

# New patent maps to visualize worldwide patent strength of competitors on LiDAR system

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*Abstract— A study of worldwide patent strength and new patent indicators of competitors based on patent maps are presented in this paper. A worldwide popular and developing technology, LiDAR system, was selected to demonstrate the analysis. Analysis results show on patent indicator 2D diagrams, including patent issue rate and issue patent families, independent claims and issue families, technology broadness of both IPC classes and classification for researchers, forward and backward citations, and geographical coverage of both GDP market and members of family. All calculations are based on patent families instead of specific national patent.*

*Patent pool in this study are from official database by USPTO, EPO, JPO, CHIPA, and WIPO. Patent strengths of top fifteen companies are shown in the form of patent families. Coordinate chart can visualize different aspects of competitors. In the evaluation of total strength, GOOGLE+WAYMO, LUMINAR, and OUSTER occupied the first three position, but some companies are outstanding in certain indicators.*

**Keywords— patent strength; patent map; patent indicators; LiDAR system.**

## I. INTRODUCTION

LiDAR is a hot technology that has continued to develop for more than a decade in the world. LiDAR is an active remote sensing system which uses pulsed laser beams to accurately map out an environment. The basic mechanism is known as “time of flight” measurement in which a laser beam is emitted towards an object, reflected off of the object and then collected in a sensor located within the LiDAR module. When the beam returns, it carries with it information about the object that it contacted including distance and optical characteristics like reflectivity.

LiDAR is becoming more popular in vehicles to make it automatic. LiDAR is used to detect the information on the road and it is passed to computerized system to make a human being like decision. Nowadays vehicle uses Adaptive Cruise Control which has LiDAR technology. It helps the vehicle that is in cruise control to slow down when there is a vehicle in the front and also speed up when there is no traffic. Another popular application of LiDAR is drone.

The laser precision of LiDAR can visually map individual features of a vehicle or an environment in what is known as a “point cloud,” a map of individual laser measurements so densely populated that it appears on a display as solid physical objects.

A study of worldwide patent strength of LiDAR system will be presented in this paper. The total strength of 15 competitors are calculated based on 9 indicators. New patent maps are shown to visualize worldwide patent strength of competitors.

Many patent strength indicators have been proposed in the past. The number of patent citations is most often used to evaluate the strength or quality of a patent. The basic concept of these study is that the higher number cited by later filing patents, the higher value of the patent. A fundamental patent in a technical field usually has the highest number of citation as prior art by subsequent patents [1].

The size of patent family is another indicator of patent strength, the larger size of family, the higher value of the patent [2][3][4]. Commercial software can calculate patent strength based on many indicators, such as backward citations, forward citations, patent litigation, family numbers, claim numbers, etc., stakeholders can understand how a particular market or technology stacks up and explores a competitive landscape among top assignees [5]. For technical developer, technology-function analysis is very useful to visualize patent comprehensive of competitors, and a patent strength indicator could be calculated by the technology-function matrix [6][7][8].

An analysis of international patent strength shown on patent maps will be presented in this study. The map is a coordinate map composed of two patent strength indicators. We made patent search in the official databases, The United States of Patent and Trademark Office (USPTO), European Patent Office (EPO), Japan Patent Office (JPO), China Patent Office (National Intellectual Property Administration, PRC., CHIPA), which are the most four important national patent offices, because they grant patents cover big market. Patent Applications are through Patent Cooperation Treaty (PCT) system also included, the system managed by World Intellectual Property Organization (WIPO), consolidates one application beginning at international phase, and then enters national phase or regional phase to get more national patents.

II. METHODOLOGY AND DATA

The patent pool in this study was gotten from official databases by organized search queries as shown in Table 1. Different databases offer different types of search interface. We utilized key words and International Patent Classification G01S, which is "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; analogous arrangements using other waves." The search queries made the pools consistent as could as possible, the search date is January 10, 2020. We can get the first patent pool is publication documents in the five offices, many of them are one invention file to more than one office.

Table 1 Search queries and the numbers of documents

database	Search query	Documents
USPTO	SPEC/"LIDAR" OR SPEC/"light detection and ranging" OR SPEC/"ladar" AND (ICL/G01S17\$ OR ICL/G01S7\$) AND PD/20010101->20190630	2,065
JPO	[(光検出と測距)/TX+OR/TX+(レーザー画像検出と測距)/TX+OR/TX+(ライダー)/TX+OR/TX+(ライダー)/TX+OR/TX+(LiDAR)/TX] * [G01S7/00/IP+G01S17/00/IP] AND PD:20010101~20190630	3,517
EPO	DEDE = LiDAR OR DEFR = LiDAR OR DEEN = LiDAR AND IPC = (G01S7 OR G01S017) AND PUD >=20000101 AND PUD <=20190630 AND PUK=(A1 OR A2)	754
CNIPA	公开(公告)日=20010101:20190630 AND IPC=(G01S7 OR G01S17) AND 说明书=(激光雷达 OR LiDAR) AND 公开国家/地区/组织=(CN)	3,797
WIPO	IC_EX:(G01S7/00 OR G01S17/00) and DP:[01.01.2001 TO 30.06.2019] and DE:(LiDAR OR radar)	1,396

Fig.1 shows LiDAR related patent application trends in five offices based on application year. It is shown that patent applications were filed in Europe, China, and Japan since 20 years ago. We can roughly divided it into three period. Before 2006 is the first period, very few application except JPO. During 2007 and 2013 is a growth period, and enter rapid growth period after 2014, especially in CHIPA and USPTO, more than one thousand application in 2018. JPO

received application earlier but has not grown significantly in recent years.

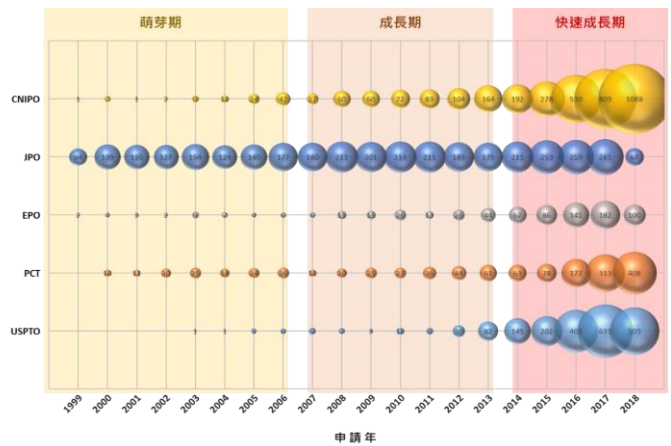


Fig.1 Patent application trends in five offices

Fig.2 is the numbers of patent application in the five offices of top 25 applicants, selected from the first patent pool. We can see that the US market is the most important that all applicants have applications, and GOOGLE+WAYMO get the first position. Worldwide vehicle manufactures like to use PCT system, BOSCH has 115 PCT applications. European companies have more EPO applications than others. The Japanese companies, DENSO, TOSHIBA, MITSUBISHI, and TOYOTA have many applications in JPO, but others have not, because Japanese market is relatively closed. As for the Chinese market, BOSCH and GM are the companies most interested in this market, some Chinese applicants have many applications but not shown in this Figure, because they have few applications abroad.

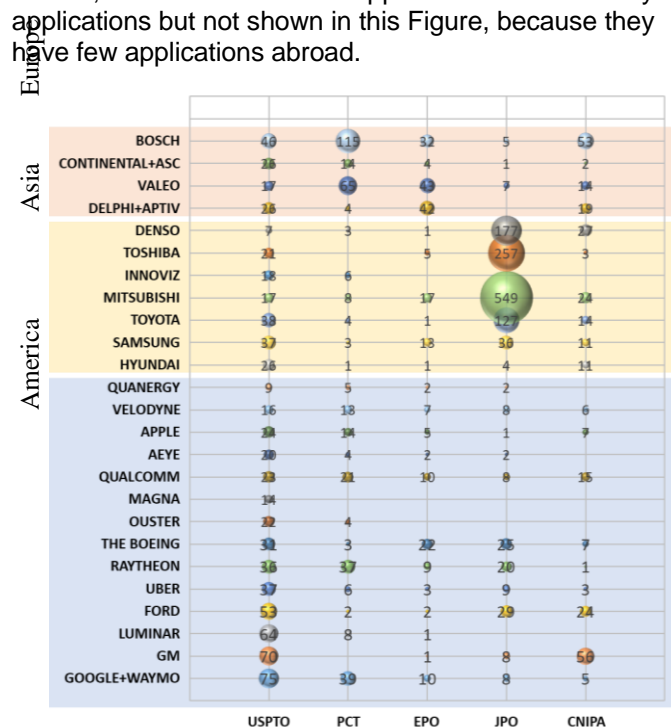


Fig.2 Top 25 applicants in five offices

We selected 15 applicants and manually screened to the second patent pool, and organized the patent documents into patent families, as shown in Table 2. One patent family is equivalent to one invention. We selected the vehicle related LiDAR into the second pool, and sorted out other LiDAR related patents, like wind power, aircraft, etc.

Table 2 Top 15 applicants and patent families

Applicants	Patent families
FORD	27
GM	41
TOYOTA	25
HYUNDAI	18
CONTINENTAL	10
BOSCH	27
MAGNA	5
LUMINAR	46
VELODYNE	16
QUANERGY	7
OUSTER	6
AEYE	6
INNOVIZ	10
GOOGLE+WAYMO	60
UBER	26

### III. ILLUSTRATION

#### A. Patent strength indicators

The following patent strength indicators are used in this paper:

- Published patent families: patent documents based on exactly the same priority, including continuous and divisional application.
- Issued patent families: at least one member issued will be counted one issued families.
- Average independent claims: the average numbers of independent claims for one applicant. The family member who have the maximum number of independent claims, will be the number of independent claims of the family.
- Numbers of technology classifications: the numbers of technologies finished by one applicant based on the concept of researchers.
- Numbers of IPC classes: the numbers of technologies finished by one applicant based on International Patent Classification classes.
- Average cited numbers: cited families of every patent family and every year.

- Average citations: average numbers of citations for one patent family, including patent and non-patent citations.
- Average members of one patent family: one patent office counted as one member, PCT application during international phase counted as one member.
- Patent coverage of GDP: issued patent coverage on GDP, based on IMF publication of 2019.
- Total strength: sum of all normalized indicators.

#### B. Patent strength of issue rate

Fig. 3 is a patent strength diagram of patent issue rate, the X axis is normalized numbers of patent publication families, and the Y axis is normalized numbers of patent issue families. This diagram visualizes patent issue rates of inventions for competitors. The sizes of bubbles are proportional to the total strengths.

The GOOGLE+WAYMO, who has highest total strength, and is far away the coordinate origin, which means it has the most inventions and the highest issue rate. The LUMINAR occupied the second position, and then GM. The AEYE has larger bubble but near origin, it has fewer inventions but higher total strength. Three vehicle companies, BOSCH, FORD, and TOYOTA, have higher inventions but issue rates are not high.

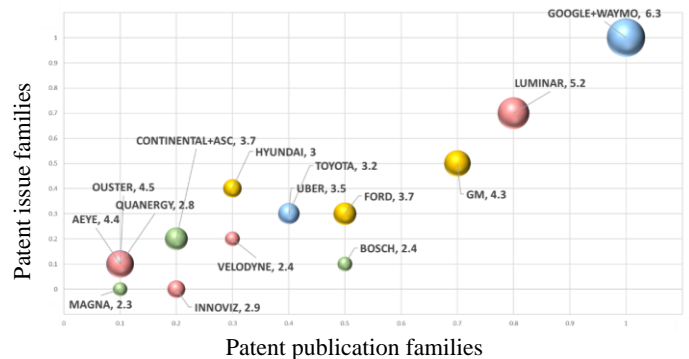


Fig.3 Patent strength of issue rate

#### C. Patent strength of claim broadness

Fig.4 is a patent strength diagram of claim broadness, the X axis is normalized numbers of patent issue families, and the Y axis is normalized numbers of average independent claims in one patent. This diagram visualizes valid patent strength and claim broadness of inventions for competitors. One independent claim is one invention based on the definition of patent law. One patent may has more than one independent claim if meet the unity of invention of statutory requirement. The more independent claims, the broader patent right in one patent.

The GOOGLE+WAYMO has higher issue families, LUMMAR and GM occupied the second, third position again. But three applicants, INNOVIZ, AEYE, and OUSTER, even lower issue families, have relatively high independent claims more than 10 in one patent,.

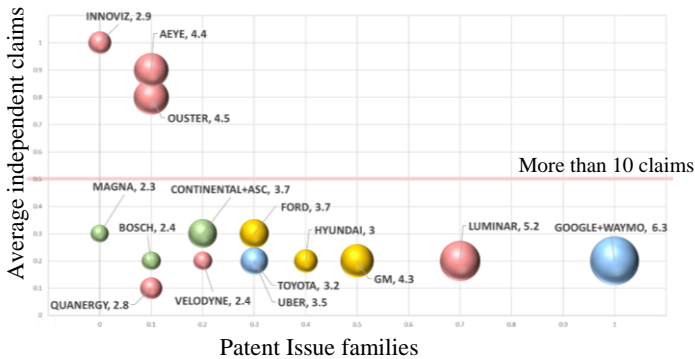


Fig.4 patent strength of claim breadth

*D. Patent strength of technology breadth*

Fig.5 is a patent strength diagram of technology breadth, the X axis is normalized varieties of technology for research, and the Y axis is normalized numbers of IPC classes.

The vehicle related LiDAR technology can be divided into three main classifications: input units, process units, and output units. Two classes in output units, cloud data gathering, including 2d and 3d, and distance data collection. Two classes in process units, data calculation and system machine learning. The output units have six classes, light pulse adjustment, light beam field of view adjustment, sensor housing structure, sensor damage protection, phase array in sensor, and sensor system monitoring. This classifications are based on to the concept of researchers.

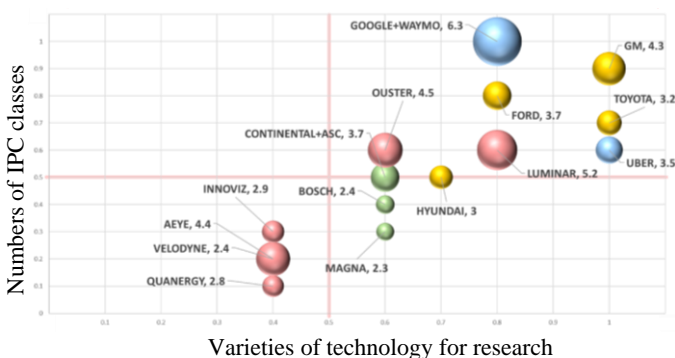


Fig.5 patent strength of technology breadth

Four vehicle manufactures, GM, TOYOTA, FORD, and GOOGLE+WAYMO, located in the first quadrant and far away center, have relatively broad technology for both researchers and IPC classes, they need

comprehensive technology to fulfill LiDAR on their vehicles, including input, output and process units. AEYE, VELODYNE, and QUANERGY, located in the third quadrant, have relatively narrow technologies, they only develop in more specific fields.

*E. Patent strength of technology depth*

Fig.6 is a patent strength diagram of technology depth, the X axis is normalized numbers of average cited, and the Y axis is normalized numbers of average citations.

The higher cited numbers mean higher inventive steps, the higher citations mean the invention based on broader prior arts. Three applicants, OUSTER, LUMINAR, and AEYE have higher citations than others, they develop their technology based on broader prior arts. AEYE is one of them has high cited. GOOGLE+WAYMO has lower citations but higher cited numbers. Worldwide vehicle manufactures, TOYOTA, FORD, HYUNDAI, BOSCH, and GM, all have lower cited and citations, which mean that they develop their own LiDAR system.

Patent cited numbers are most often used as an indicator of patent strength. We can see QUANERGY has the highest cited numbers but does not have a high total strength. Instead, GM and UBER have higher total strength than QUANERGY, but very low cited numbers.

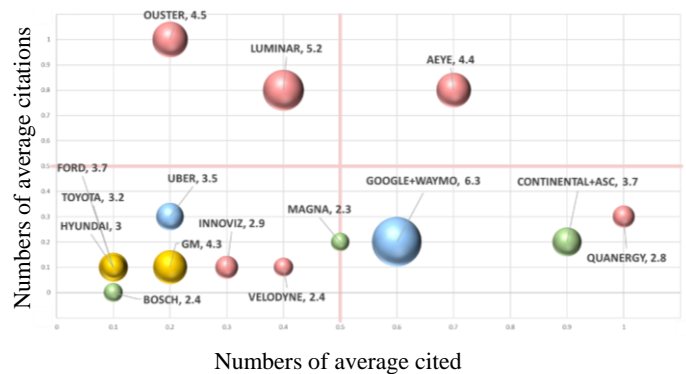


Fig.6 patent strength of technology depth

*F. Patent strength of geographical coverage*

Fig.7 is a patent strength diagram of geographical coverage, the X axis is normalized numbers of average members of one family, and the Y axis is normalized numbers geographical market coverage based on GDP.

The higher average members of family means higher cost to get patent of one invention, and the invention is more important for applicants. But higher members of one family does not equivalent to higher geographical coverage, because regions and markets covered by each country differs greatly. The geographical GDP coverage of one patent family means the size of market for one patent family can



enforce, the higher GDP coverage, the stronger of the patent.

The GOOGLE+WAYMO has the highest GDP coverage but middle members of family, similar to LUMINAR. On the contrary, AEYE and OUSTER have highest members of family, but low coverage GDP. This diagram can truly visualized the breadth of patent coverage and avoid the demerits of only the number of patent family members.

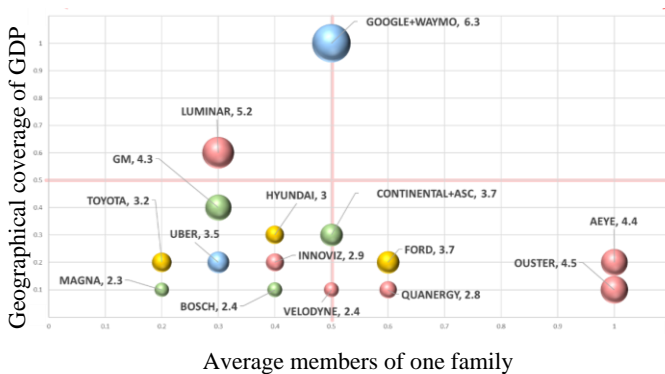


Fig.7 patent strength of geographical coverage

#### IV. CONCLUSIONS

The total patent strength of nine indicators in this paper, fifteen LiDAR competitors ranked in order of GOOGLE+WAYMO, LUMINAR, OUSTER, AEYE, GM, FORD, CONTINENTAL+ASC, UBER, TOYOTA, HYUNDAI, INNOVIZ, QUANERGY, BOSCH, VELOCITYNE, and MAGNA.

In this paper, five 2D diagrams visualize patent strength of competitors in different aspects, patent issue rate, claim broadness, technology broadness, technology depth, and geographical coverage. All patent indicators are based on patent families, which are equivalent to inventions, and reflect the strength of competitors' innovation.

The forward and backward citations also counted based on patent families, citations for one family are the number of members' cited families, and avoid double counting.

Patent independent claims visualized true numbers of invention, each individual claim can become one patent if the applicant uses divisional application. Consider the number of independent claims closer to the actual number of inventions defined by patent law.

Geographical coverage of GDP can visualized market coverage of one patent family, to avoid the disadvantages of using family members.

Without these new indicators, some companies like INNOVIZ, AEYE, OUSTER, who have high independent claims, high average citations, may be evaluated unimportant.

In LiDAR industrial related news, many companies have already cooperated, the patent strength diagrams also helpful for companies to fine cooperation partners according to specific indicators which they concern, or under their complementary need.

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