



Face Recognition Based on Citation Network and Main Path Analysis Research on Technology Evolution Path

Shenxu Wang, Duanwu Yan^(✉), Decheng Duan, and Mingcheng Liu

School of Economics and Management, Nanjing University of Science and Technology,
Nanjing, Jiangsu, China
yanwu123@sina.com, mcfly@njjust.edu.cn

Abstract. By studying the technology evolution path in the field of face recognition, we can understand the knowledge evolution path and innovative development direction in the field of face recognition, which is conducive to predicting and grasping the future development of face recognition. Firstly, obtain patent data and build a patent citation network in the field of face recognition; Then according to the life cycle theory, the development stages of face recognition are divided, and the citation network is segmented. Finally, the SPC main path extraction algorithm is used to extract the main paths in different development stages of face recognition, and the patent content of the main paths is analyzed. By analyzing the content of the core patents on the main path, the development direction of each development stage in the field of face recognition is roughly clarified, and the evolution path of face recognition knowledge technology “facial feature localization and recognition — multi-facial feature recognition — facial feature digitalization and algorithm analysis” is found.

Keywords: citation network · main path analysis · face recognition · technology evolution

1 Introduction

Face recognition technology is widely used in economy, citizen security and other fields, such as border protection citizen recognition [1], Smart Campus [2] Wait. At present, all countries in the world are actively using face recognition technology, among which Chinese citizens have the highest acceptance of face recognition technology in the world [3].

The development of science and technology has always been the focus of the state’s attention. The development of technology mainly includes fundamental breakthroughs, technological improvements and technological diffusion [4]. Patent information is highly structured and covers a wide range. Statistics show that 80% of the world’s technical knowledge can be found in patents. [5] Mining valuable potential information from patents has become a research hotspot in the field of technical analysis. [6] The technological evolution path can reveal the development context of the technical field. By

studying the technological evolution path, we can know the development process of the technical field and the innovation points of each stage. Based on the analysis method of citation network and main path recognition, this paper analyzes the technological evolution path of each development stage in the field of face recognition, which is helpful to grasp the development vein and future trend of face recognition technology.

2 Methods and Design

In this paper, the patent database will be obtained through accurate retrieval, and the patent citation network will be established through the cited information of patents. After data preprocessing and cleaning, a pure patent citation network will be obtained. After data cleaning, the patent documents obtained in this paper are divided into life cycle stages according to the life cycle theory, so that all the citation data are divided into patent citation networks of various time stages. Then, SPC algorithm is used to obtain the main path of development of each stage. Finally, the global main path is analyzed for patent content.

3 Results and Discussion

3.1 Data Acquisition and Life Cycle Division

In this paper, patent literature in the field of biometrics was selected as the data source, and the Deventer patent database was selected to search with a specially designed retrieval method, and 33,659 patents from 1976 to 2022 were obtained. Through data cleaning and the replacement of patents of the same family, a pure citation network with 12802 nodes and 26695 edges is obtained.

By using LogletLab software to analyze and fit the patents published in the field of biometric technology from 1976 to 2021 for analysis, and got the patent publication number-year curve (Fig. 1), and the corresponding Growth rate curve of patent publication number (Fig. 2).

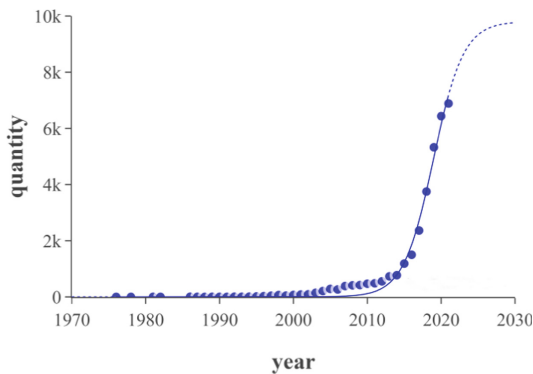


Fig. 1. Patent publication number-year curve

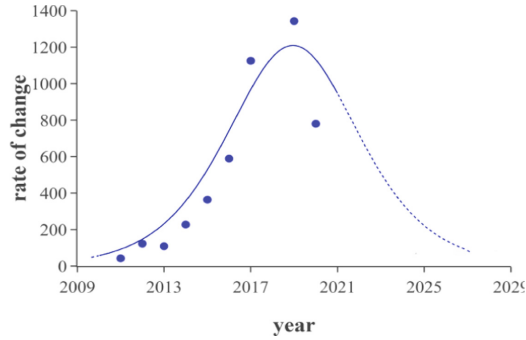


Fig. 2. Growth rate curve of patent publication number

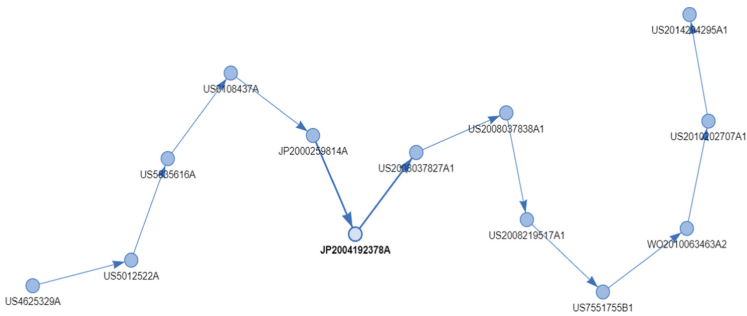


Fig. 3. Main path in germination stage

Since 1970s, the field of biometrics has started to sprout. The dividing time T_{ig} of germination period and growing period is 2014. Since 2014, the number of patents published in the field of face recognition has increased rapidly, and this technical field has entered the growing period. The dividing time point T_{gm} of growth period and maturity period is 2019, by which the growth rate of patent disclosure will reach the maximum, and the field of face recognition will reach maturity. The dividing time point of maturity period and recession period is T_{md} 2024. It is expected that the growth rate of patent disclosure will be flat and enter recession period by 2024.

3.2 Main Path Extraction and Analysis

According to the life cycle divided in the previous step, the citation network is divided into germination citation network, growing citation network and early mature citation network, and the corresponding citation matrix is generated. The processed citation matrix is analyzed by weak and strong components, and SPC algorithm is selected as the main path extraction algorithm. The germination main path (Fig. 3), germination + growth main path (Fig. 4) and global main path (Fig. 5) were extracted respectively.

We can see that the patents in the first half of the global main path roughly overlap with the patents in the germination and growing stages, which indicates that the technological evolution direction of each stage of this technology is the same. We analyze the content

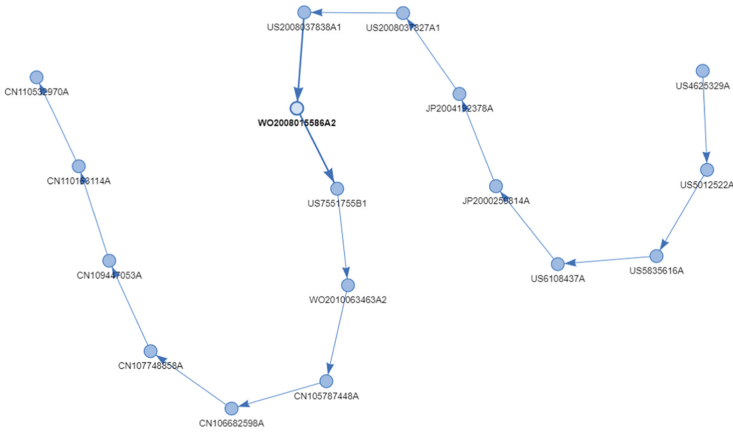


Fig. 4. Main path of germination + growing period

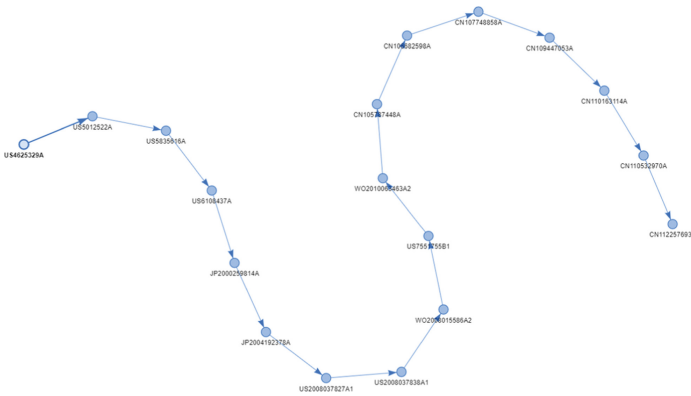


Fig. 5. Global main path

of the global main path. The first stage is the facial feature location and recognition stage (1986–2004): US4625329A discloses an image analyzer for locating the driver’s face to assist driving; US5012522A discloses a machine for locating and recognizing faces in a video scene; US5835616A discloses a two-step process for automatically finding faces in electronic digitized images and confirming the existence of faces by checking facial features; US6108437A discloses a facial recognition system, which extracts two kinds of facial features for recognition; JP2000259814A provides a human body recognition device, which is used to stabilize and guarantee the face component extraction process in face recognition; JP2004192378A provides a high-precision face image processor using multiple cameras, which extracts the features of various face areas of users for recognition. At the beginning, even the user’s face can only be located, but not specific feature recognition. Then, the research focuses on locating a single facial feature or a specific area of the user, and extracting and recognizing it.

The second stage is the multi-facial feature recognition stage (2004–2008): WO2008015586A2 An image processing device for tracking faces in an image stream iteratively receives newly acquired images from the image stream, which may include one or more face regions; US2008037838A1 stores multiple identifiers of multiple faces in the database, and selects at least one area for recognition of the face area captured by the image; US2008037827A1 provides a face recognition method for processing two or more sets of face images. At this time, the face recognition technology tends to be mature, and many facial features can already be recognized. Compared with the previous stage, the number of recognized facial features is increased, and the accuracy of facial recognition is improved, but the analysis of facial features itself is lacking.

The third stage is the stage of facial feature digitization and algorithm analysis (2009–present): US7551755B1 has exposed a processor-based system operated by digital embedded programming instructions. The face recognition module extracts a set of face classifier parameter values from the standardized face region known as face imprinting and parameterizes the facial features. WO2010063463A2 is a face recognition technique that involves using a multi-classifier face detector to determine the probability that an image region includes a face above a threshold; CN105787448A discloses a face shape tracking method based on spatiotemporal cascade shape regression. Five face feature points are obtained through face detector sets, and the five face feature points are evaluated to obtain similar transformation parameters. The speed of face tracking by multi-view cascade regression is faster and more accurate. A multi-pose face feature point detection method based on cascade regression is presented in CN106682598A. The method includes the steps of extracting the pose index features and establishing the corresponding optimal weak regression device. CN107748858A discloses a multi-pose eye localization algorithm based on cascade convolutional neural network, which is suitable for face recognition, eye tracking and other intelligent systems. CN109447053A provides a face recognition method based on double constrained attention neural network model, which extracts facial features into facial feature matrix for recognition. CN110163114A discloses a face Angle and face ambiguity analysis method, system and computer equipment, through the analysis of face features and ambiguity to extract higher quality images; CN110532970A discloses an age and gender attribute analysis method, system and computer equipment for two-dimensional face images, which can detect the age and gender of faces in images. CN112257693A provides an identification method and equipment to match the first and second features of users, and determine the identity of users through specific identification combination conditions. At this stage, the face recognition technology is more comprehensive, not only for the past identity recognition, but for all kinds of technologies, and can be captured by the facial features of the user attributes are analyzed.

4 Conclusions

To sum up, it can be concluded that the technical flow of face recognition is “facial feature location and recognition — multi-facial feature recognition — facial feature digitization and algorithm analysis”. At the initial stage, only simple facial location can be carried out, and it can be used as an auxiliary system in other technologies, such as camera

character location or driver assistance system in cars. Later, users can be identified by their faces. At the second stage of development, it has become an independent system, and it can be used in a more complex environment, by identifying various facial features of users. At present, it has become a comprehensive system, which is not only used for user identification, but also used for the analysis of facial features.

Although this paper successfully extracted and analyzed the main path in the field of face recognition, the research results of this paper still have some shortcomings: (1) This paper obtained about 34,000 patent data in the field of face recognition through design search, but compared with this technical field, the patent database constructed in this research process may not fully summarize the development of this technical field. (2) This paper adopts the research method of main path analysis based on citation network, which can't interpret the whole patent data, but the final main path analysis result, so the result lacks some comprehensiveness. To sum up, the research results of this paper have research value, but there is still room for improvement. In the future, the research methods (such as timing themes, etc.) of interpreting the whole patent data can be used for auxiliary analysis, so as to make the final results more comprehensive.

Acknowledgements. This article is the result of the 2021 National Undergraduate Scientific Research Training Project (Grant No.: 202110288014) of the “Nanjing University of Science and Technology Research Training ‘Hundred Thousands’ Plan”.

References

1. Tucker Aaron. The Citizen Question: Making Identities Visible Via Facial Recognition Software at the Border [J]. *IEEE TECHNOLOGY AND SOCIETY MAGAZINE*, 2020, 39(4): 52-59.
2. Mou Guodong, Tan Qiaoqiao, Li Tianlai, Liu Liang. Application of face recognition technology in smart campus [J]. *Computer Knowledge and Technology*, 2021, 17(16):190-192
3. Kostka Genia and Steinacker Léa and Meckel Miriam. Between security and convenience: Facial recognition technology in the eyes of citizens in China, Germany, the United Kingdom, and the United States [J]. *Public Understanding of Science*, 2021, 30(6): 671-690.
4. Ichiro Watanabe and Soichiro Takagi. Technological Trajectory Analysis of Patent Citation Networks: Examining the Technological Evolution of Computer Graphic Processing Systems[J]. *The Review of Socionetwork Strategies*, 2021,; 1–25.
5. Chen Liang, Yang Guancan, Zhang Jing, Fan Yunman. Research on Multi-main Path Method for Technology Evolution Analysis [J]. *Library and Information Work*, 2015, 59(10):124-130+115.
6. Liu Meijia. Research on the evolution of RFID technology based on patent analysis [D]. Beijing: Beijing University of Technology, 2014.

Open Access This chapter is licensed under the terms of the Creative Commons Attribution-NonCommercial 4.0 International License (<http://creativecommons.org/licenses/by-nc/4.0/>), which permits any noncommercial use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons license and indicate if changes were made.

The images or other third party material in this chapter are included in the chapter's Creative Commons license, unless indicated otherwise in a credit line to the material. If material is not included in the chapter's Creative Commons license and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder.

