Network Analysis of LED Fusion Technology

Young-Duk Koo, Dae-hyun Jeong

***Abstract*—** This study investigates not only the LED lighting field but also the networks of fusion technologies of vehicle-transportation, of medicine-environment, of communications, and of agriculture & life science-other field. Data were analyzed for interconnectivity and technological importance through the IPC classification since the year of 2000, of Korean, U.S., Japanese, European, Chinese, and other international patents.

Key technology for each technology field was also discovered through IPC network analysis, and the internal and external intensities between technologies were examined through network density and Gini index.

It is concluded that key fusion technology of medicine-environment and of agriculture & life science-other field is “photoelectric-related semiconductor device” technology, and that of vehicle-transportation, and of communications is “photoelectric circuit device control” technology. In the network structure of LED fusion technologies, the similarities between fusion technologies of agriculture & life science-other field and of medicine-environment were estimated to be high. It is estimated that in the LED technology field, R&D has more technological variety when centering on other technologies, such as control device, instead of the conventional photoelectric semiconductor technology field, consequently having a better aspect of fusion.

***Keywords*—** LED fusion technology, fusion technology of vehicle-transportation, fusion technology of medicine-environment, fusion technology of communications, fusion technology of agriculture & life science-other field, patent analysis

I. Introduction

A social network can be expressed as a network of relationships where people are connected. It is the most important for people to establish a relationship, whether intentional or inevitable. A social network is established on the foundation of these social relationships among people, usually including role- or behavior-based relationships, or cognitive or emotional relationships. The social network theory is based on the graph theory, which is a mathematical model representing the relationships between element pairs in a specific set, expressed by the nodes and the links connecting between the nodes (KISTEP, 2008:14).

The entire structure of a network, the characteristics of the links, and the influences of nodes can be explained by analyzing the shapes of nodes or links. Social network analysis is one of the analysis methods based on this network theory, which is widely employed in various fields today, such as sociology, anthropology, geology, and medicine [4].

The objectives of network analysis include investigating the relationships between social beings such as persons, organizations, or countries through a network, and finding the shapes and content of the network structure. Network analysis is a quantitative method for analyzing the interactions between the nodes using a graph that visualizes the relationships between the nodes in a system. Particularly, this method has provided a powerful analysis means to social network researchers who have been studying social bonding, connections, and networks through quantitative analysis of the specific concepts such as density, centrality, and structural equivalence. In the studies of organization theory and policy network, this method has been used for social Network Analysis (SNA) or network theory [1-3].

In this study, analysis elements will be examined on the micro level, and the network theory will be investigated mainly with betweeness centrality.

Betweeness centrality is a measure of centrality with the betweeness of a specific node connecting one node to another in a network. The betweeness of specific nodes is expressed as the ratio of the number of specific nodes existing in the actual shortest distance to the number of shortest distances between pairs of other nodes. In other words, betweeness centrality measures the degree of betweeness among other nodal points. Its numerical expression is as follows: when $i < j$, $b_{ij}(p_k) = d_{ij}(p_k)$ d_{ij}, and its denominator is the number of geodesic connecting p_i and p_j, and its numerator is the number of geodesic connecting p_i and p_j while including p_k.

$$B_c(p_k) = \frac{2\sum_{i}^{n}\sum_{j}^{n} b_{ij}(p_k)}{n^2 - 3n + 2}$$

Network density is measured based upon the concepts of inclusiveness and degree. Inclusiveness represents the number of actors interconnected in a network, and is calculated with the remaining numbers after subtracting the number of isolated nodes from the total number of nodes in the network. Degree signifies an extent that one node is connected to another node. In other words, the degree of a node indicates the number of other nodes directly connected to the specific node. To examine the accurate density of a network, inclusiveness and degree should be considered simultaneously. That is, in order to accurately measure density, the following two factors should be

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examined: how far the range of the network reaches; and how densely each node is connected to other nodes in the network.

This is expressed by the following formula:

$$\text{Density} = k/g(g-1)/2;$$

k is the number of lines, and g is the number of nodes existing within the network. The denominator g (g-1)/2 is the maximum possible number of lines in the applicable network [4].

II. Future Prospects for the LED fusion industry

Although the BLU (BackLight Unit) market, which is for cellular phone, computer, and TV, is currently dominating the LED industry, it is predicted that various high value-added fusion markets, such as vehicle and medical environment (UV LED), will continue to expand from 2013.

Toward the goal of acquiring technologies for LED product commercialization and design variety, the scope of application is being extended through the acquisition of target technologies for interior lighting design, LED lighting fixtures for replacing fluorescent light and street light, and special lightings for vehicle and medical treatment.

The global LED market has been growing largely due to drastically increased demand for super size display, vehicle exterior, and LCD backlight. In the field analysis, it is estimated that LCD TV, general lighting, and vehicle will lead the entire LED market.

The largest field in the LED market has been TV backlight, which took up to 35% of the entire LED market in 2010, a 7% increase from 2009, and it is expected to reach the maximum occupancy rate of approximately 48% in 2011. However, the general lighting field is expected to lead the LED market from 2012, and consequently, the occupancy rate of TV backlight field is expected to decrease.

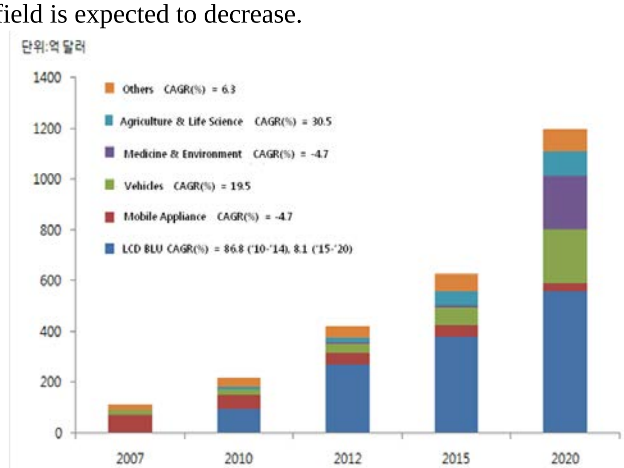

Fig 1. Prospects for LED applications

For the vehicle LED, its application has expanded to various fields such as headlight, interior dashboard, dome light, and high mount stop lamp. Additionally, the growth of the energy-conserving electric and hybrid vehicle market is leading the growth of the vehicle LED field. Although the adoption rate of LED in headlight is still lower than that of halogen due to its high price, it will be gradually adopted by the vehicles that have highlighted advantages of luxury car or high efficiency.

Therefore, in this study, the networks of fusion technologies of vehicle-transportation, of medicine-environment, of communications, and of agriculture & life science-other field were analyzed along with the LED lighting field. Data were analyzed for interconnectivity and technological importance through the IPC classification since the year of 2000, of Korean, U.S., Japanese, European, Chinese, and other international patents.

III. Network analysis of LED fusion technology

A. Vehicle/Transportation Fusion Technology

Network analysis of vehicle-transportation fusion technology revealed that the “photoelectric circuit device control (H05B-037/02)” field has the highest betweeness centrality, followed by the mini LED (F21Y-101/02)" field. In other words, for vehicle-transportation fusion technology, photoelectric circuit device control and mini LED technologies are the key technologies for the development of vehicle-transportation fusion technology.

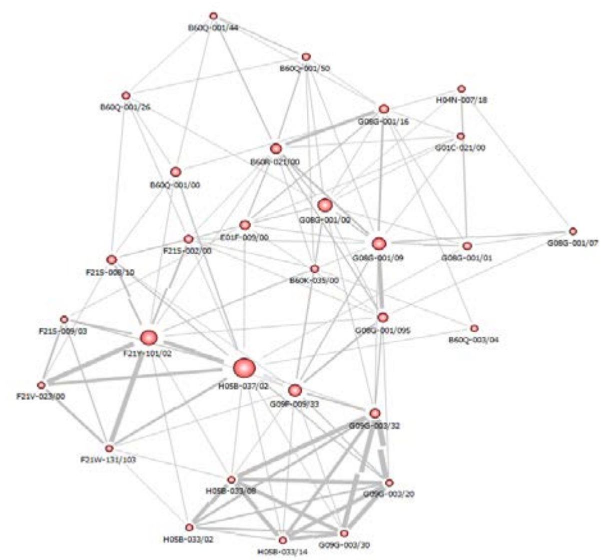

Fig 2. Network Analysis of Vehicle-Transportation Fusion technology

TABLE I
Major IPC betweeness centrality of Vehicle-Transportation Fusion technology

IPC	Betweeness centrality	IPC	Betweeness centrality
H05B-037/02	0.176	B60Q-001/50	0.012
F21Y-101/02	0.116	B60Q-001/26	0.011
G08G-001/00	0.096	B60Q-001/44	0.007
G08G-001/09	0.080	G09G-003/20	0.007
G09F-009/33	0.072	F21W-131/103	0.007
B60R-021/00	0.047	H04N-007/18	0.007
B60Q-001/00	0.044	H05B-033/08	0.006
G08G-001/095	0.042	H05B-033/02	0.005
G09G-003/32	0.041	B60Q-003/04	0.005
E01F-009/00	0.036	F21S-009/03	0.004
G08G-001/16	0.034	G08G-001/07	0.004

F21S-008/10	0.031	F21V-023/00	0.002
G08G-001/01	0.023	G09G-003/30	0.001
F21S-002/00	0.019	H05B-033/14	0.001
B60K-035/00	0.016	G01C-021/00	0.000

B. Medicine-Environment Fusion Technology

Network analysis of medicine-environment fusion technology revealed that the between centrality of the “photoelectric-related semi-conductor device (H01L-033/00)” field was 0.265, indicating a strong technology fusion activity in this field. In other words, for medicine-environment fusion technology, the between centrality of the photoelectric-related semi-conductor device field was a lot higher than that of other fields, which signifies a high significance level for technology.

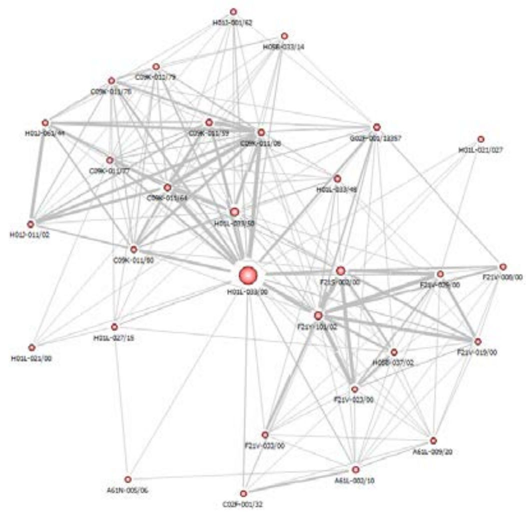

Fig 3. Network of Medicine-Environment Fusion Technology

TABLE Ⅱ
MAJOR IPC BETWEENESS CENTRALITY OF MEDICINE-ENVIRONMENT FUSION TECHNOLOGY

IPC	Betweeness centrality	IPC	Betweeness centrality
H01L-033/00	0.265	C09K-011/79	0.008
H01L-033/50	0.057	C09K-011/78	0.006
F21S-002/00	0.053	C09K-011/80	0.006
F21Y-101/02	0.043	F21V-019/00	0.004
C09K-011/08	0.019	A61L-009/20	0.003
G02F-001/13357	0.018	F21V-008/00	0.001
C09K-011/64	0.017	F21V-033/00	0.001
C09K-011/59	0.016	H01J-061/44	0.001
A61L-002/10	0.015	H01J-001/62	0.001
H01L-033/48	0.014	H01L-021/00	0.001
C09K-011/77	0.012	A61N-005/06	0.001
H05B-037/02	0.012	H05B-033/14	0.001
H01L-027/15	0.011	H01L-021/027	0.000
F21V-029/00	0.010	H01J-011/02	0.000
F21V-023/00	0.009	C02F-001/32	0.000

C. Communication Fusion Technology

Network analysis of communication fusion technology revealed that the “photoelectric circuit device control (H05B-037/02)” field has a high technological concentration ratio, thus implicating a high significance level for technology.

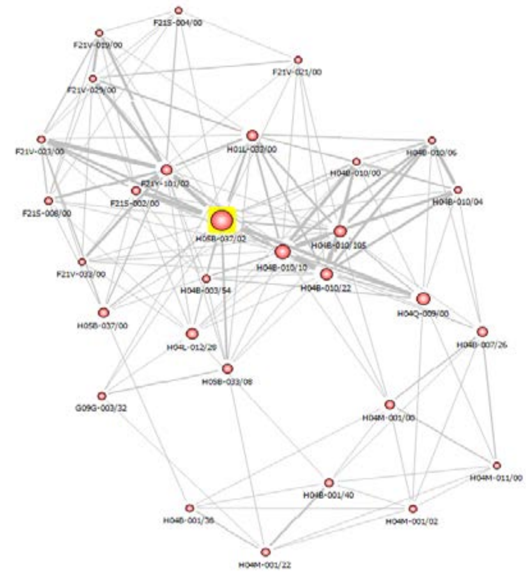

Fig 4. Network of Communication Fusion Technology

TABLE Ⅲ
MAJOR IPC BETWEENESS CENTRALITY OF COMMUNICATION FUSION TECHNOLOGY

IPC	Betweeness centrality	IPC	Betweeness centrality
H05B-037/02	0.142	H04B-001/38	0.014
H04B-010/10	0.083	G09G-003/32	0.012
H04Q-009/00	0.059	H04M-001/02	0.011
H04B-010/105	0.052	F21V-023/00	0.011
H04B-010/22	0.052	H04B-003/54	0.011
H04L-012/28	0.051	F21S-008/00	0.011
H01L-033/00	0.043	H04B-010/00	0.008
F21Y-101/02	0.038	F21V-029/00	0.006
H05B-037/00	0.036	H04M-011/00	0.006
H05B-033/08	0.035	F21V-021/00	0.006
H04B-007/26	0.030	F21V-033/00	0.005
H04M-001/00	0.029	H04B-010/06	0.004
F21S-002/00	0.022	H04B-010/04	0.004
H04M-001/22	0.022	F21S-004/00	0.002
H04B-001/40	0.018	F21V-019/00	0.002

D. Agriculture & Life Science-Other Field Fusion Technology

For agriculture & life science-other field fusion technology, studies show that the “photoelectric-related semi-conductor device (H01L-033/00)” field has high between centrality, indicating the significance of technology.

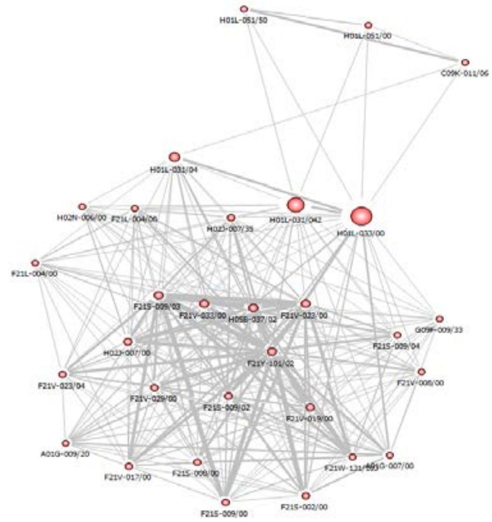

Fig 5. Network of Agriculture & Life Science-Other Field Fusion Technology

TABLE VI
MAJOR IPC BETWEENESS CENTRALITY OF AGRICULTURE & LIFE SCIENCE-OTHER FIELD FUSION TECHNOLOGY

IPC	Betweeness centrality	IPC	Betweeness centrality
H01L-033/00	0.101	F21V-023/04	0.007
H01L-031/042	0.076	F21V-017/00	0.006
H01L-031/04	0.028	F21S-002/00	0.006
H05B-037/02	0.019	F21W-131/103	0.005
F21Y-101/02	0.019	G09F-009/33	0.005
F21S-009/03	0.017	A01G-007/00	0.004
F21V-033/00	0.016	F21V-008/00	0.004
F21V-023/00	0.016	A01G-009/20	0.003
H02J-007/00	0.012	F21L-004/08	0.003
F21V-019/00	0.011	F21S-009/04	0.003
F21S-009/02	0.011	F21L-004/00	0.003
F21V-029/00	0.010	C09K-011/06	0.002
H02J-007/35	0.010	H02N-006/00	0.002
F21S-008/00	0.008	H01L-051/00	0.001
F21S-009/00	0.007	H01L-051/50	0.001

IV. RELATIONSHIP BETWEEN TECHNOLOGY FUSION

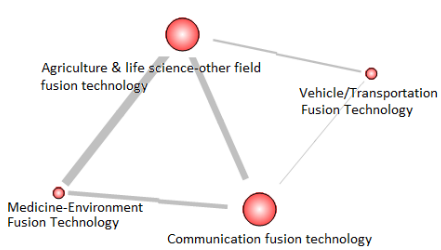

Fig 6. Network Structure of LED Fusion Technology

The analysis of the network structure of LED fusion technology revealed that technological similarities between the fusion fields of agriculture & life science-other field, of medicine-environment, and of communications are high. For fusion technologies of vehicle-transportation and of communication, the "photoelectric circuit self control (H05B-037/02)" field is found to be the key technology, whereas for fusion fields of medicine-environment and of agriculture & life science-other field, the "photoelectric-related semi-conductor device (H01L-033/00)" technology is found to be important.

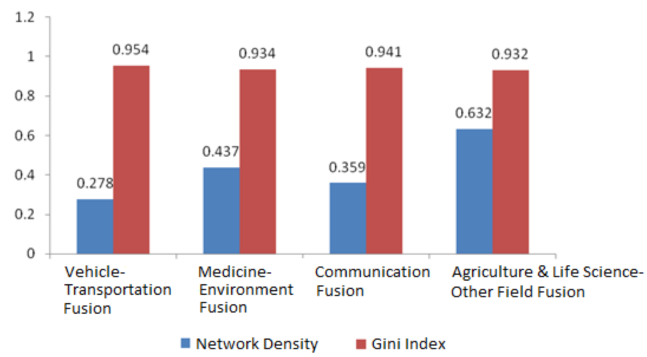

Fig 7. Analysis of Network Density between LED Fusion Technologies and Gini Index

Network density and Gini index for each technology field showed that agriculture & life science fusion technologies have strong innnerconnections, and the vehicle-transportation fusion field is adopting the greatest variety of technologies.

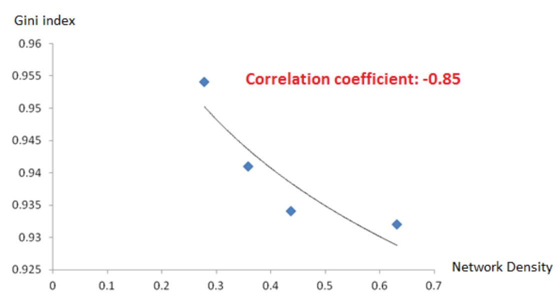

Fig. 8 Correlation Analysis of Network Density between LED Fusion Technologies and Gini Index

The analysis of correlation between two variables indicated that the Gini index value decreases as network density increases, as shown in the Figure. In other words, in developing the applicable technology, the number of technology application cases increases internally as technological variety decreases.

V. CONCLUSION

The analysis of technology network of LED fusion technology showed that for fusion technologies of medicine-environment, and of agriculture & life science-other field, "photoelectric-related semi-conductor device" technology was found to be the key technology, whereas for fusion technologies of vehicle-transportation and of communications, “photoelectric circuit device control” technology was found to be the key technology.

Furthermore, the network structure of LED fusion technology showed that fusion technologies of agriculture & life science-other field and of medicine-environment have strong technological similarities.

Network density and Gini index for each technology field revealed that while agriculture & life science fusion technologies have strong innerconnections, the vehicle-transportation fusion field is adopting the greatest variety of technologies. In other words, the stronger the internal intensity is among technologies, the less the applicable technology is adopted externally.

Network analysis for the LED application technology fields described above revealed that the LED application fields have the biggest number of fusion technologies developed for the vehicle-transportation fusion, indicating that photoelectric circuit technology is most important for fusion technology development. However, the fusion of conventional element technologies in the photoelectric-related semi-conductor device field is relatively decreasing. In other words, among the LED technology fields currently under development, the most active fusion field is found to be in vehicle and communication.

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