Analysis on Development Tendency of Computer Vision and Graphics based on Bibliometrics

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Abstract. In this paper, the bibliography included in Web of Science is taken as the data sample. This paper analyzes articles and reviews published from 2010 to 2020 in the field of computer vision and graphics to reveal the major countries or regions. We use leiden-type community algorithm to identify research topics. Besides, we explore the research fronts in the field of computer vision and graphics based on highly cited papers. The results show that the research on computer vision and graphics in the United States started earlier. The United States has always been in the leading position. China has developed rapidly in recent years. The United Kingdom, South Korea and India are also prominent. Deep learning, face recognition, image retrieval and volume rendering are the hottest research topics in the field of computer vision and graphics. Convolutional neural network and deep learning are the most emerging research fronts in the field of computer vision and graphics.

1. Introduction
With the development of artificial intelligence, computer vision and graphics have been rapidly developed. Computer vision originates in the 1950s. Computer vision uses data symbols, computer information model and information network platform to transport information. Computer vision is a new kind of track system, through capturing the vision to make information expressed intuitively. Computer vision is widely used in many fields such as industrial detection, digital image retrieval[1], biological-image analysis[2] and vehicle navigation[3]. Computer graphics includes image interaction, graphics model building, graphics standardization, graphics visualization and so on. Computer graphics plays an important role in computer aided design, computer animation art, virtual reality[4] and cultural heritage[5].

Computer vision and graphics are advanced research directions in the field of computer science and artificial intelligence. It is necessary to understand the latest research progress and development tendency. Therefore, we adopt bibliometrics methods to analyze academic papers in the field of computer vision and graphics, explore the publishing trend, major countries or regions, research topics and research fronts in the field of computer vision and graphics.

2. Data sources and methods

2.1 Data sources
Data in this paper is collected from InCites and Web of Science. InCites is a statistical analysis tool that includes papers from Web of Science core collection. Incites has a diverse set of bibliometric indicators.
In this paper, we select and download "Computer Vision & Graphics" papers from Incites. "Computer Vision & Graphics" is a citation topic that belongs to one of the 326 meso-topics. The papers are limited to article and review. The publication year of the papers is from 2010 to 2020. Finally, 93020 related papers are retrieved, among them, 1248 papers are highly cited papers. We retrieved the data on March 1, 2021.

2.2. Analysis methods and tools
In this paper, the bibliometrics method is used to analyze the papers in the field of computer vision and graphics. We reveal the global trend and major countries based on bibliometrics methods. We reveal the research topics using the clustering leiden-type community algorithm, and identify the research fronts using burst detection algorithm. Three tools are used in this paper, such as InCites, Excel and CiteSpace.

All papers are algorithmically clustered based on cited and citing relationships between papers. In this paper, we use a leiden-type community algorithm to cluster the research topics. Then we use algorithmic tools to label each research topic according to the most important keywords from the papers in the topic.

Kleinberg proposes the burst detection algorithm which can help detect the burst terms. Burst terms means the words whose frequency increases sharply in some publishing years or that appear suddenly in a short period of time[6]. The burst detection algorithm can help find out the burst terms in each period according to the growth rate of word frequency. Many researchers use burst detection algorithm to identify research fronts. The burst detection module in CiteSpace software developed by Chen Chaomei integrates the function of the burst detection algorithm. In this paper, we use CiteSpace software to identify a group of burst terms from highly cited papers. Research fronts are determined based on the burst time and strength of the burst terms.

3. Empirical analysis

3.1. Posting trend
Figure 1 shows the time distribution of papers in the field of computer vision and graphics. From 2010 to 2020, 93020 papers were published. The number of papers shows an increasing trend. From 2010 to 2017, the number of papers grew slowly. After 2018, the growth rate became faster, and the research heat began to increase.

![Figure 1. Annual distribution of papers in the field of computer vision and graphics.](image)

3.2. Locations analysis
Table 1 shows the statistical results of 93020 papers in the field of computer vision and graphics. In the past eleven years, a total of 143 countries or regions have published computer vision and graphics papers. China published 34,805 papers twice as many papers as the United States. However, in terms of total citations, papers published by the United States have the highest citations and higher influence and attention around the world.
Table 1. The top ten countries or regions in the volume of papers.

| Country/Region   | Paper Number | Citations  |
|------------------|--------------|------------|
| China            | 34805        | 415906     |
| USA              | 16323        | 482976     |
| UK               | 5894         | 144516     |
| South Korea      | 5248         | 51686      |
| India            | 4653         | 42488      |
| Germany          | 4341         | 111937     |
| France           | 4324         | 113826     |
| Spain            | 3634         | 49318      |
| Canada           | 3288         | 93849      |
| Australia        | 3192         | 69050      |

We list five major countries’ annual distribution of papers including China, the United States, the United Kingdom, South Korea and India, as shown in Figure 2. From 2010 to 2011, Papers published by China were slightly lower than that of the United States. After 2012, China surpassed the United States, showing a rapid growth. India surpassed South Korea in 2018 and the United Kingdom in 2019.

3.3 Research topics analysis

3.3.1 Identify Research Topics

According to leiden-type community algorithm mentioned in 2.2, we explore the micro-topics in the field of computer vision and graphics. Fourteen clusters are obtained as showed in table 2. Fourteen clusters represent the micro-topics in the field of computer vision and graphics. Every micro-topic include some papers. Micro-topics are algorithmically labeled with most significant keyword from the papers belonged to the corresponding topic. The fourteen micro topics in the field of computer vision and graphics are deep learning, face recognition, image retrieval, volume rendering, image segmentation, action recognition, image enhancement, object tracking, OCR, cell segmentation, retinal images, defect detection, digital topology and video summarization. Among them, deep learning, face recognition, image retrieval and volume rendering are the hottest research topics.

Table 2. Fourteen micro-topics in the field of computer vision and graphics.

| Number | Micro Topics          | Paper Number | Citations  |
|--------|-----------------------|--------------|------------|
| 1      | Deep Learning         | 15977        | 390196     |
| 2      | Face Recognition      | 13239        | 203327     |
| 3      | Image Retrieval       | 12194        | 142340     |
| 4      | Volume Rendering      | 11552        | 120132     |
By observing the development trend of the fourteen micro topics, it can be found that the number of papers of most topics is on the rise. Deep Learning is the fastest growing research topic in the field of computer vision and graphics in the past decade. The growth rate of image retrieval, volume rendering, image segmentation, digital topology and video summarization is relatively slow.

### Table 3. Annual distribution of papers in micro topics of computer vision and graphics.

| Micro Topics          | 2010  | 2011  | 2012  | 2013  | 2014  | 2015  | 2016  | 2017  | 2018  | 2019  | 2020  |
|-----------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| Deep Learning         | 254   | 249   | 373   | 433   | 624   | 809   | 1078  | 1595  | 2743  | 5059  | 2760  |
| Face Recognition      | 826   | 867   | 1006  | 1028  | 1253  | 1229  | 1344  | 1429  | 1647  | 1825  | 785   |
| Image Retrieval       | 869   | 927   | 1035  | 1097  | 1170  | 1281  | 1300  | 1249  | 1346  | 1396  | 524   |
| Volume Rendering      | 911   | 996   | 1029  | 1114  | 1080  | 1086  | 1116  | 1206  | 1275  | 1261  | 478   |
| Image Segmentation    | 627   | 704   | 698   | 810   | 836   | 721   | 811   | 804   | 770   | 897   | 331   |
| Action Recognition    | 324   | 389   | 442   | 540   | 699   | 689   | 754   | 861   | 990   | 1184  | 604   |
| Image Enhancement     | 347   | 385   | 429   | 418   | 532   | 559   | 586   | 667   | 740   | 844   | 435   |
| Object Tracking       | 247   | 260   | 306   | 323   | 458   | 450   | 537   | 540   | 722   | 937   | 466   |
| OCR                   | 158   | 190   | 221   | 218   | 283   | 252   | 276   | 328   | 332   | 419   | 240   |
| Cell Segmentation     | 165   | 148   | 198   | 219   | 229   | 284   | 271   | 309   | 271   | 347   | 343   |
| Retinal Images        | 162   | 159   | 192   | 224   | 219   | 227   | 251   | 280   | 337   | 378   | 276   |
| Defect Detection      | 124   | 134   | 113   | 128   | 142   | 133   | 176   | 173   | 260   | 353   | 348   |
| Digital Topology      | 162   | 177   | 183   | 160   | 180   | 152   | 180   | 169   | 162   | 195   | 118   |
| Video Summarization   | 104   | 96    | 101   | 97    | 89    | 74    | 93    | 104   | 108   | 106   | 85    |

### Table 4. National distribution rank of papers in micro-topics of computer vision and graphics.

| Micro Topics          | USA    | China  | UK     | South Korea | Germany |
|-----------------------|--------|--------|--------|-------------|---------|
| Deep Learning         |        |        |        |             |         |
| Face Recognition      | China  | USA    | India  | South Korea | UK      |
| Image Retrieval       | China  | USA    | South Korea | France   | UK      |
| Volume Rendering      | USA    | China  | Germany | France     | UK      |
| Image Segmentation    | China  | USA    | France  | India       | Germany |
| Action Recognition    | China  | USA    | UK     | South Korea | Spain   |
| Image Enhancement     | China  | USA    | South Korea | UK        | India   |
| Object Tracking       | China  | USA    | South Korea | UK        | India   |
| OCR                   | China  | India  | USA    | Spain       | France  |
| Cell Segmentation     | USA    | China  | Germany | UK         | India   |
| Retinal Images        | China  | USA    | Singapore | India      | Australia|
| Defect Detection      | China  | USA    | South Korea | Canada    | Spain   |
| Digital Topology      | China  | USA    | France  | India       | South Korea |
| Video Summarization   | China  | USA    | India  | South Korea | UK      |
3.4. Highly cited papers analysis

Highly cited papers are papers that belong to the top 1% of papers in a field published in a specified year. The 1% is determined by the highly cited threshold calculated for the field in the specified year. A total of 1248 highly cited papers are selected from 93020 papers in the field of computer vision and graphics from 2010 to 2020. Among 1248 highly cited papers, 6 papers are cited more than 10,000 times, as shown in Table 5. The most cited paper is "NIH Image to ImageJ: 25 years of image analysis", published in Nature Methods in 2012. This paper is cited 23467 times. This paper discusses the origins, challenges and solutions of NIH Image and ImageJ software and how their history can serve to advise and inform other software projects[7]. The second most cited paper is "Deep Learning", published in Nature in 2015, with a total of 18827 citations. This paper gives a detailed overview of deep learning[8]. The third most cited paper is "Fiji: an open-source platform for biological-image analysis" published in Nature Methods in 2012, with a total of 18114 citations. This paper introduces an open source platform for biological image analysis[9]. The other three papers with more than 10,000 citations are about machine learning and neural networks.

Table 5. Top six highly cited papers.

| Title | Year | Journal | Citations |
|-------|------|---------|-----------|
| NIH Image to ImageJ: 25 years of image analysis | 2012 | Nature Methods | 23467 |
| Deep learning | 2015 | Nature | 18827 |
| Fiji: an open-source platform for biological-image analysis | 2012 | Nature Methods | 18114 |
| Scikit-learn: Machine Learning in Python | 2011 | Journal of Machine Learning Research | 15831 |
| ImageNet Classification with Deep Convolutional Neural Networks | 2017 | Communications of the ACM | 14221 |
| Dropout: A Simple Way to Prevent Neural Networks from Overfitting | 2014 | Journal of Machine Learning Research | 10293 |

3.5. Research fronts analysis analysis

The burst terms can be used to reveal research fronts in a field. In this paper, we detect the burst terms from 1248 highly cited papers in computer vision and graphics, and then identify the research fronts. CiteSpace burst detection function is used to identify burst terms. At first, 50 burst terms are obtained. After manual screening and judgment, we get 22 burst terms. These 22 burst terms represent the research fronts in the field of computer vision and graphics. Table 6 shows the burst terms and their burst strength, starting and ending time. From 2010 to 2015, the burst terms in the field of computer vision and graphics mainly include: shape, active contour, semi-supervised learning, image restoration, eigenface, reconstruction, texture, face recognition, object recognition, sparse representation, registration, color and scene classification. From 2016 to 2020, the burst terms include: diagnosis, machine learning, recurrent neural network, convolutional neural network, deep learning, artificial intelligence, computer aided detection, semantic segmentation and prediction. Convolutional neural network and deep learning are the most emerging research fronts. In recent years, convolutional neural network and deep learning have been making breakthroughs in computer vision tasks such as image classification, semantic segmentation, target detection and video classification, and has achieved great success in various fields such as face recognition, posture recognition, medical treatment and unmanned driving.

Table 6. Top 22 burst terms with the strongest strength.

| Burst Terms | Strength | Begin | End  | 2010 - 2020 |
|-------------|----------|-------|------|-------------|
| shape       | 3.94     | 2010  | 2011 |             |
4. Conclusion

In this paper, bibliometrics methods, leiden-type community algorithm and burst detection algorithm are used to analyze the development tendency of computer vision and graphics. We analyze the publishing trends, major countries or regions, research topics and research fronts based on papers in the field of computer vision and graphics. The analysis draws the following conclusions: The number of papers published in the field of computer vision and graphics is increasing obviously. China and the United States are the leading producers in this field. The research topics focus on deep learning, face recognition, image retrieval and volume rendering. The research fronts mainly includes convolutional neural network, deep learning, computer aided detection and prediction.

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