Visualization Analysis on Collaborative Network and Research Hot-Spot for Aerospace Engineering Subject

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Abstract. Based on SCIE and DII documents (2006-2015) and social network analysis, this paper analyzes one-mode network structural characteristics of co-authoring, institutional cooperation and patent owner cooperation, then constructs two-mode network by the N-Cliques factions division and author keyword coupling analysis, via the visual tool NETDRAW. It finds 7 cooperative groups, different research hot-spots, Matthew cooperative networks are present, there is a big difference between academic and patent cooperation networks.

Introduction

The State Council promulgated overall plan to promote construction of world-class universities and first-class disciplines[1], and insisted on taking disciplines as the basis to support higher education institutions to optimize disciplinary structure in 2015. One of the effective ways to improve level of discipline development is to fully understand overall cooperation network of the subject. Many scholars have carried out research on subject cooperation network. Qiu Junping carried out network research of discipline cooperation[2]. Chai Yue built a university network of disciplines and characteristics of analysis[3]. Sung-Seok K[4],Hyunseok P[5],Kumar S[6] mainly concentrated in regional or national academic cooperation network research for the development of scientific research strategy. Those papers have not used multi-type literature data source to reveal cooperation networks of the engineering disciplines. Above all, based on the SCIE and DII patent data sources, this paper constructs a two-mode network by using social network analysis method and the coupling analysis of author keywords.

Data Sources and Research Methods

The paper selects the core collection of Web of Science data, and retrieval type is WC=(ENGINEERING AEROSPACE), "WC" represents the subject type, aerospace science and technology subject corresponds to "ENGINEERING AEROSPACE". Patent data select Derwent patent database and retrieval type is IP = (B64B-001/00 OR B64C-001/00 ... OR B64G-099/00), "IP" refers to IPC number, the international patent classification number. This subject corresponds to IPC classification is No. B64 (AIRCRAFT; AVIATION; COSMONAUTICS). 46,311 records were retrieved.

Social network analysis (SNA) comes from matrix theory and graph theory in field of mathematics[7]. Social network refers to a set of social actors acting as nodes and relationships among them, revealing nodes on behalf of structural changes in actors.

Network Structure Analysis

Degree centrality measures location and power of a node in the network. If an actor is directly linked to many other actors, then the actor is in a central position. The co-occurrence matrix is loaded into the Ucinet software and along Network→Centrality→Degree path. Degree centrality results are shown in Table 1.

Table 1 Collaborative network degree centrality measurement results

Number	Author	NrmDegree	Organization	NrmDegree	Patentee	NrmDegree
1	BAO, WEN	0.826	RAS	1.469	AIRBUS	1.693
2	CHANG, JUNTAO	0.794	NASA	1.431	AIRBUS-France	1.407
3	MULDER, M.	0.689	MIT	1.376	AIRBUS-Germany	1.400
4	VAN PAASSEN, M. M.	0.646	DLR	1.196	European helicopter	0.589
5	QUARTA, ALESSANDRO A.	0.508	ESA	0.894	European helicopter-France	0.518
6	MENGALI, GIOVANNI	0.498	USAF	0.604	Boeing	0.501
7	LI, JUNFENG	0.477	JAPAN AEROSP EXPLORAT AGCY	0.563	AIRBUS-Helicopter	0.345
8	YU, DAREN	0.413	GEORGIA INST TECHNOL	0.442	Thales Group	0.296
9	MULDER, J. A.	0.392	Indian Institute of Technology	0.42	Safran Group-Aircelle	0.165
10	HUANG, WEI	0.381	CALTECH	0.392	AIRBUS-English	0.151

Co-Author network centralization=1.33% ; Co-Organization network centralization=0.68%; Co-Patentee network centralization=1.59%

As can be seen from Table 1, Prof. Bowen of Harbin Institute of Technology has the largest degree centrality, the team composed by Chang Juntao and Yu Daren is at the center of the author co-authoring network. The Russian Academy of Sciences and Airbus dominate their respective networks. Despite the prominence of Chinese researchers in individual co-authorship network, Chinese organizations and patentees are not at the center of the network. The overall network centralization of the three cooperative networks is less than 2%, indicating that there are a large number of authors, organizations, and patentees in the three networks have no cooperation.

Betweenness centrality measures the ability of a node controlling other nodes. If a node is between many other two points on the path in the network, it can influence the network by controlling the transmission of information[8]. Betweenness centrality is analyzed along Network→Centrality→Freeman Betweenness→Nodes Betweeness path. The analysis results are shown in Table 2.

Table 2 Results of cooperative network betweenness centrality measurement

Number	Author	nBetwe e-nness	Organization	nBetwee -nness	Patentee	nBetwee-nness
1	SCHEERES, DANIEL J.	2.028	RAS	17.269	ESA-France	1.266
2	ALFRIEND, KYLE T.	1.497	MIT	9.853	AIRBUS	1.169
3	VADALI, SRINIVAS R.	1.457	NASA	8.96	General Electric Company	1.112
4	YAMAKAWA, HIROSHI	1.284	ESA	4.247	AIRBUS-Germany	0.716
5	SCHAUB, HANSPETER	1.263	USAF	2.949	AIRBUS-France	0.674
6	SANKAR, LAKSHMI N.	1.23	Chinese Academy of Sciences	2.227	European helicopter	0.337
7	BUTCHER, ERIC A.	1.229	Beihang University	2.149	United Technologies Corporation	0.2
8	MORTARI, DANIELE	1.219	Cranfield University	2.100	Kawasaki Heavy Industries Limited	0.2
9	BAEDER, JAMES D.	1.183	GEORGIA INST TECHNOL	1.846	HISPANO SUIZA	0.169
10	CRASSIDIS, JOHN L.	1.136	University of Michigan	1.748	European helicopter-France	0.168

Co-Author network centralization=1.90%; Co-Organization network centralization=16.81%; Co-Patentee network centralization=1.19%

As can be seen from Table 2, individual scholars DANIEL J. has the largest betweenness centrality, and nine of the top ten scholars belong to American universities. Europe and the United States academy and airlines are at the core position, controlling resources flows. Chinese Academy of Sciences and Beihang University are among the forefront, which suggests their impacts on other organizations' co-existing. Co-organization network centralization is 16.81%, much higher than the patentee' (1.19%), which indicates the control abilities of academic research institutions in cooperative resource is much stronger than the patentees'.

Closeness centrality measures the ability of a node is not controlled by other nodes. If a node is connected to many other nodes in the network by a relatively short path, it has a relatively high closeness centrality[9]. Closeness centrality is performed along Network→ Centrality→Closeness path. The analysis results are shown in Table 3.

Table 3 Results of cooperative network closeness centrality measurement

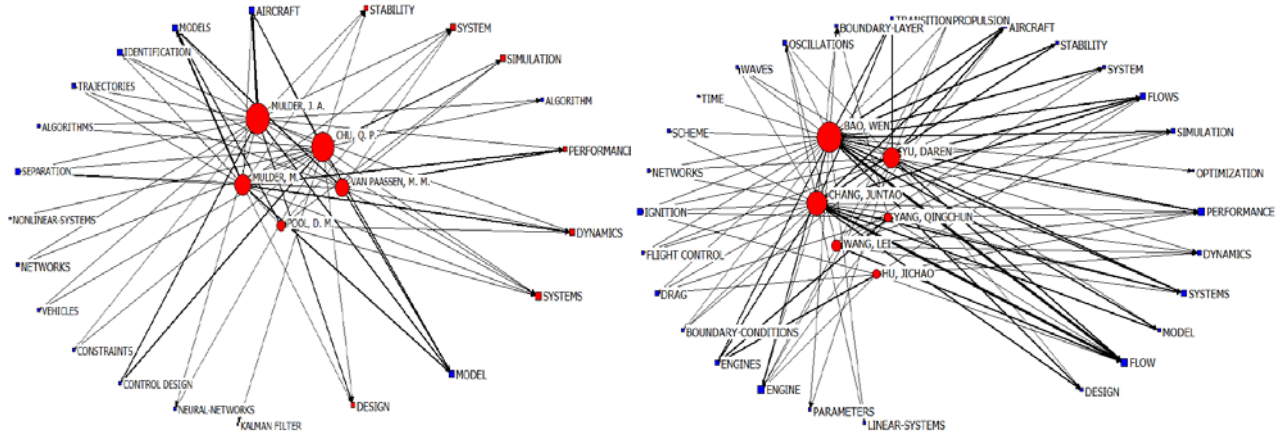
Number	Author	nCloseness	Organization	nCloseness	Patentee	nCloseness
1	SCHEERES, DANIEL J.	0.536	RAS	77.928	AIRBUS	1.04
2	ALFRIEND, KYLE T.	0.536	MIT	73.617	AIRBUS-France	1.04
3	BUTCHER, ERIC A.	0.535	NASA	72.385	AIRBUS-Germany	1.039
4	VADALI, SRINIVAS R.	0.535	ESA	65.283	EADS	1.039
5	SCHAUB, HANSPETER	0.535	USAF	62.681	DLR	1.038
6	CRASSIDIS, JOHN L.	0.535	DLR	60.702	AIRBUS-English	1.038
7	JUNKINS, JOHN L.	0.535	University of Michigan	59.45	General Electric Company	1.038
8	SINGLA, PUNEET	0.535	GEORGIA INST TECHNOL	59.45	AIRBUS-helicopter	1.038
9	MORTARI, DANIELE	0.535	CALTECH	59.45	European helicopter-France	1.038
10	LEE, DAERO	0.535	University of Colorado	57.475	European helicopter	1.038

Co-Author network centralization and Co-Patentee network centralization can't be calculated; Co-Organization network centralization=52.92%;

Nodes, both appearing in table 2 and table 3, aren't controlled by the network control the overall cooperative network resources, they are network bridges. If these nodes leave suddenly, it will have a huge impact on information exchange of the whole cooperative network. As there are no links between nodes of various groups, co-author network centralization can't be calculated. The reason why co-patentee network centralization can't be calculated is the existence of isolated points in the network. The special nature of the technical knowledge contained in the patent makes most patentees applying for patents alone without cooperation with other patentees.

Cooperation Groups and Research Hotspots Visualization

The co-author network is divided into two cooperating groups, and the hot-spot knowledge map is shown in Fig.1.



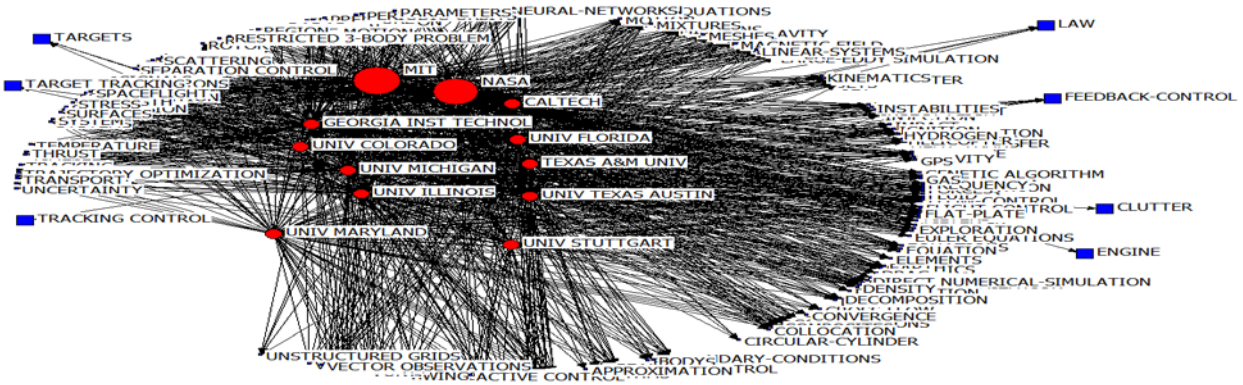
(a) Group 1 (b) Group 2

Figure 1 Co-author network research hot-spot knowledge map

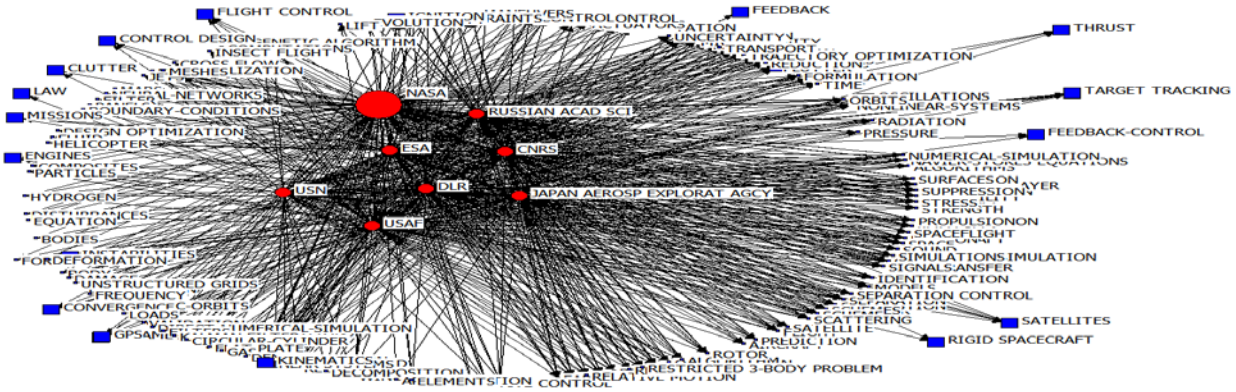
As shown in Fig.1 (a), Mulder J A and Chu Q P belong to Delft University of Technology are the most important nodes in group 1. This team proposed a low-cost power system, by simulating in the high-end simulator, removing system platform constraints composed of platform filter, time delay and noise characteristics, so as to identify pilots' perception and control behavior. As shown in Fig.1 (b), Professor Bao Wen and Chang Juntao are core characters in group 2. The group's representative research is hypersonic cruise missiles, trans-atmospheric vehicles and reusable space propeller

thrusters, and recently create a unique cooling scheme to solve limited heat source of low-temperature heat.

The co-organization network is divided into two cooperating groups, and the hot-spot knowledge map is shown in Fig.2.



(a) Group 1

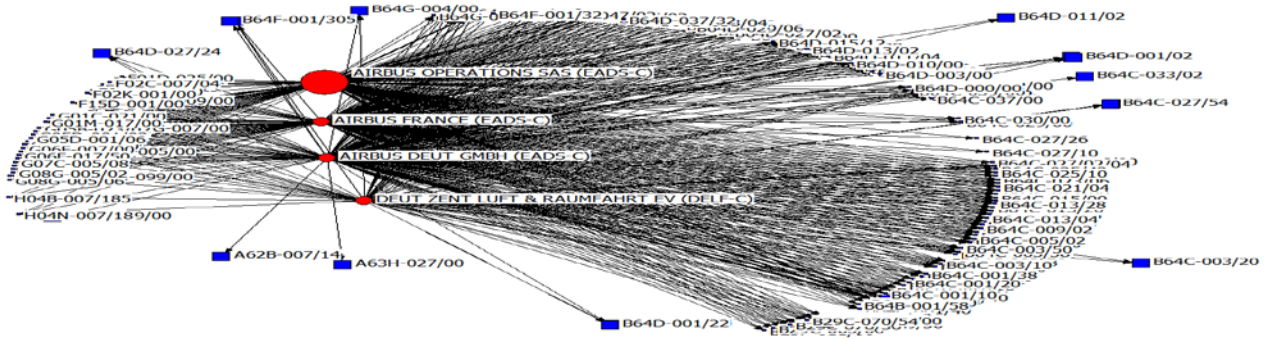


(b) Group 2

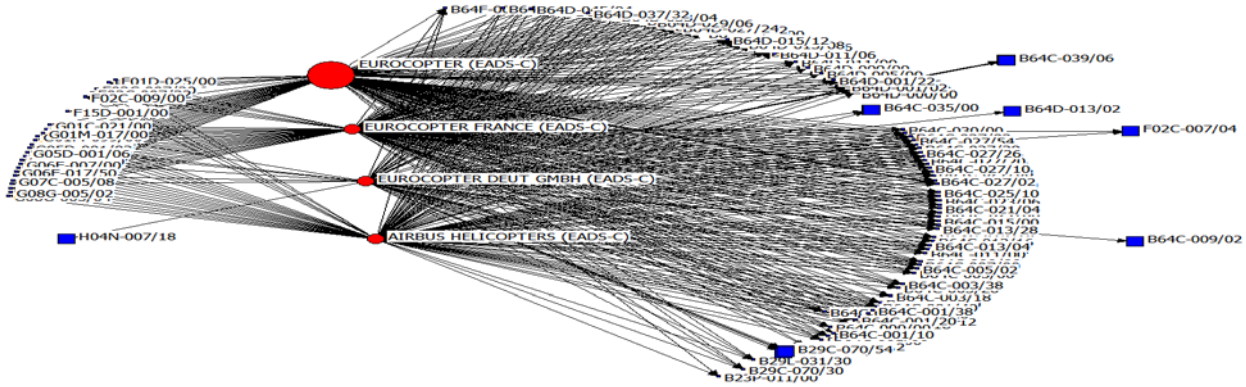
Figure 2 Co-organization network research hot-spot knowledge map

As shown in Fig.2 (a) and Fig.2 (b), group 1 is an American academic institution group centered on NASA and MIT, and group 2 is a research institution group taking NASA as the core. The main research direction of two groups above is space station, target tracking and monitoring of aircraft feedback. Although ESA, Japan Aerospace Research Institute and RAS are main members of group 2, the research content is United States leading space station frontier field. The reason of research knowledge units focusing on tracking and monitoring is the US space station has entered into a stable development stage. The Planetary Defense Coordination Department has been set up to track and monitor space stations and celestial bodies in the universe.

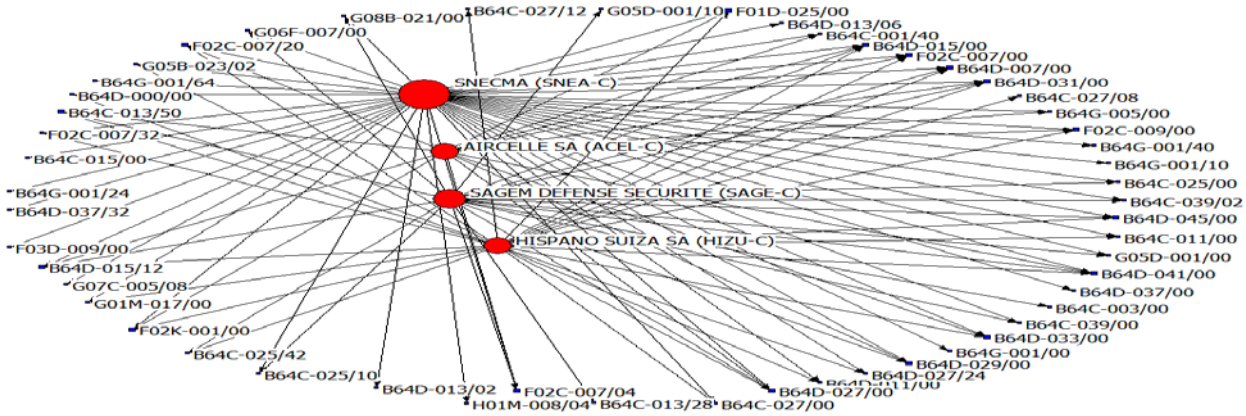
The co-patentee network is divided into three cooperating groups, and the hot-spot knowledge map is shown in Fig.3.



(a) Group 1



(b) Group 2



(c) Group 3

Figure 3 Co-patentee network research hot-spot knowledge map

From Fig.3, Group 1 is Airbus corporation, and its main research directions are helicopter, aircraft and auxiliary equipment related to the production line of Airbus. Group 2 is European Helicopter corporation and its research directions are helicopter and aircraft models as well as auxiliary equipment related to the European Helicopter production line. Group 3 is composed of subsidiaries of Safran Group. IPC nodes' size is uniform, thus technical points are evenly distributed. Safran is a high-tech multinational group in the aerospace industry. Subsidiary Snecma' research direction is the development and production of aircraft power plant. Subsidiary Aircelle whose research direction embodied in the engine system and engine room system, has main technical points including air thrust, heat flow devices, emergency braking system. Safran Electronics Defense's research direction is reflected in the field of aeronautic optoelectronics and key software, with patented technologies in European optoelectronics, helicopter unmanned aerial vehicle control systems and inertial navigation systems (INS). Subsidiary HISPANO SUIZA SA focuses on power-train systems, which are distributed in information technology, new materials, manufacturing processes, innovative design.

Results and Discussion

Based on the above analysis, specific differences between aerospace science and technology journals and patent cooperation networks are shown in Table 4.

Table 4 Comparative Analysis of Aerospace Engineering Subject Periodicals and Patent Cooperation Networks

Contrast	Feature	Periodicals Cooperation Networks	Patent Cooperation Networks
Different points	cooperation degree	Very high, mature stage	Lower, primary stage
	Network density	Lower, more contact and loose	Higher, less contact and close
	Cooperation model	Geo-based, industry-based supplement	Kinship-based
	Representative group	Massachusetts Institute of Technology as the core of the US academic institutions, NASA as the core of the National Aeronautics and Space Administration	Airbus, European helicopters, Safran Group and other parent companies as the core, subsidiaries have their own strengths of large airlines
	Research area	Earth Sciences, Space Science, Monitoring and Tracking of Space Stations and Celestial Bodies, Emphasis on Simulation, Model Optimization, etc. Space Exploration Area	Defense technology, commercial aircraft, helicopters, aerospace, military transport and combat aircraft and related services, with a focus on technology areas such as manufacturing, service and maintenance
Identical points	Matthew Effect	Scale-free network characteristics, a few nodes have a large number of connections, most nodes are connected very little	

There are great differences between journals and patent literature-based cooperative networks in the aerospace engineering subject. It is believed that the cooperation should be aimed at the differences, promote the integration of academic research and applied research, so as to promote development of the subject and the level of aerospace industry.

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