.1016/j.techfore.2014.10.013

[30] K.T. Liu, Y.C. Li, 2020, New patent maps to visualize worldwide patent strength of competitors on LiDAR system, Journal of Multidisciplinary Engineering Science Studies, 6(3) 3094-3098.
http://www.jmess.org/wp-content/uploads/2020/03/JMESSP13420625.pdf

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