A Study Of Worldwide Patent Strength Of Competitors
On Advanced Driver Assistance System

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Abstract—**A study of worldwide patent strength and patent comprehensive of competitors based on patent maps are presented in this paper. A worldwide developing technology, advanced driver assistance system, was selected to demonstrate the analysis. The slope of an applicant on publications- issues diagram is an easily calculated indicator of patent strength, the occupied nodes percentage on a technology-function matrix is an easily calculated indicator of patent comprehensive.**

Patent pool in this study are from official database by USPTO, EPO, JPO, SIPO, and WIPO. Patent strengths of top ten competitors and patent comprehensive of top three based on patent maps are analyzed, the result shows that Toyota takes the lead in worldwide patent numbers, but other five Japanese companies have higher quality, and General Motor owns the most comprehensive patents.

Keywords—ADAS; patent strength; patent map; patent comprehensive;

I. INTRODUCTION

Patent right is an important asset of a company, modern companies own thousands of patents, and patent evaluation based on patent strength has gathered great importance in recent years. This paper introduces a study of worldwide patent strength. More specifically, easily calculated indicators of patent strength and comprehensive based on patent maps.

In the latest two decades, patent citation analysis to determine strength and value of a patent is prosperous in patent bibliometric, which is a mathematical and statistical study of patent quantity and quality based on patent documents. Researchers developed some indicators to evaluate quality of patent. Narin and Olivastro [1] studied patent citation cycles, Narin [2] analysed current impact index of US patents for countries of citizenship. Alber [3] analyzed technology strength based on current impact index. 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 fields usually has the highest number of citation as prior art by subsequent patents [4].

However, all the studies and commercial software evaluates patent strength based on citations are limited in United States Patents, because all indexes based on patent citations rely on the prior arts list in the patent publication documents. The most convenient documents are patent gazette published by United States Patent and Trademark Office. Other patent offices, for example European Patent Office, whose prior art lists in search reports are PDF type, it is more difficult to calculate the patent strengths of other countries based on the number of citations. Patent strengths are different in different countries. A company owns high value patents in the U.S. is not necessary have high value in Europe.

The size of patent family is another indicator of patent strength, the larger size of family, the higher value of the patent. Harhoff [5] has ever evaluated the value of patents not only by citations but also family size, which can represent worldwide patent strength. However, the market covered in a country may be quite different from another country, an invention with a larger patent family size may cover narrower market than a smaller one. Therefore, the definition of patent family is important to determine the patent strength [6].

We need an indicator, which is easily calculated based on the official publications, to represent worldwide patent strength.

The multiple national patent filing costs are high for international companies because they produce hundreds of inventions in a year. In order to reduce patent cost, a good filing strategy is important to get worldwide patents [7]. National routes are applications file to national patent offices, these routes need different languages and examination fees at filing. The Patent Cooperation Treaty (PCT) system consolidates one application beginning at international phase, and then enters national phase or regional phase to get more national patents. The fees in international phase of PCT system is lower comparing to national routs, but get the patents issued slowly because it needs thirty months during international phase.

In recent years, more and more companies select main countries by national routs, others by the PCT rout as their filing strategy, which reduces cost and gets main national patents quickly. The United States of Patent and Trademark Office(USPTO), European Patent Office(EPO), Japan Patent Office(JPO), China Patent Office(State Intellectual Property Office of the P.R.C., SIPO) become the most four popular national patent offices, because they grant patents cover big market.

An analysis of international patent strength based on patent maps will be presented in this paper. A typical worldwide developing technology, advanced driver assistance system (ADAS), was selected to demonstrate the analysis. We made patent search in the database of USTPO, EPO, JPO, SIPO, and World Intellectual Property Organization (WIPO) individually, patent activities and patent strengths of main applicants are shown on publications-issues diagram, worldwide patent strengths of top ten competitors are calculated based on a new indicator. Furthermore, patent comprehensive of top three competitors are calculated based on technology-function matrixes [8].

II. METHODOLOGY AND DATA

The pool of patents in this study was gotten from official databases by organized search queries. We found that GPS is an important key word in advanced driver assistance system during search. Table 1 is the search queries in USPTO, JPO, EPO, SIPO and WIPO, and both the numbers of publication and issue we got. Different databases offer different types of search interface. We utilized patent classification and key words and made the pools consistent as could as possible.

Table 1 Search queries and the numbers of publication and issue

database	Search query	Publication issue
USPTO	(SPEC/GPS and CPCL /B60W and APD/20060 101->20151231)	2598
		1486
JPO	[GPS/TX]*[B60W?/IP]*[20060101:20151231/AD]	1788
		961
EPO	GPS in the full text AND 20060101:2015231 as the publication date AND B60W as the IPC classification	367
		109
SIPO	Application date= 2006 0101:20151231 AND IPC=(B60W) AND description=(GPS) AND priority=2006 0101: 20151231 AND patent type=("I") AND language =(CN)	757
		196
WIPO	ALL:GPS AND IC:B60W AND AD:([01.01.2006 TO 31.12.2015]) AND DP: ([01.01.2006 TO 31.12.2015])	1020
		n/a

The top 10 main applicants are selected to be competitors and compare their patent strengths. Table 2 is the top 10 main applicants in USPTO, JPO, EPO, SIPO, and WIPO. In USPTO, the U.S.'s and Japanese companies occupy top 9, only one Swedish company, Volvo, rank 10. The top 10 applicants in JPO are almost Japanese companies, except one German company, Daimler. Six Japanese companies and four European companies occupy top ten in EPO. In China, automobile companies from the U.S., Japan, German, Sweden, Korea, occupy top 10.

Table 2 main applicants and ranking in USPTO, EPO, JPO, SIPO and WIPO

	Nationality	USPTO	JPO	EPO	SIPO	WIPO
Ford	US	1			1	
GM	US	3			2	
Google	US	4			10	8
Toyota	JP	2	1	1	3	1
Denso	JP	5	3	10		
Nissan	JP	6	2	3	8	5
Aisin	JP	7	5	2	7	
Honda	JP	8	4	7	9	10
Hitachi	JP	9	6	5		9
Mitsubishi	JP		7			
Equos	JP		9			
Fujitsu	JP		10			
Scania	SE			6	5	2
Bosch	DE			8	4	4
Daimler	DE		8			
Audi	DE			9		
Continental	DE				7	7
Volvo	SE	10		4		6
Jaguar	UK					3
Hyundai	KR				6	

The top 9 automobile companies in the world by Forbes are Toyota Motors, Volkswagen, Daimler, BMW, Honda Motors, General Motors, Ford Motor, Nissan Motor, Hyundai Motor, and SAIC Motor. We can see that Volkswagen, BMW and SAIC aren't shown in the table.

After sum up the rank number in the five offices, we got the top 11 competitors in this study are Toyota, Nissan, Aisin, Scania, Ford, Denso, GM, Bosch, Hitachi, Honda, and Volvo.

III. ILLUSTRATION- PATENT STRENGTH

A. Activities of main applicants in the US

Fig. 1 is a publications-issues diagram, which is a patent map, of main applicants in the US. In the figure, x-axis is the number of publications, which is equivalent to the number of applications, y-axis is the number of issues. The size of bubbles is proportional to its

publication numbers. This figure shows the activities of main applicants. Three companies in the leading group, Toyota, Ford, and GM, which are far from the origin.

The bubbles near x-axis means low granted numbers, Hitachi, Aisin, and Flextronics, whose applications have not yet granted, it means that they enter ADAS fields late comparing to other companies, or they abandon more patents during prosecution.

The slope of a company means the percentage of granted, the higher slope near 1, the higher patent strength. Nissan and Google are very close to slope 1, they have high quality patents. To get a patent granted is not difficult in modern patent prosecution though, especially for big companies, who know prior arts very well. Some applications were abandoned during prosecution, because of low value under their own evaluation. In the other hand, a company with lower slope means high percentage of pending, the reason may be longer time to amend claims, and also means lower value of patent.

The longer the bubble from the origin means higher patent strength based on both numbers of applications and issues.
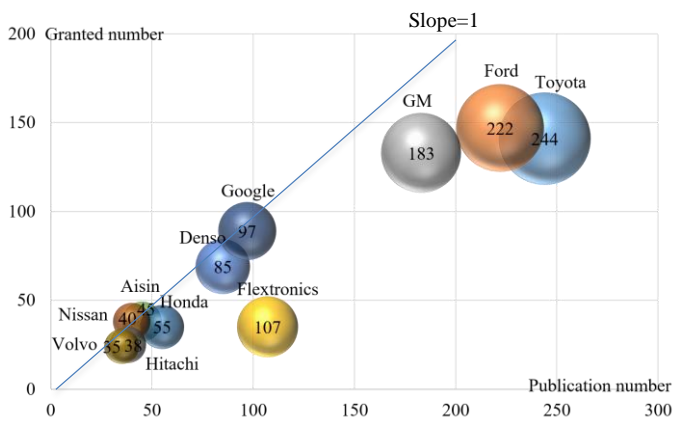

Fig. 1 Activities of main applicants in the US

B. Activities of main applicants in JP

Fig. 2 is Activities of main applicants in Japan. We can see that almost Japanese companies. Toyota, Nissan, Honda, Mazda, and Mitsubishi are all Japanese automobile companies. Denso, Aisin, and Fujitsu are their satellites. Toyota is very far from the origin, but Hitatchi owns the highest percentage of granted.

Both European and U.S.'s companies have very low patent activities in Japan, the reason could be Japan is not their major market.

Toyota is far away the origin alone, and owns more than three times patents than the second applicant, Nissan. Other companies gather in the district below 100 granted numbers.
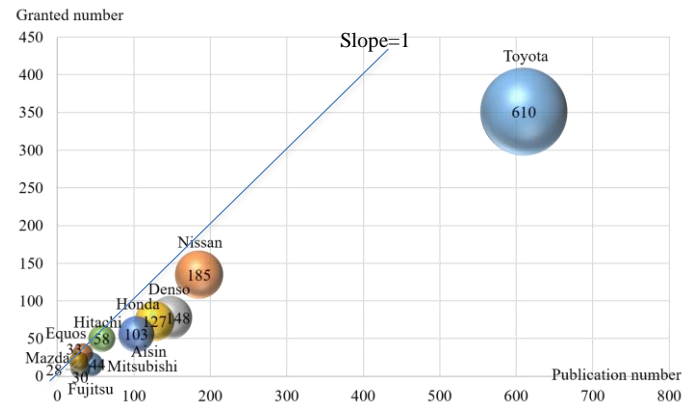

Fig.2 Activities of main applicants in JP

C. Activities of main applicants in Europe

Fig.3 is Activities of main applicants in Europe. All companies are more close to x-axis, comparing to Fig.1 and Fig.2. It shows a normal condition that higher cost and more time, comparing USPTO and JPO, to get patent granted from European Patent Office. It compels applicants screen their applications strictly to EPO. Toyota is the top 1 applicant again, but Aisin, the second, has higher percentage of granted number.

Japanese companies have high activities in Europe and far away from the origin, however, lower slopes than the slopes in the U.S. and Europe.
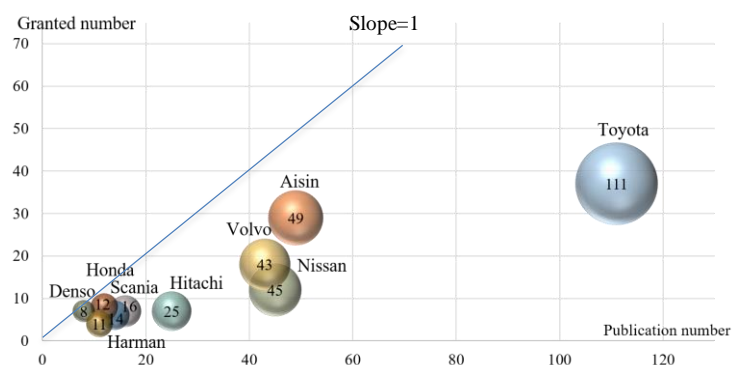

Fig. 3 Activities of main applicants in the EP

D. Activities of main applicants in China

Fig. 4 is activities of main applicants in China. China is a huge market, attracting many companies from other countries. Five companies are from Japan, two of them are from the U.S., three of them are from Europe, two are Germany, the other is Sweden.

Toyota, General Motor, and Ford are the top three applicants in China. Ford, as a US company and top one applicant, pay attention in China but almost give up Japan the Europe. Besides, Ford is very close to x-axis in the figure, it means that it enter the market late, high percentage of applications are still pending.

China is less important than the U.S. and Europe for the five Japanese companies, we can see that their applications are low.
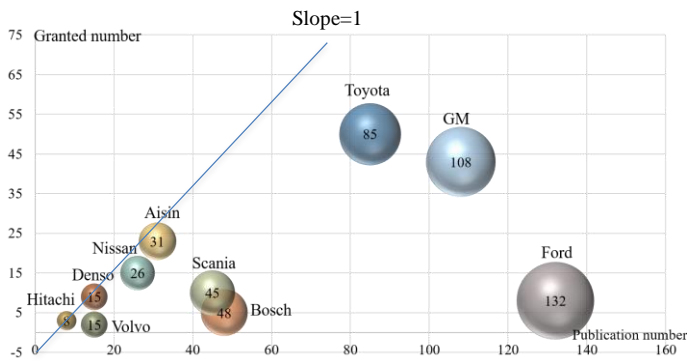

Fig. 4 Activities of main applicants in the CN

E.   Main applicants in USPTO, JPO, EPO, SIPO, and WIPO

Fig.5 is the top 11 applicants in USPTO, JPO, EPO, SIPO and WIPO, and their patent application numbers.

The PCT applications in WIPO have possibilities to enter any countries they like. The top three applicants in WIPO is Toyota, Scania, and Bosch.

The normal filing strategy is that, first file to mother country, and selected valuables into other countries by one year and claim priority. For example, the top 1 applicant, Toyota, first file to Japan, and selects one third to one fourth to file USPTO and WIPO, and selects one third to one fourth again to EPO and SIPO. Nissan has a similar strategy.

Ford and GM pays attention to the U.S. and China only, it selects half of U.S. applications to China.

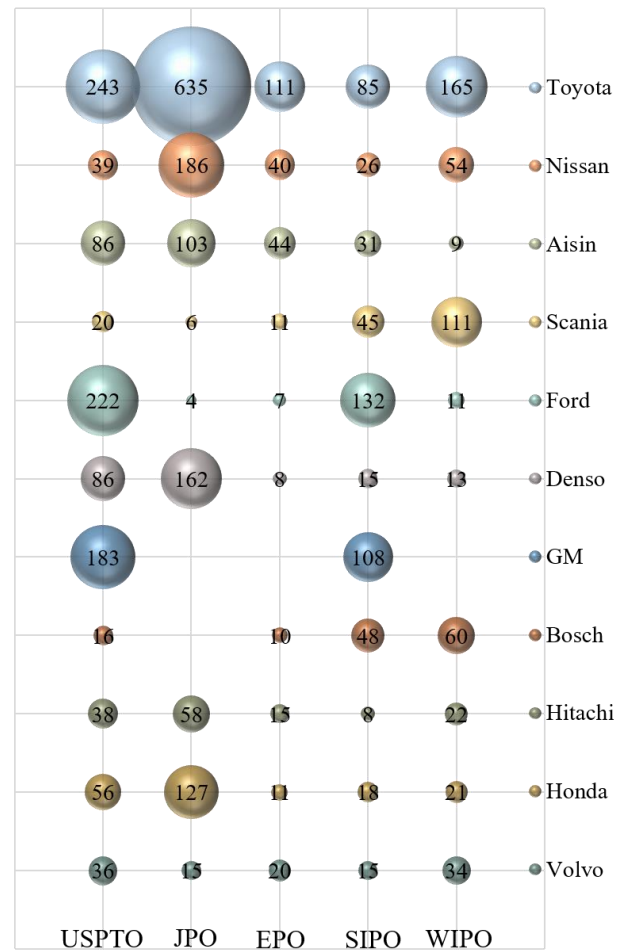Scania and Bosch utilize PCT system to get worldwide patents.

Fig.5 top 11 applicants in USPTO, JPO, EPO, SIPO and WIPO

F.   Patent strength of Main applcicants in USPTO, JPO, EPO, and SIPO

Table 2 is the slopes in publication-issue diagram of competitors in USPTO, JPO, EPO, and SIPO.

Table 2 Patent strength of main applicants based on slope

	USPTO	JPO	EPO	SIPO	TTL
Toyota	0.58	0.55	0.33	0.59	2.05
Nissan	0.85	0.53	0.27	0.58	2.23
Aisin	0.84	0.54	0.59	0.74	2.71
Scania	0.87	0.33	0.44	0.22	1.86
Ford	0.66	0	0.67	0.06	1.39
Denso	0.81	0.48	0.88	0.6	2.77
GM	0.73	0	0.5	0.4	1.63
Bosch	0.72	0	1	0.1	1.82
Hitachi	0.66	0.86	0.28	0.38	2.18
Honda	0.64	0.57	0.43	0.45	2.09
Volvo	0.69	0.67	0.42	0.13	1.91

If we regard the slope, percentage of granted, as an indicator of patent strength, we can find that the strongest company would be Denso, 2.77 in total. Aisin has 2.71 and occupies the second, another three Japanese companies, Nissan, Hitachi, and Honda, have higher value than Toyota. Ford is strong in USPTO, EPO, but weak in JPO and SIPO.

Table 3 is the normalized distance in publication-issue diagram of competitors. We can see that the strongest company is Toyota, who get top 1 in USPTO, JPO, and EPO. Ford occupies the second, and then GM, Nissan, and Aisin.

Table 3 Patent strength of main applicants based on distance from origin

	USPTO	JPO	EPO	SIPO	TTL
Toyota	1	1	1	0.75	3.75
Nissan	0.2	0.32	0.4	0.23	1.15
Aisin	0.21	0.16	0.49	0.29	1.15
Scania	0.11	0	0.15	0.35	0.61
Ford	0.94	0	0.12	1	2.06
Denso	0.39	0.25	0.09	0.13	0.86
GM	0.8	0	0.02	0.88	1.7
Bosch	0.11	0	0.07	0.36	0.54
Hitachi	0.16	0.11	0.22	0.06	0.55
Honda	0.23	0.2	0.13	0.09	0.65
Volvo	0.15	0.02	0.4	0.11	0.68

IV. ILLUSTRATION- PATENT COMPREHENSIVE

A technology-function matrix is a two dimensional matrix, which using the functions and the technical means to be its two coordinate axes, and drawing each nodes proportional to the number of patents. A bigger node means higher patent density which is a popular and crowded technical problem and solution. On the contrary, a smaller node means lower patent density which is a neglected or not yet solved problem and solution.

Technology-function matrix could be used to show the patent comprehensive or breadth of a company. There are many technical problems have to be solved in advanced driving assistance system. Fig.5 is one kind of technology-function matrix of Toyota formed by the U.S. patents. The x-axis shows input information of a vehicle, the y-axis is output function. Five classes of Input information are shown in the matrix, eleven output functions in total. A vehicle with all functions in the matrix have a powerful advanced driving assistance system.

Toyota is strong in sensing surrounding environment and possess almost comprehensive output function,

except future prediction has not yet finished. Toyota has occupied 25 nodes in the matrix.
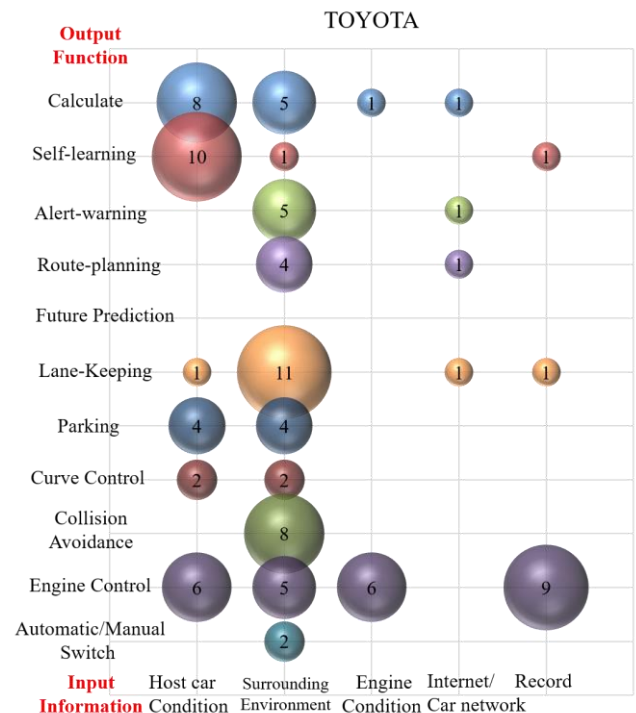

Fig. 5 Technology function matrix of Toyota

Fig.6 is a technology-function matrix of Ford, who are empty in three output functions, self-learning, route-planning, curve control, collisions avoidance. It means that Ford's ADAS is less comprehensive than Toyota's in output functions. If all patents are integrated in a vehicle, Toyota's vehicle will have more powerful functions.

However, Ford's output functions are corresponding to more complete input information, including engine conditions, car network, and record. Therefore, Ford occupies 29 nodes, more than Toyota, in the same matrix.

Fig.7 is a technology function matrix of GM. GM's vehicle owns almost all output functions except self-learning. All output functions corresponding to host car condition, and surrounding environment. GM's vehicle is strong in sensing surrounding environment, and depends on host conditions to do autonomous output controlling.

If we regard the occupancy in the matrix as an indicator of patent comprehensive, we can get that the indicator of GM is 0.58, Ford is 0.51, and Toyota is 0.45. GM has the most comprehensive patent on advanced driving assistance system.
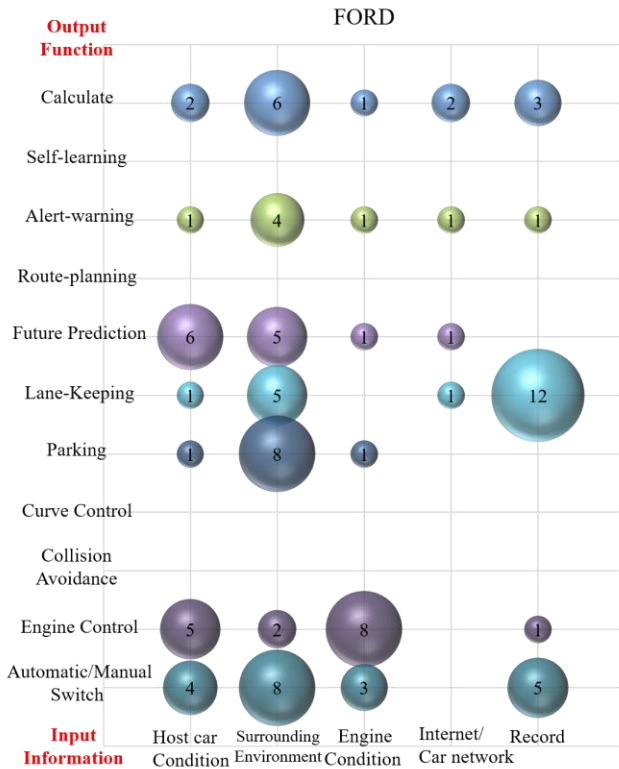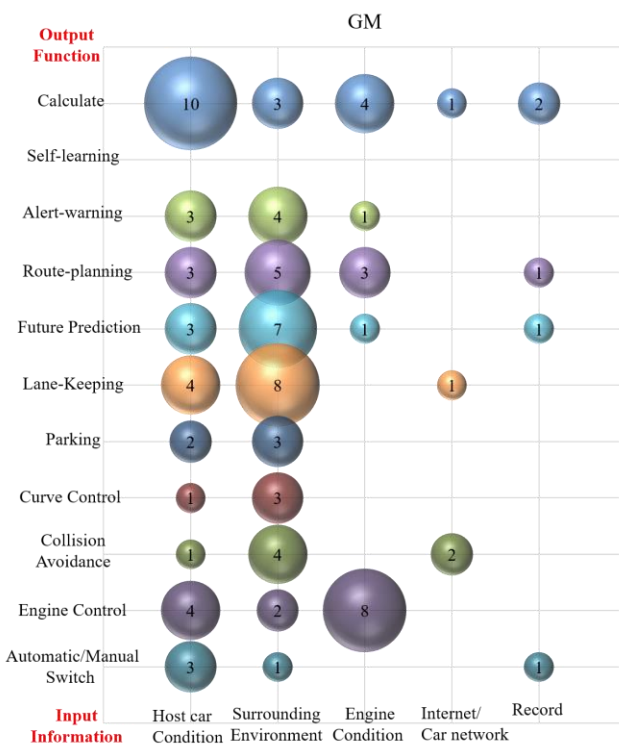
Fig. 7 Technology function matrix of GM

Fig. 6 Technology function matrix of Ford

V. CONCLUSIONS

Patent maps are useful tools for patent analysis, the publications-issues diagram visualizes patent activities of main applicants in USPTO, EPO, JPO, and SIPO. A matrix of international main applicants shows their international filing strategies. The technology-function matrix visualizes technical completeness and vacancies of top three applicants.

We can easily get the indicators of patent strength and comprehensive based on patent maps at the same time. The results of analysis show that Toyota is the top 1 applicant and patentee in advanced driving assistance system all over the world, however, Denso owns the highest percentage of granted patents, Aisin, Nissan, Hitachi, and Honda also have higher strength than Toyota.

GM and Ford have less patents in Japan, Europe, comparing Japanese companies, however, GM owns the most comprehensive ADAS, and has the strongest patent based on the analysis of technology-function matrix of U.S. patents.

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