II. Information & Electronic Engineering

1 Engineering research hotspots and engineering research focus

1.1 Development trends of engineering research hotspots

The top 10 engineering research hotspots in the information and electronic engineering field are summarized in Table 1.1.1. They cover the subfields of electronic science and technology, optical engineering and technology, instrument science and technology, information and communication engineering, computer science and technology, control science and technology, and other disciplines. Among them, "Multi-object tracking technologies," "Characteristics and analyses of neural networks/neural network modeling and fuzzy logic," "Robust adaptive boundary control," "Ultra-wideband slot antennas," "Dynamic network visualization," "Global optimization algorithms," "Multi-criteria decision making," "Reversible data-hiding schemes," "High-utility itemset mining algorithms," and "Optical coherence elastography" are in-depth research topics of traditional research.

The numbers of core papers in each engineering research hotspot published annually from 2011 to 2016 are shown in Table 1.1.2.

(1) Multi-object tracking technologies

In recent years, multi-object tracking has emerged as an important science and technology. It is related to a variety of disciplines, including stochastic statistics, mathematical optimization, image processing, pattern recognition, artificial intelligence, and automatic control. Multi-object tracking has been widely used in military applications, especially in the application of airborne detection and remote warning.

The current issues in multi-object tracking include occlusions, the randomness of the number of objects, complex backgrounds, and real-time requirements. The focus of overseas research has shifted from multi-object tracking technology using a single sensor to multi-object tracking with multiple sensors. With the rapid movement of objects and the changing environment of multi-object tracking technology, tracking the maneuvering object has attracted a renewed interest. Another research hotspot is the implementation of artificial neural networks to achieve multi-object tracking. Owing to the potential self-organization and self-learning abilities of artificial neural networks, this will be a promising research direction for multi-object tracking.

(2) Global optimization algorithms

According to the optimization objective, the global

Table 1.1.1 Top 10 engineering research hotspots in information and electronic engineering

No.	Engineering research hotspots	Core papers	Citation frequency	Average citation frequency	Mean year	Proportion of consistently cited papers	Patent-cited publications
1	Multi-object tracking technologies	48	1974	41.13	2012.63	8.3%	0
2	Dynamic network visualization	47	1089	23.17	2012.36	4.3%	0
3	Characteristics and analyses of neural networks/ neural network modeling and fuzzy logic	91	2856	31.38	2013.08	20.9%	1
4	Global optimization algorithms	47	2061	43.85	2013.02	14.9%	0
5	Robust adaptive boundary control	50	1961	39.22	2013.86	26.0%	0
6	Multi-criteria decision making	48	1615	33.65	2013.75	27.1%	0
7	Reversible data-hiding schemes	46	1879	40.85	2013.43	23.9%	1
8	High-utility itemset mining algorithms	48	971	20.23	2014.02	6.3%	0
9	Optical coherence elastography	45	1485	33.00	2013.33	17.8%	0
10	Ultra-wideband slot antennas	47	1281	27.26	2013.72	6.4%	0

Table 1.1.2 Annual number of core papers belonging to each of the top 10 engineering research hotspots in information and electronic engineering

No.	Engineering research hotspots	2011	2012	2013	2014	2015	2016
1	Multi-object tracking technologies	12	13	7	13	3	0
2	Dynamic network visualization	17	9	9	11	1	0
3	Characteristics and analyses of neural networks/ neural network modeling and fuzzy logic	25	17	12	9	19	9
4	Global optimization algorithms	7	10	10	15	5	0
5	Robust adaptive boundary control	6	5	10	7	13	9
6	Multi-criteria decision making	11	4	4	6	13	10
7	Reversible data-hiding schemes	4	8	13	9	9	3
8	High-utility itemset mining algorithms	1	5	7	18	13	4
9	Optical coherence elastography	5	8	10	14	5	3
10	Ultra-wideband slot antennas	2	10	7	11	14	3

optimization algorithms are divided into single-objective, multi-objective, and hierarchical multi-objective optimization problems. According to the data type, they are divided into discrete, continuous, and hybrid optimization problems. Because global optimization problems often have many local optimal solutions, they are difficult to solve with the classical optimization method. Particularly in the big data environment, there may be a huge number of local optimal solutions, which creates a considerable challenge in the search for a global optimal solution. In particular, no effective global judgment criterion has been determined. Consequently, the advantages and disadvantages of different local optimal solutions are difficult to evaluate, which hinders the unification of the global optimization objective. Global optimization problems are frequently encountered in data mining, image processing, machine learning, artificial intelligence, and other fields. Different global optimization algorithms are used for different data characteristics and targets.

(3) Robust adaptive boundary control

Robust adaptive control concerns systems with uncertainties and has broad application areas, such as robotics and flight control. Robust adaptive boundary control is a rather large category and includes boundary disturbance attenuation, nonlinear active disturbance control, adaptive boundary control, and sliding mode control.

The theory of boundary measurement and control was developed within the robust adaptive boundary control research domain. It is critical to target the most challenging engineering problems that arise in real practical applications and to form novel solutions using boundary measurement and control methodologies. The challenging areas in which robust adaptive boundary control is needed include—but are not limited to—active control of combustion instabilities, structural vibration control of aerospace vehicles, active flow control, pinning control of large-scale networks, boundary measurements and related inverse problems in biologic tissues, and boundary manipulation physics and control system technologies.

(4) Multi-criteria decision making

Multi-criteria decision making can be divided into two classes, multi-attribute decision making and multi-objective decision making, based on whether the decision scheme is finite or infinite. A current means of multi-criteria decision making is to merge the effectiveness of all attributes to obtain the full effectiveness and then to rank the schemes. In 1965, Zadeh proposed the fuzzy set theory. In 1970, Bellman and Zadeh introduced the fuzzy set theory in multi-criteria decision making and proposed the fuzzy multi-criteria decision making (FMCDM) model to resolve the uncertainty problem in actual decision making; this model has become a popular research direction in the current multi-criteria decision making research hotspot.

(5) Reversible data-hiding schemes

Reversible data hiding is an information-hiding technology that can fully restore the source data after hidden data is correctly extracted. Reversible data hiding is used mainly in covert communications, copyright protection, and content integrity authentication. Reversible data hiding is classified into three categories: ① single-pixel hiding and pixel group hiding, ② spatial domain hiding and transform domain hiding, and ③ even hiding and uneven hiding. At present, research on pixel group hiding, uneven hiding, and difference expansion is the most popular.

Anti-attack is another research topic that must be investigated simultaneously with data hiding. Attackers aim to destroy original source data or extract hidden information; therefore, anti-attack capabilities must rely on other information encryption methods.

(6) High-utility itemset mining algorithms

The high-utility itemset mining algorithms have played a more intuitive and direct-supporting role in solving the decision-making problem in some practical application scenarios. In 2004, Yao et al. proposed the concept of high-utility itemset mining. Other researchers have proposed a number of high-utility itemset mining algorithms, including the incremental high-utility pattern (IHUP) algorithm, utility pattern growth (UP-growth) algorithm, and high-utility itemset miner (HUI-miner) algorithm.

Although high-utility itemset mining has made remarkable achievements, challenges remain in the following research areas: data mining of columnar storage, development of appropriate standards for measuring high-utility itemsets, visual mining, parallel mining of high-utility itemsets, and mining of high-utility itemsets in network environments.

(7) Optical coherence elastography

Optical coherence elastography (OCE) is of great importance in the research of microstructure imaging of biological tissue. According to the mode of excitation, OCE can be classified as sound surface-wave propagation OCE, shear wave propagation OCE, acoustic radiation force OCE, pressure-type OCE, and magnetic induction OCE. OCE offers a special advantage in measuring the unique organizational level of biomechanics at the micron level, cell level, and even the molecular level. The method is a new nondestructive approach to evaluating tissue elasticity and is superior to ultrasonic imaging and magnetic resonance imaging. Its development process is the same as those of other means of elastic imaging, from static imaging to dynamic imaging, and from low resolution to high resolution. In the future, the image resolution, imaging depth, and imaging velocity of the method are expected to be gradually improved.

(8) Ultra-wideband slot antennas

The ultra-wideband slot antenna has a basic antenna form in which radiation is produced through grooving on metal and excitation with a coaxial cable, microstrip cable, or waveguide. The slot antenna can replace the oscillator antenna in the microwave section, solving problems that the oscillator antenna is too small to make and feed. The wideband characteristics of the circular and elliptic slot antennas are well known. A slot antenna can achieve ultra-wideband bandwidth and its bandwidth depends on the shape of the slot. For example, the length-to-width ratio of the slot has a significant impact on the bandwidth of an antenna with a wide rectangular slot, and the long-to-short axis ratio has great influence on the bandwidth of the elliptical slot. Improvement of the feed network can greatly improve the working bandwidth.

(9) Dynamic network visualization

In a dynamic network structure, the nodes and edges of a network evolve over time. A dynamic network can be observed and analyzed by visualization, and important insights can be obtained. In an existing network, some features can be automatically analyzed with traditional data analysis methods. However, the greatest advantage of combining traditional methods and visualization is that useful patterns can be determined by using large amounts of data and further observation with traditional methods. In dynamic network visualization, more attention must be paid to the heterogeneity of the key topology and the time dimension of the network data. Data visualization of large-scale networks is a very challenging topic and a well-known problem.

(10) Characteristics and analyses of neural networks/neural network modeling and fuzzy logic

A neural network is a mathematical model that imitates the behavior of animal neural networks and processes information in a distributed and parallel way. The combination of modeling based on neural networks and fuzzy logic can improve the generalization ability and efficiency of the model. Currently, the main technological development orientations are: first, improving the accuracy of fuzzy systems by adjusting fuzzy logic membership functions based on neural networks; second, using fuzzy logic to improve the learning ability of the neural network and appropriate heuristic control logic to control the learning process to increase the training efficiency and reduce the demand for data quality. Based on these methods, a combination of the fuzzy system and the neural network is constructed to improve the generation quality and the ability of the model to acquire special knowledge. A neural network is used to approximate a fuzzy logic system, which reduces the difficulty of computer implementation and improves engineering efficiency.

With the development of deep learning technology, the theory and technology of neural networks have advanced rapidly. Additionally, the integration with other disciplines has become more abundant in recent years, which has further promoted the development of neural network technology.

1.2 Understanding of engineering research focus

1.2.1 Multi-object tracking technologies

Multi-object tracking technology has been widely used in video surveillance, autonomous driving, human-computer interaction, virtual reality, and augmented reality, and has significant practical value in military and civilian fields. Multi-object tracking has been greatly enhanced by the rapid development of machine learning methods, the continuous improvement of hardware performance, and increasingly rich data sets.

To meet the demand for a high-performance and robust multi-object tracking algorithm for practical applications, a series of challenging scientific and technical problems have been introduced, including the appearance modeling of objects, visual representation and feature selection, occlusions, data association algorithms, probability inference between state changes in video sequences, and decision optimization. To address the above challenges, innovative research is needed based on the rapid development of modern artificial intelligence technology through the combination of theory and practice, model and algorithm, and new ideas and changes in model systems.

At present, the main hotspots of this research frontier can be summarized as follows.

(1) Multi-object initialization. The development of a full-time multi-object tracker with speed and accuracy but without limitations on the type of objects being tracked remains a frontier topic.

(2) Appearance modeling for multiple objects. In visual recognition, effective feature representation remains an interesting and challenging issue. Multi-object tracking requires not only the design of robust visual representations, but also accurate statistical measurements to estimate the similarities between different observations.

(3) Motion modeling for multiple objects. The movement of an object in a scene is usually erratic and it is difficult to model acceleration or stopping. The effective multi-object tracking algorithm must design and implement a nonlinear motion model.

(4) Combination of online and offline tracking. The implementation of these two dissimilar methods to obtain a simpler and more effective multi-object tracking algorithm remains a challenging topic.

(5) Object association algorithm. Overlapping and blocking between multiple objects is an inevitable fatal problem in multi-object tracking. The establishment of an effective way to deal with overlapping and occlusion is an important future development direction.

There are 61 core papers focusing on "Multi-object tracking technologies" (Table 1.2.1). The top five countries are the USA, China, Switzerland, Germany, and Korea. Papers published by authors from the USA accounted for 56.25%, more than half, and two of the three consistently cited papers are published by the USA. China ranked the second with core papers accounting for 20.83% of the total number of papers. According to Table 1.2.2, the top five institutions in paper output are the University of Southern California (Univ So Calif), the Chinese University of Hong Kong (Chinese Univ Hong Kong), Darmstadt University of Technology in Germany (Tech Univ Darmstadt), the Swiss Federal Institute of Technology in Zurich (ETH), and the University of Central Florida (Univ Cent Florida), two of which are in the USA and one is in China. From the network analysis of collaboration among researchers in different countries or regions, shown in Figure 1.2.1, Figure 1.2.2, Table 1.2.3, and Table 1.2.4, the USA occupies the core position. The cooperation among published researchers in the top four countries or regions is also closer.

Based on the results of this analysis, it is clear that the USA, regardless of the number of papers or the collaboration with other countries or regions, is the leader in this research focus, while China is following closely to

Table 1.2.1 Major producing countries or regions of core papers on the engineering research focus “Multi-object tracking technologies”

No.	Country/Region	Core papers	Proportion of core papers	Citation frequency	Proportion of citation frequency	Average citation frequency	Consistently cited papers	Patent-cited publications
1	USA	27	56.25%	824	47.71%	30.52	2	0
2	China	10	20.83%	167	9.67%	16.70	0	0
3	Switzerland	8	16.67%	601	34.80%	75.13	0	0
4	Germany	8	16.67%	434	25.13%	54.25	0	0
5	Korea	2	4.17%	31	1.80%	15.50	1	0
6	Singapore	2	4.17%	23	1.33%	11.50	0	0
7	Belgium	1	2.08%	171	9.90%	171.00	0	0
8	France	1	2.08%	36	2.08%	36.00	0	0
9	Portugal	1	2.08%	25	1.45%	25.00	0	0
10	Australia	1	2.08%	16	0.93%	16.00	0	0

Table 1.2.2 Major producing institutions of core papers on the engineering research focus “Multi-object tracking technologies”

No.	Institution	Core papers	Proportion of core papers	Citation frequency	Proportion of citation frequency	Average citation frequency	Consistently cited papers	Patent-cited publications
1	Univ So Calif	6	12.50%	209	12.10%	34.83	1	0
2	Chinese Univ Hong Kong	6	12.50%	110	6.37%	18.33	0	0
3	Tech Univ Darmstadt	5	10.42%	246	14.24%	49.20	0	0
4	ETH	4	8.33%	288	16.68%	72.00	0	0
5	Univ Cent Florida	4	8.33%	154	8.92%	38.50	0	0
6	Penn State Univ	3	6.25%	139	8.05%	46.33	0	0
7	Ecole Polytech Fed Lausanne	2	4.17%	244	14.13%	122.00	0	0
8	Swiss Fed Inst Technol	2	4.17%	69	4.00%	34.50	0	0
9	Oregon State Univ	2	4.17%	64	3.71%	32.00	0	0
10	Xiamen Univ	2	4.17%	35	2.03%	17.50	0	0

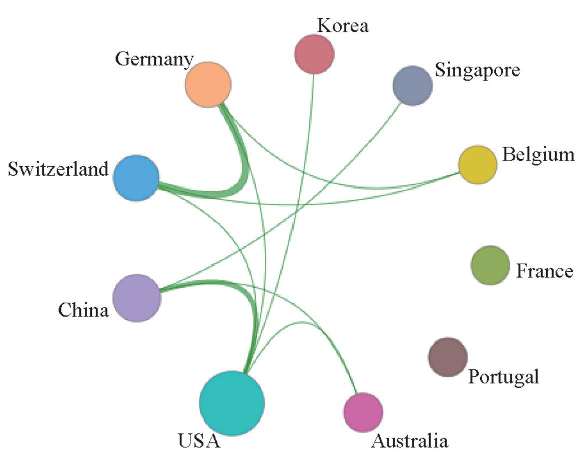

Figure 1.2.1 Collaboration network of the major producing countries or regions of core papers on the engineering research focus “Multi-object tracking technologies”[1]

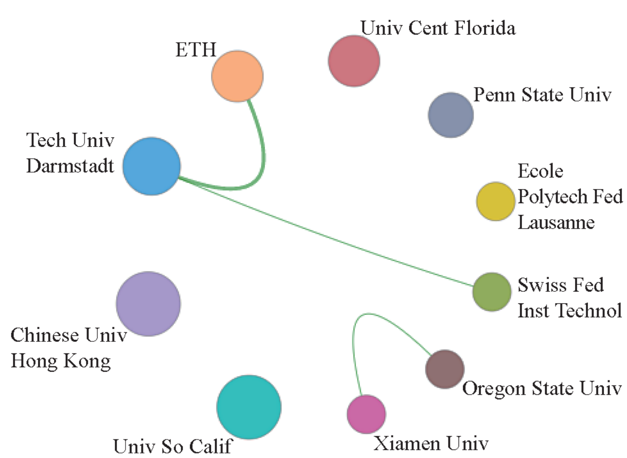

Figure 1.2.2 Collaboration network of the major producing institutions of core papers on the engineering research focus “Multi-object tracking technologies”

[1] In the figure, the nodes refer to the countries or regions, the size of the nodes refers to number of papers, the connecting line between nodes refers to papers published based on research cooperation, and the thickness of the connecting line indicates the number of papers based on research cooperation. These are the same in full text.

Table 1.2.3 Major producing countries or regions of core papers that are cited by core papers on the engineering research focus “Multi-object tracking technologies”

No.	Country/Region	Number of core papers cited by core papers	Proportion	Mean year
1	USA	6	33.33%	2013.5
2	China	5	27.78%	2014.2
3	Singapore	2	11.11%	2014.5
4	Korea	2	11.11%	2014.5
5	Austria	1	5.56%	2014.0
6	Germany	1	5.56%	2014.0
7	Switzerland	1	5.56%	2014.0

Table 1.2.4 Major producing institutions of core papers that are cited by core papers on the engineering research focus “Multi-object tracking technologies”

No.	Institution	Number of core papers cited by core papers	Proportion	Mean year
1	Chinese Univ Hong Kong	3	13.04%	2014.0
2	GIST	2	8.70%	2014.5
3	Adv Digital Sci Ctr	1	4.35%	2015.0
4	Anhui Univ	1	4.35%	2015.0
5	Boston Univ	1	4.35%	2012.0
6	ETH	1	4.35%	2014.0
7	Graz Univ Technol	1	4.35%	2014.0
8	Hanyang Univ	1	4.35%	2015.0
9	Hefei Univ Technol	1	4.35%	2015.0
10	KETI	1	4.35%	2015.0

the USA, which cooperates closely with other countries or regions.

1.2.2 Dynamic network visualization

Because the data produced in most computer-related and communication fields have an additional time dimension compared with traditional data, the good organization of the data and their presentation with efficient visualization methods are valuable for understanding and analyzing their inner structure. Solving this problem is of great significance to the communication industry and academic research. Scholars and experts in the field of visualization and visual analysis worldwide are trying to solve this problem.

Among the scholars studying dynamic network visualization, those in the USA produce 31.91% of the core papers in this field, ranking the first; they are followed by researchers in Germany, the Netherlands, France, China, and other countries or regions. The core papers produced in the top 10 countries or regions are cited more than 20 times (Table 1.2.5). Peking University, University of Toulouse, the French Civil Aviation University (ENAC), and University of Groningen are the top four institutions. Four papers are produced by each of these four institutions, with more than 90 citations, and a proportion of citations of more than 9% (Table 1.2.6). The collaboration networks between the major countries or regions and the major institutions on the engineering research focus “Dynamic network visualization” are shown in Figure 1.2.3 and Figure 1.2.4.

Regarding the core papers that are cited by core papers, Germany, Switzerland, and China are the top three countries based on the country or region statistics, with no less than three core papers that are cited by core papers, and the proportions of those papers are higher than 15% for each of the three countries in the list (Table

Table 1.2.5 Major producing countries or regions of core papers on the engineering research focus "Dynamic network visualization"

No.	Country/Region	Core papers	Proportion of core papers	Citation frequency	Proportion of citation frequency	Average citation frequency	Consistently cited papers	Patent-cited publications
1	USA	15	31.91%	203	21.06%	13.53	1	0
2	Germany	12	25.53%	348	36.10%	29.00	2	0
3	The Netherlands	10	21.28%	239	24.79%	23.90	0	0
4	France	8	17.02%	178	18.46%	22.25	0	0
5	China	8	17.02%	152	15.77%	19.00	0	0
6	Scotland	4	8.51%	79	8.20%	19.75	0	0
7	Switzerland	4	8.51%	56	5.81%	14.00	0	0
8	Ireland	3	6.38%	74	7.68%	24.67	0	0
9	Canada	3	6.38%	50	5.19%	16.67	1	0
10	Singapore	2	4.26%	24	2.49%	12.00	0	0

Table 1.2.6 Major producing institutions of core papers on the engineering research focus "Dynamic network visualization"

No.	Institution	Core papers	Proportion of core papers	Citation frequency	Proportion of citation frequency	Average citation frequency	Consistently cited papers	Patent-cited publications
1	Peking Univ	4	8.51%	113	11.72%	28.25	0	0
2	Univ Toulouse	4	8.51%	93	9.65%	23.25	0	0
3	ENAC	4	8.51%	93	9.65%	23.25	0	0
4	Univ Groningen	4	8.51%	93	9.65%	23.25	0	0
5	Eindhoven Univ Technol	4	8.51%	73	7.57%	18.25	0	0
6	Hong Kong Univ Sci Technol	4	8.51%	51	5.29%	12.75	0	0
7	Fraunhofer Inst IAIS	3	6.38%	129	13.38%	43.00	0	0
8	Univ Konstanz	3	6.38%	69	7.16%	23.00	1	0
9	ENAC Univ Toulouse	2	4.26%	64	6.64%	32.00	0	0
10	Univ Rostock	2	4.26%	60	6.22%	30.00	1	0

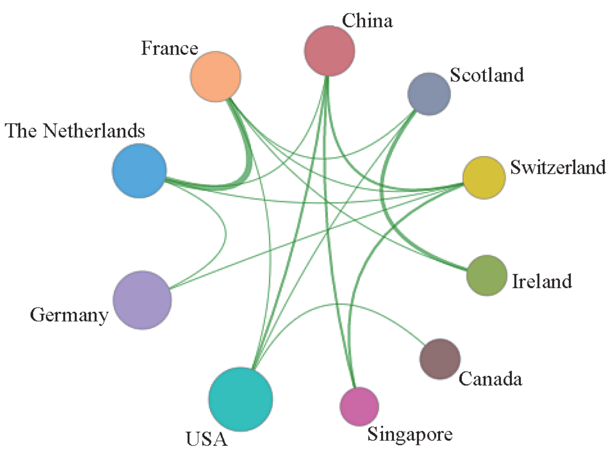

Figure 1.2.3 Collaboration network of the major producing countries or regions of core papers on the engineering research focus "Dynamic network visualization"

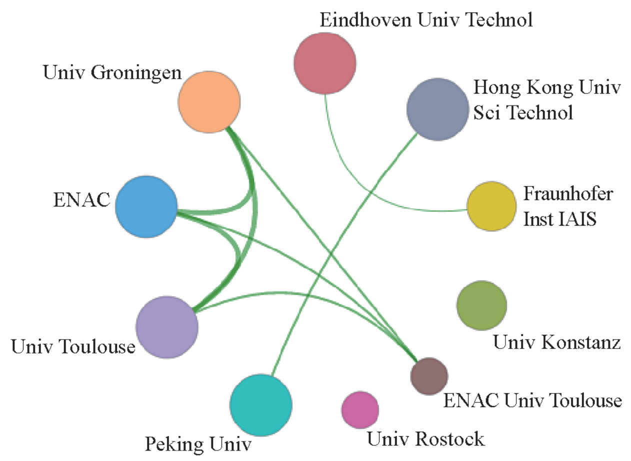

Figure 1.2.4 Collaboration network of the major producing institutions of core papers on the engineering research focus "Dynamic network visualization"

1.2.7). Hong Kong University of Science and Technology ranks the first among institutions with three papers with a proportion higher than 12%. It is followed by the Max Planck Institute for Human Cognitive and Brain Sciences, Nanyang Technological University, and the Swiss Federal Institute of Technology, with two papers each and a proportion of 8% for each institution (Table 1.2.8).

Currently, research on "Dynamic network visualization" focuses on incremental rendering on the node-connection graph, especially on some types of graphs, such as trees, strings, parallel graphs, and directed acyclic graphs. Many scholars aim to use node topology to visualize a dynamic network in the 2D plane, and visual forms with a more visual metaphor effect, such as 3D graphs, have been proposed in the literature. In addition to rendering, interesting work is being performed on the scalability of visual dynamic networks. Little information exists in the literature on the methodology for visualizing large dynamic network data sets. With an increasing amount of data, the nodes overlap and the traditional method inevitably produces complexity in visual computing. Animation is a commonly used approach to explaining dynamic network changes, and the tradeoff between data processing speed and rendering performance should be considered. Efforts devoted to these research topics will be significant for understanding the structure and relationship of dynamic network data.

1.2.3 Characteristics and analyses of neural networks/neural network modeling and fuzzy logic

Recently, with the development of the Internet and big data, the global demand for artificial intelligence

Table 1.2.7 Major producing countries or regions of core papers that are cited by core papers on the engineering research focus "Dynamic network visualization"

No.	Country/Region	Number of core papers cited by core papers	Proportion	Mean year
1	Germany	4	21.05%	2012.75
2	Switzerland	3	15.79%	2012.67
3	China	3	15.79%	2013.67
4	Singapore	2	10.53%	2013.50
5	Australia	2	10.53%	2014.50
6	France	2	10.53%	2014.50
7	USA	2	10.53%	2014.50
8	Chile	1	5.26%	2014.00

Table 1.2.8 Major producing institutions of core papers that are cited by core papers on the engineering research focus "Dynamic network visualization"

No.	Institution	Number of core papers cited by core papers	Proportion	Mean year
1	Hong Kong Univ Sci Technol	3	12%	2013.67
2	Max Planck Inst Human Cognit Brain Sci	2	8%	2013.50
3	Nanyang Technol Univ	2	8%	2013.50
4	Swiss Fed Inst Technol	2	8%	2013.50
5	Fraunhofer Inst IAIS	1	4%	2013.00
6	Griffith Univ	1	4%	2014.00
7	Inria Chile CIRIC	1	4%	2014.00
8	Inria	1	4%	2015.00
9	Microsoft Res Inria Joint Ctr	1	4%	2015.00
10	Monash Univ	1	4%	2015.00

technology has become enormous. Neural networks, particularly deep neural networks that represent depth learning, have promoted the development and application of artificial intelligence in technology. The development of neural networks has been an important issue in practical applications, such as Google's AlphaGo, which further demonstrates the outstanding performance of depth learning in artificial intelligence. From the data presented in Table 1.2.9 and Table 1.2.10, we can see the technical demands and development potential of different countries or regions in this field. The combination of fuzzy logic and neural networks utilizes and balances the advantages and disadvantages of these approaches and is another important research field.

From keywords of the core papers such as neural network, deep learning, and fuzzy control, the leading edges of the research field include: optimizing neural networks, mainly by optimizing the learning algorithm; optimizing self-learning structures, mainly the model's self-adjustment ability; and optimizing fuzzy rules.

Among the leading issues of the combination of neural network learning algorithms with fuzzy logic are structure learning and parameter learning. Rule learning includes the heuristic search method, the fuzzy grid method, the tree partition method, and the learning algorithm based on fuzzy clustering. The research in this field can further

Table 1.2.9 Major producing countries or regions of core papers on the engineering research focus "Characteristics and analyses of neural networks/neural network modeling and fuzzy logic"

No.	Country/Region	Core papers	Proportion of core papers	Citation frequency	Proportion of citation frequency	Average citation frequency	Consistently cited papers	Patent-cited publications
1	China	44	48.35%	973	37.35%	22.11	7	0
2	Taiwan of China	33	36.26%	1248	47.91%	37.82	6	0
3	Saudi Arabia	15	16.48%	259	9.94%	17.27	4	0
4	India	10	10.99%	177	6.79%	17.70	1	0
5	USA	4	4.40%	135	5.18%	33.75	0	0
6	Egypt	3	3.30%	63	2.42%	21.00	1	0
7	Romania	2	2.20%	89	3.42%	44.50	0	0
8	Canada	2	2.20%	36	1.38%	18.00	0	0
9	Spain	1	1.10%	29	1.11%	29.00	0	1
10	Turkey	1	1.10%	26	1.00%	26.00	0	0

Table 1.2.10 Major producing institutions of core papers on the engineering research focus "Characteristics and analyses of neural networks/neural network modeling and fuzzy logic"

No.	Institution	Core papers	Proportion of core papers	Citation frequency	Proportion of citation frequency	Average citation frequency	Consistently cited papers	Patent-cited publications
1	Kaohsiung Marine Univ	17	18.68%	775	29.75%	45.59	3	0
2	Pingtung Univ Educ	15	16.48%	482	18.50%	32.13	2	0
3	King Abdulaziz Univ	15	16.48%	259	9.94%	17.27	4	0
4	Cheng Kung Univ	13	14.29%	357	13.70%	27.46	3	0
5	Fac Sci	12	13.19%	208	7.98%	17.33	3	0
6	Dept Civil Engn	10	10.99%	384	14.74%	38.40	2	0
7	Southeast Univ	10	10.99%	155	5.95%	15.50	2	0
8	Cent Univ	9	9.89%	346	13.28%	38.44	3	0
9	Kaohsiung First Univ Sci &Technol	9	9.89%	224	8.60%	24.89	1	0
10	Chongqing Jiaotong Univ	8	8.79%	232	8.91%	29.00	1	0

improve the performance and training speed of neural networks, and the combination of distributed systems can enhance the generation speed of model parameters. The leading countries and regions in this field of research include the Chinese mainland, Taiwan of China, the USA, and Canada.

The optimization of structure self-learning includes mainly connection design methods and evolutionary design methods. Connection design methods include the supplementary algorithm and cut algorithm. The research in this field can reduce redundant parameters and the volume of the neural network and provides a feasible method for optimized neural network modeling, which has advanced neural network engineering. The leading countries and regions in this research field include the Chinese mainland, the USA, Canada, and Australia.

Fuzzy logic rules are often obtained empirically and have poor precision. Fuzzy logic rules with the self-adaptive characteristics of neural networks solve the network black box problem. Although scholars have proposed some methods to further promote the development of this field, no breakthrough has been achieved. In addition, other research areas, including the development of a probabilistic graph model and convex optimization theory, have made some progress in explaining the neural network black box problem by theoretically determining the characteristics of neural networks to some degree. At present, the leading countries and regions in this field include the Chinese mainland, the USA, Canada, and Taiwan of China.

Besides combining fuzzy logic and neural networks, other research has been conducted on overcoming the limitations of neural networks, such as combining the generative adversarial net of game theory to further reduce the demand quality of network data. Additionally, with the development of deep neural networks, model parameters and the compression problem have become important research topics, and the study of the neural network itself is still in progress. In recent years, the convolution neural network, recurrent neural network, and long short-term memory network have become the focus of neural network research and been implemented in engineering. Meanwhile, some specific structures, like the activation function, are being constantly developed. With the continuous progress of artificial intelligence technology, the field will be further integrated with other research areas and is expected to have wide implications and produce new technologies.

According to the network map that illustrates the collaboration among the key engineering research associations, the currently major research countries and regions are the China, Taiwan of China, Saudi Arabia, and India (Figure 1.2.5 and Figure 1.2.6). China ranks the first in the number of core papers and the number of core papers that are cited by core papers (Table 1.2.11), which demonstrates that China has become the key research country in this field. However, the number of institutions producing core papers that are cited by core papers ranks

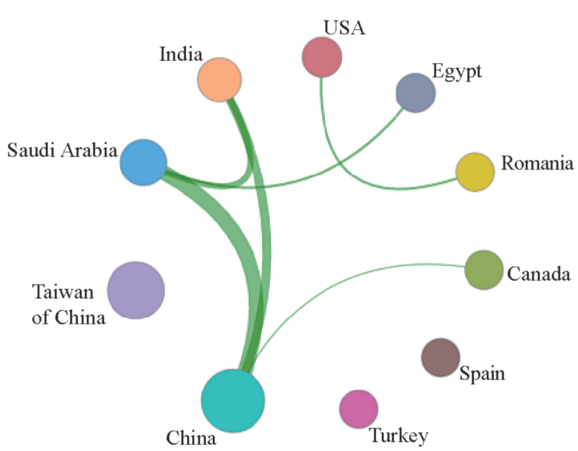

Figure 1.2.5 Collaboration network of the major producing countries or regions of core papers on the engineering research focus “Characteristics and analyses of neural networks/neural network modeling and fuzzy logic”

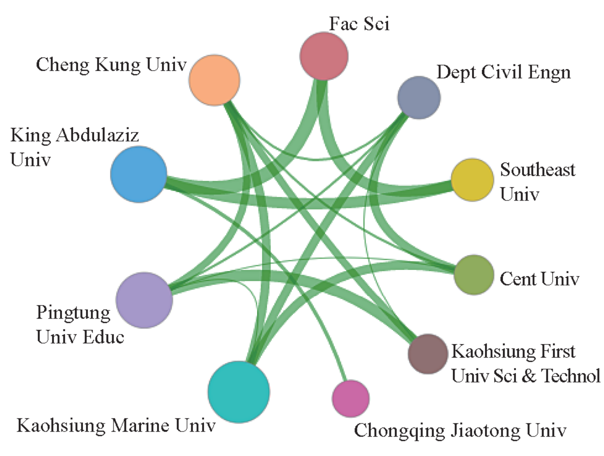

Figure 1.2.6 Collaboration network of the major producing institutions of core papers on the engineering research focus “Characteristics and analyses of neural networks/neural network modeling and fuzzy logic”

lower (Table 1.2.12), which shows that China must further optimize the allocation and improve the concentration of research resources in this field. In addition, China and some countries or regions that are active in this technical field rarely cooperate. Therefore, promoting academic exchange and cooperation should also be a focus of the development efforts in this technical field in China.

2 Engineering development hotspots and engineering development focus

2.1 Development trends of engineering development hotspots

The top 10 engineering research hotspots, summarized by the Field Group of Information and Electronic Engineering, are shown in Table 2.1.1. They cover the subfields of electronic science and technology, optical engineering and technology, instrument science and technology, information and communication engineering, computer science and technology, control science and technology, and other disciplines. Among them, "Wireless mobile communication technology and equipment," "Vehicle autonomous-driving technology and its application," "Laser light source technology," "Image recognition and visual interaction technology," "Cloud computing and virtualization," and "Unmanned aerial vehicle" are areas of further study in traditional research. The annual numbers of core papers published in each hotspot from 2011 to 2016 are shown in Table 2.1.2.

(1) Image recognition and visual interaction technology

Image recognition and visual interaction technology

Table 1.2.11 Major producing countries or regions of core papers that are cited by core papers on the engineering research focus "Characteristics and analyses of neural networks/neural network modeling and fuzzy logic"

No.	Country/Region	Number of core papers cited by core papers	Proportion	Mean year
1	China	35	43.75%	2014.71
2	Taiwan of China	21	26.25%	2012.14
3	Saudi Arabia	13	16.25%	2014.85
4	India	7	8.75%	2015.14
5	Korea	1	1.25%	2015.00
6	USA	1	1.25%	2014.00
7	Canada	1	1.25%	2015.00
8	Algeria	1	1.25%	2016.00

Table 1.2.12 Major producing institutions of core papers that are cited by core papers on the engineering research focus "Characteristics and analyses of neural networks/neural network modeling and fuzzy logic"

No.	Institution	Number of core papers cited by core papers	Proportion	Mean year
1	Cheng Kung Univ	13	9.63%	2012.46
2	King Abdulaziz Univ	13	9.63%	2014.85
3	Pingtung Univ Educ	11	8.15%	2012.18
4	Southeast Univ	10	7.41%	2015.00
5	Kaohsiung Marine Univ	9	6.67%	2012.00
6	Bharathiar Univ	7	5.19%	2015.14
7	Kaohsiung First Univ Sci & Technol	7	5.19%	2012.57
8	Chongqing Jiaotong Univ	7	5.19%	2014.57
9	Huzhou Teachers Coll	4	2.96%	2015.25
10	Minist China	3	2.22%	2015.33

Table 2.1.1 Top 10 engineering development hotspots in information and electronic engineering

No.	Engineering development hotspots	Published patents	Citation frequency	Average citation frequency	Mean year
1	Wireless mobile communication technology and equipment	251	9976	39.75	2012.06
2	Vehicle autonomous-driving technology and its application	234	4035	17.24	2012.67
3	Laser light source technology	151	3217	21.30	2012.26
4	Image recognition and visual interaction technology	118	4684	39.69	2011.95
5	Intelligent driving assistance system and technology	178	7890	44.33	2012.90
6	Photoelectric tracking and monitoring technology	113	2336	20.67	2012.30
7	Cloud computing and virtualization	152	9322	61.33	2012.24
8	Unmanned aerial vehicle	33	633	19.18	2013.55
9	Solar energy technology	227	4598	20.26	2012.14
10	High-speed and high-density storage technology	191	8930	46.75	2012.38

Table 2.1.2 Annual number of core patents belonging to each of the top 10 engineering development hotspots in information and electronic engineering

No.	Engineering development hotspots	2011	2012	2013	2014	2015	2016
1	Wireless mobile communication technology and equipment	104	65	55	17	9	1
2	Vehicle autonomous-driving technology and its application	57	61	51	39	20	6
3	Laser light source technology	53	46	21	22	8	1
4	Image recognition and visual interaction technology	50	40	15	10	3	0
5	Intelligent driving assistance system and technology	39	28	42	53	12	4
6	Photoelectric tracking and monitoring technology	45	27	14	17	9	1
7	Cloud computing and virtualization	55	41	29	18	9	0
8	Unmanned aerial vehicle	2	10	6	5	3	7
9	Solar energy technology	94	65	29	21	17	1
10	High-speed and high-density storage technology	56	54	41	35	2	3

has been widely used in many areas, including augmented reality, digital entertainment, film and television production, medical diagnostics, autonomous driving, and video surveillance. The object detection and recognition technology that is based on convolution neural networks has achieved considerable success; additionally, it has greatly improved the accuracy of facial recognition, behavior analysis, and scene comprehension, and provided the technical basis for natural interaction between users and scenes. To obtain a real-time interactive experience, the current research is focused mainly on designing specialized hardware or accelerating the depth learning algorithm by reducing the computational complexity of the model. Currently, real-time object detection and recognition has been achieved using embedded devices. Future research will focus on designing effective computational models to reduce redundancy in deep-learning systems and improve learning efficiency while reducing the dependence on annotation data using geometric physical prior knowledge. The natural interaction experience could be further enhanced with high-level semantic analysis of images. The development and improvement of such technology will lead to more innovative image recognition and visual interaction products and introduce significant changes in everyday life.

(2) Intelligent driving assistance system and technology

The rapid growth of urban car ownership, traffic congestion, traffic accidents, shortage of parking, and other issues has resulted in a sharp decline in urban transport efficiency. This has created an urgent need to study the use of artificial intelligence in vehicle driving assistance technology and traffic management technology. Intelligent vehicle assisted driving, a primary stage of autonomous driving, is the main approach to improving current vehicle intelligence. The maturity of advanced intelligent driving assistance technology will lay the technical and industrial base for autonomous vehicle driving.

(3) Photoelectric tracking and monitoring technology

Photoelectric tracking and monitoring technology has been widely applied in industrial, agricultural, scientific, and other fields. This has entirely changed the form of competition in national military defense. In recent years, the military requires the development of photoelectric tracking and monitoring technology, which has been gradually advancing toward sensing instrument miniaturization, multi-tool information acquisition, higher accuracy, and higher intelligence.

Attitude stabilization and high precision involve the cross-disciplinary research directions of sensor technology, optical technology, computer technology, information processing technology, and control technology. The key technologies include high-precision design, manufacturing, and control technology of optoelectronic tracking servo mechanisms, advanced and efficient real-time video image target recognition and tracking, and processing technology.

(4) Cloud computing and virtualization

The close relationship between cloud computing and virtual machines can produce powerful results. Key technical issues that must be addressed in cloud computing and virtualization include multi-tenant hosting, decentralized computing, virtualized data management, virtual machine caching, virtualized GPUs, and resource provisioning. New managed cloud products, cloud security, hybrid cloud technology, and OpenStack-based open-source cloud operating systems will be an important development direction in the future.

(5) Unmanned aerial vehicle

Civilian multi-rotor unmanned aerial vehicles (UAVs) have become a new technology hotspot, and there is a very urgent need for completely independent environmental perception and intelligent control technology. In recent years, unmanned aircraft have been widely used in military operations, environmental monitoring, energy exploration, disaster assessment, power line inspection, agricultural plant protection, aviation mapping, public security, and many other fields. Therefore, UAV research is of great significance. Unmanned aircraft development must focus on key technologies such as intelligent control (single intelligence and group intelligence), broadband anti-jamming data links, environment perception and circumvention, data processing for payloads, information fusion, energy and power technologies, low-cost design, and standardization.

(6) Solar energy technology

Solar energy utilization includes mainly solar heat and solar light. With the strong support of governments worldwide, solar energy, as the main force of renewable energy, will play an increasingly important role in the global energy supply. The relatively mature solar power generation technologies are solar photovoltaic and solar thermal power generation technologies. Solar thermal power generation technology can generate electricity by concentrating light to produce high temperatures, and it is more efficient and has better application prospects than solar photovoltaic power generation technology. Although it has been studied globally for many years, only solar thermal power stations have achieved commercial operation. Tower- and disc-type power generation systems are still in the demonstration stage.

(7) High-speed and high-density storage technology

High-density, large-capacity optical storage is an area of interdisciplinary interest and includes device technology, optical technology, materials science, microelectronics technology, process technology, and computer and control technology. Studying the new generation of high-speed and high-density digital optical storage technology is of great significance to societal informatization.

Improving optical storage density has become a very important research topic. To further enhance the density and capacity of optical disks, we must introduce new technology. At present, the main two research directions in this area are super-resolution technology and three-dimensional storage technology. Three-dimensional storage technology includes mainly two-photon storage, multi-level storage, spectral hole-burning storage, waveguide multilayer storage, and holographic storage. Holographic storage with large storage capacity, high data transmission rate, short storage time, fast image matching, related-content-addressing operations, and other characteristics is likely to lead to the next generation of mass storage technology.

(8) Wireless mobile communication technology and equipment

Currently, wireless mobile communications and network technology are entering a new period of accelerated development. Mobile communication networks and space networks tend to eventually integrate into a network architecture covering space, ground, and sea. Thus, network systems and core equipment with advanced technology that is independently controllable, safe, and credible for military and civilian integration are urgently required. The information-centric media network has been viewed as a future development direction with network IT and cloud properties provided by exchange and computing integration. Emerging network technologies, such as software-defined networking and network function virtualization, will achieve the evolution of network architecture and equipment modes. Exploring future network architecture that has reconfigurable security and is efficient, scalable, open, and definable is becoming an important research direction. With the network operating system being the core of the open-network ecological chain, high-performance, scalable, service-oriented, open network operating systems will become a key future technology. Software definition, virtualization, and open communication resources are attracting increasing attention from the industry. Research on 4G wireless mobile communication has become a global research hotspot, while 5G and beyond-5G technologies are crucial for the future of mobile communications. Additionally, system architecture is undergoing changes. Future mobile communication applications are extending from the current human communication to human-computer collaborative communication, ultra-dense connection networking, vehicle networking, industrial Internet, and other areas.

(9) Vehicle autonomous-driving technology and its application

Europe, the USA, Japan, and other developed countries and regions are committed to establishing intelligent transportation systems. Future traffic systems will be based on vehicle-to-vehicle (V2V) and vehicle-to-everything (V2X) information interaction and on integrated human, vehicle, and road intelligent transportation systems with comprehensive real-time perception that understand the capacity of the driving environment and traffic conditions. Autonomous-driving vehicles with autonomous planning, control, and coordinated man-machine operation are the key to realizing future intelligent transportation systems. A new generation of autonomous-driving vehicles based on intelligent transportation systems will have the following functions:

- Higher capacity for environmental perception and understanding.
- Ability of driving behavior decision making in complex traffic conditions.
- Assisted driving capacity in complex weather conditions.
- Capacity to analyze the driver's handling ability and application scope of the assisted driving system, to implement interactive multi-target arbitration mechanisms, and to provide valuable emergency treatment time for drivers or even handle emergencies in case of danger.

(10) Laser light source technology

Laser light source technology has been widely applied in optical fiber communications and in laser audio and video systems, and has become an important pillar of the optoelectronics industry. With the continuous development of semiconductor laser technology, other solid-state lasers based on semiconductor lasers (such as fiber lasers, semiconductor pump solid-state lasers, and slab lasers) are also developing very quickly. Particularly, the advancement of fiber lasers has been very rapid—especially the rare-earth-doped fiber laser, which has been widely applied in optical fiber communications and laser materials.

2.2 Understanding of engineering development focus

2.2.1 Wireless mobile communication technology and equipment

Research in wireless mobile communication technology and equipment has been highly valued and has attracted considerable attention by the industry. It involves many specific technical research topics such as wireless mobile networks, large-scale wireless communication antennas, radio-frequency theory and technology, and the giantconnected-component multiple-access technology and systems.

In wireless mobile networks, breakthroughs will occur in the basic theory related to future mobile communications and in key 5G and beyond-5G technologies. More attention is being paid to the needs of users and creation of new user experiences. The realization of virtualization and flexible networking in large-scale networks, control of network resources on demand, and intelligent adaptation to the spatial and temporal distribution of business diversity have become urgent problems that must be solved. Specific research areas include: ① exploring the theory and methodology of resource representation, virtualization, and computing in large-scale interconnected wireless network systems; ② exploring comprehensive environmental perception and dynamic resource allocation methods; ③ exploring the techniques for matching resource flow and business flow; ④ coordination of communications and calculations; ⑤ proposing the theory and methods of on-demand virtual resource regulation to adapt to the space-time diversity needed and validating them by experiments; and ⑥ proposing the theory and algorithms for flexible layout and agile optimization of wireless networks.

In the area of multi-access technology and systems, the industry is aiming to expand the scope of future mobile communications from current human-to-human communication to a wider range of areas, such as cooperative human-computer communication, ultra-dense connectivity, networking, vehicle networking, and industrial Internet. In terms of antenna and radio-frequency theory and technology in large-scale wireless communications, the research and development of 4G LTE multi-channel antennas has been completed. However, existing multi-channel antennas still have difficulties meeting the high-rate transmission requirements of future wireless communications. Considering the transmission rate and directive gain requirements of future mobile communications, large-scale antennas can provide a larger number of physical channels for wireless transmission, but they also have more physical constraints and technical difficulties. Therefore, for both the base-station side and the terminal side, resources must be invested and appropriate research be conducted. In addition, considering the wider and non-continuous future radio-frequency (RF) bandwidth, highly integrated RF devices face a number of challenges, in terms of power consumption, figure of noise, nonlinearity, and size. Furthermore, RF devices must perform "analog computation" functions. Although RF theory and technology have increasingly become more advanced, more goals must be achieved and further theories and implementation technology must be developed for higher bandwidth, small integration, and other needs, including: exploring the relationship between the parameters of the cross-band large-scale array antenna, exploring the non-linearity and interference generation mechanism and behavior of the multi-channel high-integration RF circuit, and developing the large-scale array antenna of the base-station side and the large-scale antenna of the terminal side. For the system base-station side, the system architecture of large-scale antenna arrays, the selection of the unit antenna scheme, the inter-channel isolation scheme, and the amplitude and phase consistency between channels must be investigated. For the terminal side, the system layout scheme of the large-scale terminal antenna, the unit antenna scheme, and interunit decoupling must be studied.

Wireless mobile communications and related networks have become the basis of economic prosperity and national competitiveness and the basic platform for human social information sharing and collaboration. New smartphone applications have greatly increased the depth and breadth of Internet applications, and mobile communications application traffic is expected to show explosive growth in the next decade. Cloud computing, the Internet, the Internet of Things, and big data technology combine and develop, while new information products and services continue to emerge. The information industry, cultural industry, and social undertakings are further integrated and developed, and people will consequently enjoy more diverse, fast, and economical information and cultural services.

There are 304 core patents in the engineering development focus "Wireless mobile communication technology and equipment" (Table 2.2.1). The top five countries are the USA (148), Korea (48), Canada (25), Finland (23), and China (20). Among them, the patents applied by authors from the USA account for 58.96% of the total patents, which is a large proportion. Evidently, the USA is one of the key research countries in this area with an average citation of 44.64. The top three patent authorization institutions are GLDS (24), OYNO (23), and QCOM (23), and those with high average citation are MOTI (66.42), GOOG (57.86), and IDIG (49.24) (Table 2.2.2). From the main authorization institutions, MOTI and GOOG cooperate most often (Figure 2.2.1, Figure 2.2.2). Between 2011 and 2016, the core patents related to the engineering development focus "Wireless mobile communication technology and equipment" of the Chinese mainland and Taiwan of China were 20 and 3, respectively.

2.2.2 Vehicle autonomous-driving technology and its application

The autonomous-driving vehicle is an advanced development stage of the intelligent vehicle. Autonomous-driving systems require advanced artificial intelligence, which is still in its infancy.

Recently, well-known car manufacturers in the USA, Europe, Japan, and other countries or regions have attached great importance to autonomous-driving technology research, which has been a major breakthrough for the next generation of the automotive industry. Google, Baidu, and other IT enterprises have also joined autonomous-driving research teams and progressed rapidly. Many scientific research institutions and academies have also given attention to such research, such as the US De-

Table 2.2.1 Major producing countries or regions of core patents on the engineering development focus "Wireless mobile communication technology and equipment"

No.	Country/Region	Published patents	Proportion of published patents	Citation frequency	Proportion of citation frequency	Average citation frequency
1	USA	148	58.96%	6607	66.23%	44.64
2	Korea	48	19.12%	1675	16.79%	34.90
3	Canada	25	9.96%	917	9.19%	36.68
4	Finland	23	9.16%	1041	10.44%	45.26
5	China	20	7.97%	444	4.45%	22.20
6	Japan	16	6.37%	322	3.23%	20.13
7	Germany	8	3.19%	230	2.31%	28.75
8	UK	7	2.79%	139	1.39%	19.86
9	Sweden	6	2.39%	161	1.61%	26.83
10	Taiwan of China	3	1.20%	46	0.46%	15.33

Table 2.2.2 Major producing institutions of core patents on the engineering development focus "Wireless mobile communication technology and equipment"

No.	Institution	Published patents	Proportion of published patents	Citation frequency	Proportion of citation frequency	Average citation frequency
1	GLDS	24	9.56%	749	7.51%	31.21
2	OYNO	23	9.16%	1111	11.14%	48.30
3	QCOM	23	9.16%	891	8.93%	38.74
4	SMSU	23	9.16%	892	8.94%	38.78
5	IDIG	17	6.77%	837	8.39%	49.24
6	RIMR	15	5.98%	595	5.96%	39.67
7	MOTI	12	4.78%	797	7.99%	66.42
8	APPY	9	3.59%	380	3.81%	42.22
9	TELF	8	3.19%	389	3.90%	48.63
10	GOOG	7	2.79%	405	4.06%	57.86

Note: GLDS stands for LG Electronics Inc.; OYNO stands for Nokia Corp.; QCOM stands for Qualcomm Inc.; SMSU stands for Samsung Electronics Co., Ltd.; IDIG stands for Interdigital Patent Holdings Inc.; RIMR stands for Research in Motion Limited; MOTI stands for Motorola Mobility Inc.; APPY stands for Apple Inc.; TELF stands for Telefonaktiebolaget Ericsson L M; GOOG stands for Google Inc.

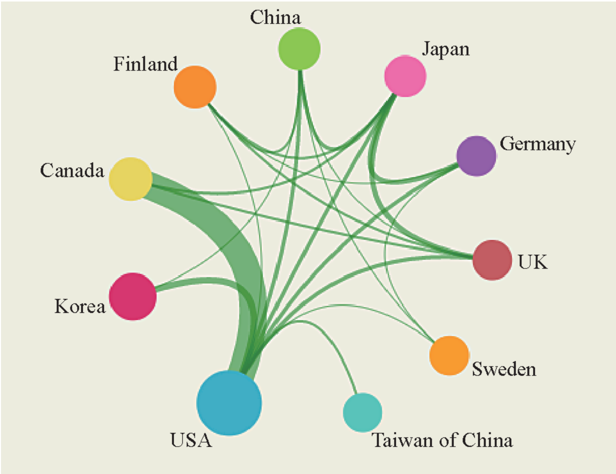

Figure 2.2.1 Collaboration network of the major producing countries or regions of core patents on the engineering development focus “Wireless mobile communication technology and equipment”

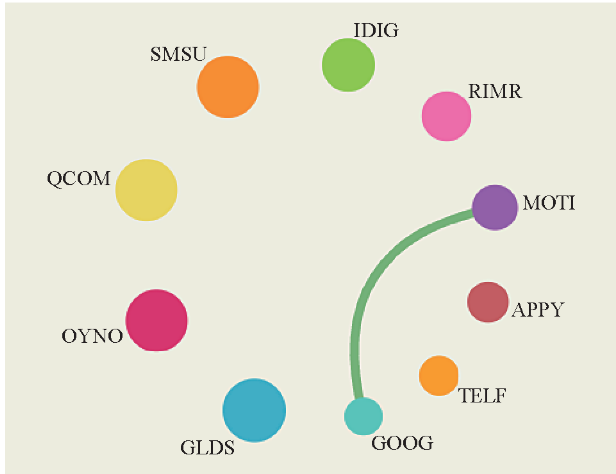

Figure 2.2.2 Collaboration network of the major producing intitutions of core patents on the engineering development focus “Wireless mobile communication technology and equipment”

fense Advanced Research Projects Agency (DARPA) and the National Natural Science Foundation of China (NSFC).

At present, Nevada, Florida, California, Texas, Michigan, and Washington, DC, in the USA have legislated to allow autonomous-driving vehicle road testing. Germany was the first country to research autonomous-driving technology. In 2013, the Mercedes-Benz S500, which has autonomous-driving ability, completed several long-distance autonomous-driving tests on urban roads and intercity roads. This vehicle actually repeated the itinerary performed by Ms. Ben Bell 125 years ago. As a car manufacturer that features automotive safety products, Volvo’s autonomous-driving vehicle has been tested over 10 000 miles (about 16 093 km) on a Spanish highway and a Swedish test runway. Additionally, Volvo has published a declaration on road safety: Volvo will be fully responsible for any traffic accident that occurs while the autonomous-driving vehicle is in autonomous mode. Although foreign research on autonomous-driving started early and has contributed significant input, the technical gap between domestic and international research in this field is gradually narrowing. In recent years, under the support of the NSFC major research program Visual Auditory Information Cognitive Computing, the National University of Defense Technology, Nanjing University of Science and Technology, Beijing Institute of Technology, Xi’an Jiaotong University, Military Transportation University, Hefei Institutes of Physical Science of Chinese Academy of Sciences, Tsinghua University, Tongji University, Shanghai Jiao Tong University, and other institutions have produced a series of theoretical and key technological research advancements in the field of autonomous-driving.

Although great progress has been achieved in autonomous-driving technology, many challenges still exist; for instance, operation in complex terrains, weather, road traffic environment conditions, as well as difficulties in achieving environmental awareness, decision making, and control performance optimization with the existing theory and methodology. The technical challenges can be summarized as follows:

• Environmental perception capacity in complex weather conditions.

• Behavioral decision capability and motion planning in complex traffic conditions.

• Vehicle control technology in special traffic conditions.

• Multi-source communication technology in dense vehicle conditions.

Sounder basic theoretical research on autonomous-driving is required to obtain the following key technologies:

• Technology for ground environment perception and understanding.

• Self-propelled truck fleet control.

• Multi-level human-computer interaction technology for autonomous driving vehicles.

• Machine learning methods and techniques for autonomous-driving vehicles.

• Autonomous-driving vehicle communication technology.

• Main technology to establish sites for demonstrating and testing the base of autonomous-driving vehicles.

• Intelligent function standards and test methods for autonomous-driving vehicles.

• Autonomous-driving vehicle control technology based on smartphones.

The study of autonomous-driving theory and technology in complex environments also provides a good platform for cross-disciplinary integration, which will promote common applications for different disciplines, learning from each other, and promoting the basic research in related fields.

In the engineering development focus "Vehicle autonomous-driving technology and its application," the top three countries in patent output are the USA (129), Japan (35), and Germany (34). Among them, the USA accounts for 55.13% of the total output (Table 2.2.3, Figure 2.2.3). The top three institutions in core patent output are GENK (18), GOOG (18), and FORD (15); it is reported that FORD cooperated closely with both BOSC and MASI (Table 2.2.4, Figure 2.2.4).

Table 2.2.3 Major producing countries or regions of core patents on the engineering development focus "Vehicle autonomous-driving technology and its application"

No.	Country/Region	Published patents	Proportion of published patents	Citation frequency	Proportion of citation frequency	Average citation frequency
1	USA	129	55.13%	2710	67.16%	21.01
2	Japan	35	14.96%	325	8.05%	9.29
3	Germany	34	14.53%	511	12.66%	15.03
4	China	18	7.69%	273	6.77%	15.17
5	Korea	7	2.99%	69	1.71%	9.86
6	Sweden	4	1.71%	73	1.81%	18.25
7	UK	3	1.28%	47	1.16%	15.67
8	Canada	2	0.85%	12	0.30%	6.00
9	India	2	0.85%	50	1.24%	25.00
10	The Netherlands	2	0.85%	9	0.22%	4.50

Table 2.2.4 Major producing institutions of core patents on the engineering development focus "Vehicle autonomous-driving technology and its application"

No.	Institution	Published patents	Proportion of published patents	Citation frequency	Proportion of citation frequency	Average citation frequency
1	GENK	18	7.69%	292	7.24%	16.22
2	GOOG	18	7.69%	483	11.97%	26.83
3	FORD	15	6.41%	187	4.63%	12.47
4	NSUM	11	4.70%	159	3.94%	14.45
5	TOYT	11	4.70%	174	4.31%	15.82
6	BOSC	7	2.99%	119	2.95%	17.00
7	HOND	6	2.56%	117	2.90%	19.50
8	DAIM	4	1.71%	161	3.99%	40.25
9	MASI	4	1.71%	102	2.53%	25.50
10	TEVE	4	1.71%	36	0.89%	9.00

Note: GENK stands for General Motors LLC; GOOG stands for Google Inc.; FORD stands for Ford Global Technologies LLC; NSUM stands for Audi AG; TOYT stands for Toyota Jidosha Kabushiki Kaisha; BOSC stands for Robert Bosch GmbH; HOND stands for Honda Motor Co., Ltd.; DAIM stands for Daimler Trucks North America LLC; MASI stands for Massachusetts Institute of Technology; TEVE stands for Continental Teves AG & CO. OHG.

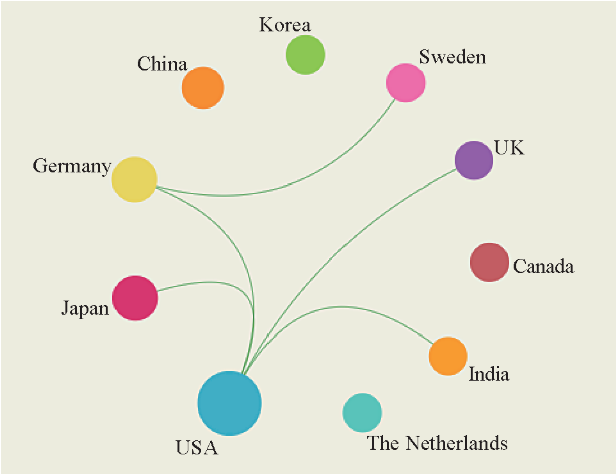

Figure 2.2.3 Collaboration network of the major producing countries or regions of core patents on the engineering development focus "Vehicle autonomous-driving technology and its application"

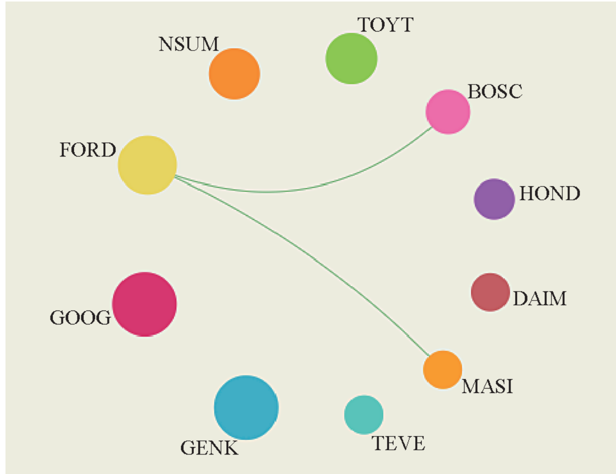

Figure 2.2.4 Collaboration network of the major producing institutions of core patents on the engineering development focus "Vehicle autonomous-driving technology and its application"

2.2.3 Laser light source technology

Over the last 50 years, laser technology has rapidly developed and has been applied in many fields, such as optoelectronic technology, laser medical and photo-biology, laser manufacturing technology, laser detection and measurement technology, laser hologram technology, laser spectral analysis technology, non-linear optics, ultrafast laser, laser chemistry, quantum optics, laser radar, laser guidance, isotope separation by laser, laser controlled nuclear fusion, and laser weapons. The appearance of these cross-technologies and new subjects greatly promotes development in traditional and emerging industries. Among all types of laser source technology, the most active and fastest-growing field is semiconductor laser weapons, which has already become an important pillar of the optoelectronic industry. Meanwhile, with the continuous development of semiconductor lasers, other semiconductor-based solid-state lasers are being rapidly developed, such as fiber lasers, semiconductor pumped solid-state lasers, and slab lasers. To realize fiber lasers, special optical fiber technology must be developed. Additionally, new-generation optical fibers must be investigated, such as photon crystal fibers. Furthermore, pumped coupling cladding technology must be developed so that parts can have minimal impact on the fiber core. Finally, optical fiber technology must be improved so that optical grating can be more efficiently employed in fiber lasers.

The future development of laser sources involves the continuous improvement of their performance, including output power and beam quality, the increase of the ranges of laser wavelengths and tunable lasers, the reduction of the laser spectrum width, the development of an ultra-short-pulse high-brightness laser with extremely high peak value, and research on miniaturization, utilization, and intelligence.

The top three countries in patent output in this area are the USA (98), Japan (21), and China (17). The USA produces 64.90% of the total patents (Table 2.2.5, Figure 2.2.5). The top three institutions in core patent output are FORO (20), GIGA (8), and HONE (5) (Table 2.2.6, Figure 2.2.6), while ASML and CYME engage in the highest cooperation.

Table 2.2.5 Major producing countries or regions of core patents on the engineering development focus “Laser light source technology”

No.	Country/Region	Published patents	Proportion of published patents	Citation frequency	Proportion of citation frequency	Average citation frequency
1	USA	98	64.90%	2476	76.97%	25.27
2	Japan	21	13.91%	324	10.07%	15.43
3	China	17	11.26%	254	7.90%	14.94
4	Germany	8	5.30%	89	2.77%	11.13
5	Austria	3	1.99%	35	1.09%	11.67
6	Switzerland	2	1.32%	4	0.12%	2.00
7	Israel	2	1.32%	30	0.93%	15.00
8	Canada	1	0.66%	61	1.90%	61.00
9	France	1	0.66%	2	0.06%	2.00
10	UK	1	0.66%	3	0.09%	3.00

Table 2.2.6 Major producing institutions of core patents on the engineering development focus “Laser light source technology”

No.	Institution	Published patents	Proportion of published patents	Citation frequency	Proportion of citation frequency	Average citation frequency
1	FORO	20	13.25%	514	15.98%	25.70
2	GIGA	8	5.30%	192	5.97%	24.00
3	HONE	5	3.31%	198	6.15%	39.60
4	KLAT	5	3.31%	92	2.86%	18.40
5	ASML	4	2.65%	116	3.61%	29.00
6	CYME	4	2.65%	116	3.61%	29.00
7	ESII	4	2.65%	105	3.26%	26.25
8	LENS	4	2.65%	44	1.37%	11.00
9	LOCK	4	2.65%	130	4.04%	32.50
10	SORA	4	2.65%	182	5.66%	45.50

Note: FORO stands for Foro Energy Inc.; GIGA stands for Gigaphoton Inc.; HONE stands for Honeywell; KLAT stands for KLA-Tencor Corp.; ASML stands for ASML Netherlands BV; CYME stands for Cymer Inc.; ESII stands for Electro Scientific Industries Inc.; LENS stands for Lensar Inc.; LOCK stands for Lockheed Martin Corp.; SORA stands for SORAA Inc.

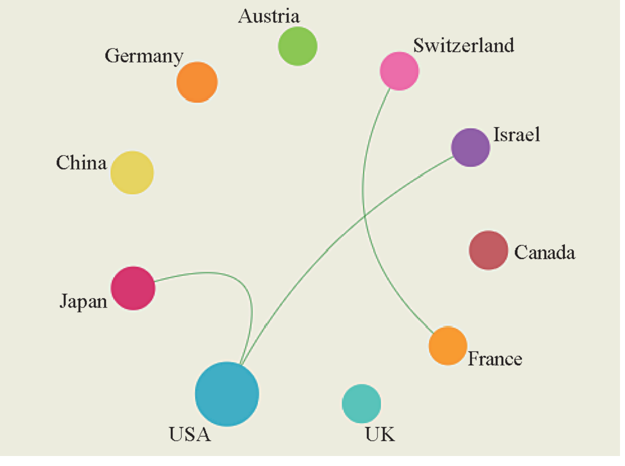

Figure 2.2.5 Collaboration network of the major producing countries or regions of core patents on the engineering development focus “Laser light source technology”

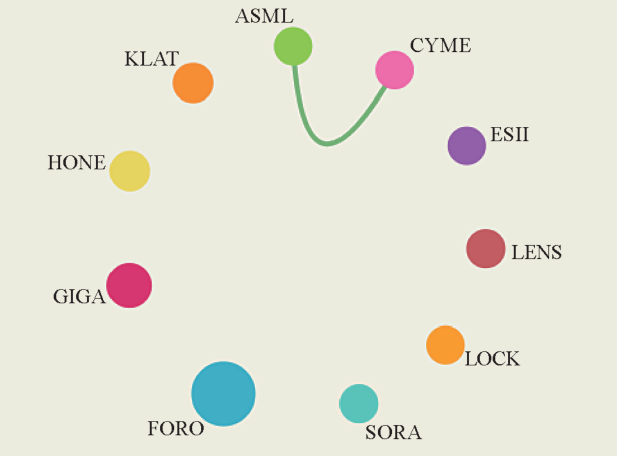

Figure 2.2.6 Collaboration network of the major producing institutions of core patents on the engineering development focus “Laser light source technology”

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