

## Analysis on the Development of Augmented Reality in the United States

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**Abstract:** Augmented Reality (AR) is a multi-disciplinary field, which includes computer vision, computer graphics, sensors, networks, GPS and many other technologies. With the increasing maturity of augmented reality technology, augmented reality system will gradually enter various application fields, which has great application value and application prospects. In this study, Web of Science Core Collection database is used as data source. Using Excel, Bibexcel, VOSviewer and CiteSpace software for data mining and quantitative analysis of the 1993-2019 year research papers on augmented reality in the United States, we explore the trend of change, the distribution of research forces, key areas, research hot spots and cooperation.

### 1. Introduction

Augmented reality (AR) technology is a research hotspot in recent years and has a wide application prospect. Although similar to the traditional VR technology, it is different from the traditional full virtual reality technology. In the augmented reality world, users can not only see all kinds of virtual images generated by computers, but also observe the surrounding environment in real time through display devices, so they have the ability to render real and virtual dual signals. It plays an irreplaceable role in a variety of applications that need the combination of reality and reality, such as medical surgery, entertainment games, automobile and aviation navigation, remote control and so on[1].

In the 1960s, Sutherland, as the ancestor of 3D display technology, developed the first generation of VR helmet-mounted display which can be used as perspective. By installing some devices, it can be used as AR device. However, its volume is huge and display effect is rough, which can easily cause user fatigue, so the market situation is not good [2]. Due to the limitations of hardware and image processing research, AR technology has not made significant progress in the next 20 years. Until the term augmented reality came into being in 1992, Tom Caudel and his colleagues were developing head-mounted display systems. The release of AR-Quake, the first AR game in 2000, marks the beginning of AR's entry into business. In 2017, Apple announced that iOS 11 will bring a new AR component ARKIT, making the iPhone the world's largest AR platform, which makes one have to believe that AR really has great potential for development [3].

In this study, bibliometrics is used to analyze and excavate augmented reality technology in order to provide scientific reference and theoretical guidance for the future research direction of augmented reality.

### 2. Method and source

In this study, the Web of Science Core Collection of Clarivate is selected as the data source. It is a world-renowned Citation Index database. It is widely used in scientific research and evaluation because of its pioneering content, high quality data and long history. The papers included in this database can reflect the development trend of the scientific frontier to a certain extent [4-6]. The literature type is unlimited, the language is English, and the time range is all year. The retrieval time

was February 16, 2019, and 12109 records in the world, 2428 records in the United States were retrieved. Using Excel, Bibexcel, VOSviewer and CiteSpace software to analyze and excavate the information of the publication year, organization, research area, subject word (key word) and so on, we obtain the development trend of augmented reality technology, cooperative network, research focus and hot spot in the United States.

The number of published articles worldwide is 12109 records. Fig.1 shows the number of published articles in the top 20 countries or regions. The volume of publications in the United States is significantly higher than that in other countries, which is more than twice that of South Korea or Japan. so this study chooses the development of augmented reality in the United States as the research object.

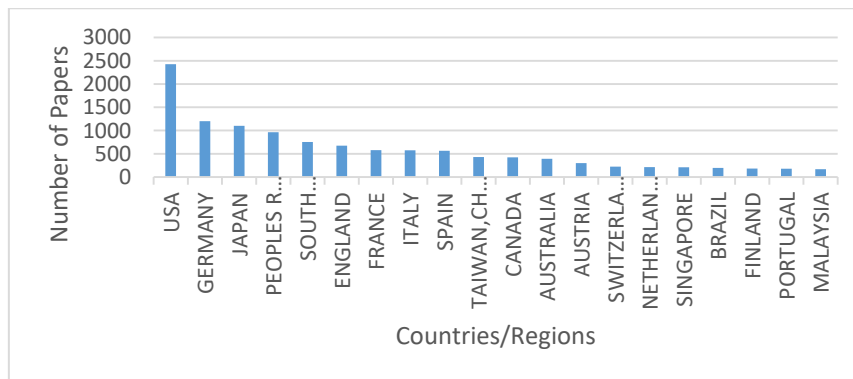


Fig.1. Number of published articles in the top 20 countries or regions

### 3. Analysis of annual change trend

We have retrieved data from all year but there have papers related to augmented reality technology between 1993 and 2019, which is consistent with the proposal of augmented reality concept. The number of papers published in the United States is 2428 and the research trend of augmented reality technology is on the rise. In 1993-2010, the number of papers per year is below 100, which can be called the initial stage. From 2011-2018, the number of rapid growth can be called a period of rapid development. In 2017, the largest number of articles was published, reaching 328. As can be seen from Fig.2, augmented reality has been growing.

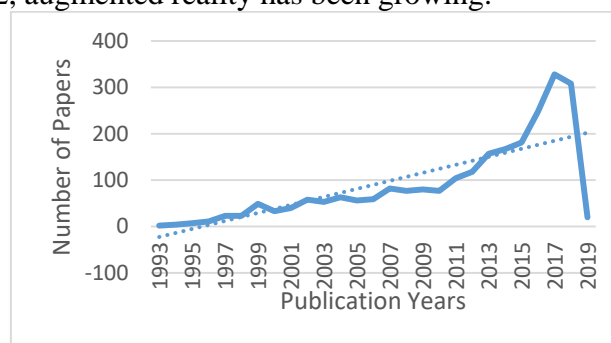


Fig.2. The published numbers of annual year

### 4. Organization analysis

Fig.3 shows the overlay visualization of VOSviewer and illustrates the partnership between research organizations in the United States. We can see that the most active institutions in recent years are mainly University of Southern California, Stanford University, Johns Hopkins University, Microsoft Research, University of California, Los Angeles, Arizona State University. Table I shows the top 20 organization of augmented reality. University of California, State University System of Florida and University of Central Florida are the top three.

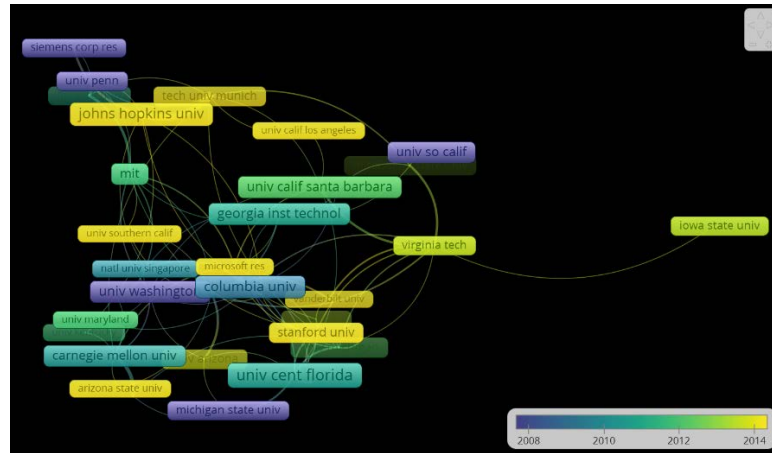


Fig.3. Inter-organizational cooperation networks

TABLE I. Organizations And Number of Papers

NO.	Organizations	Papers	NO.	Organizations	Papers
1	UNIVERSITY OF CALIFORNIA SYSTEM	167	11	UNIVERSITY OF WASHINGTON	66
2	STATE UNIVERSITY SYSTEM OF FLORIDA	129	12	MASSACHUSETTS INSTITUTE OF TECHNOLOGY MIT	65
3	UNIVERSITY OF CENTRAL FLORIDA	97	13	UNIVERSITY OF ILLINOIS SYSTEM	64
4	UNIVERSITY SYSTEM OF GEORGIA	93	14	UNIVERSITY OF WASHINGTON SEATTLE	64
5	JOHNS HOPKINS UNIVERSITY	92	15	UNITED STATES DEPARTMENT OF DEFENSE	63
6	UNIVERSITY OF NORTH CAROLINA	80	16	PENNSYLVANIA COMMONWEALTH SYSTEM OF HIGHER EDUCATION PCSHE	62
7	UNIVERSITY OF SOUTHERN CALIFORNIA	76	17	CARNEGIE MELLON UNIVERSITY	60
8	COLUMBIA UNIVERSITY	74	18	STANFORD UNIVERSITY	55
9	GEORGIA INSTITUTE OF TECHNOLOGY	71	19	UNIVERSITY OF NORTH CAROLINA CHAPEL HILL	54
10	UNIVERSITY OF CALIFORNIA SANTA BARBARA	67	20	UNIVERSITY OF MICHIGAN	52

## 5. Key research field and hot spot analysis

### 5.1 Distribution of key disciplines

The top 10 subject areas involved in the research of augmented reality mainly concentrated in the first four fields, of which the maximum number of documents in Computer Science is 1409,

accounting for 58.0% of the total number of documents, indicating that the researchers have the highest degree of concern. Ranked second was Engineering, 839, accounting for 34.6% of the total volume. Ranked third is Imaging Science Photographic Technology, 244, accounting for 10.0% of the total volume. Ranked fourth is Optics, 235, accounting for 9.7% of the total volume (Fig.4).

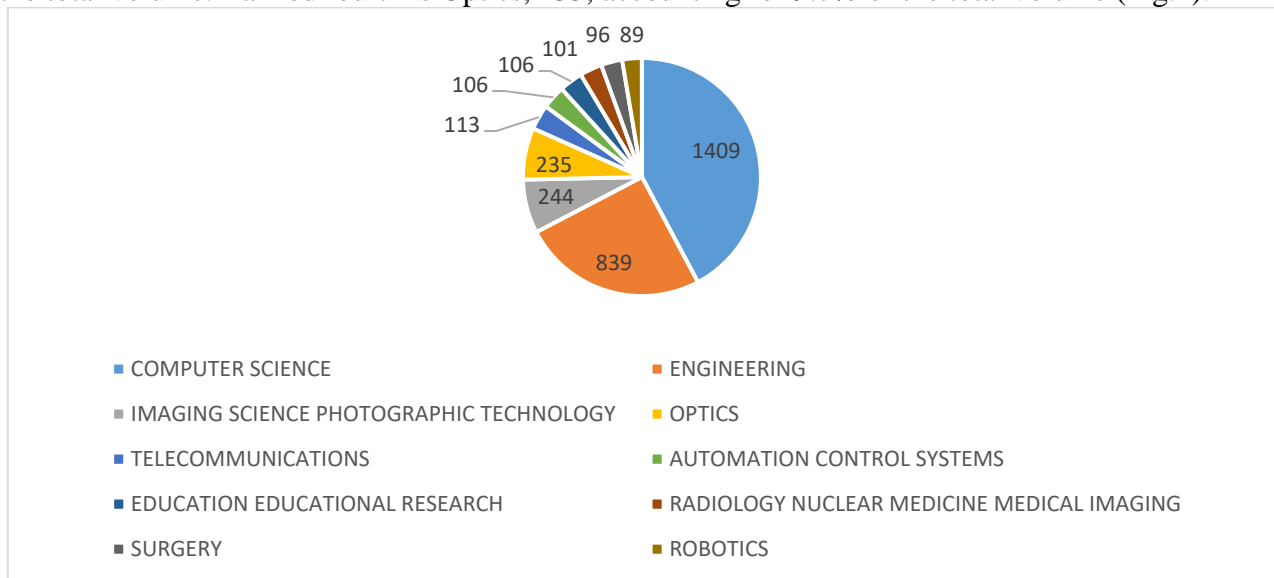


Fig.4. The major research areas of augmented reality

## 5.2 Research focus and hot spot analysis

Key words directly reflect the main contents of the article. By using the word frequency statistics, the focus of the research field can be more refined. Based on the research of word frequency statistics of author's keywords, we get the high frequency keywords frequency distribution map of augmented reality research papers. These are augmented reality, virtual reality, mixed reality, stimulation, tracking, visualization, haptics, etc.. Table II lists the keywords of TOP10. In addition to augmented reality, the key words with higher frequency are virtual reality, mixed reality, simulation, tracking, which are 203, 49, 32, 32 respectively.

TABLE II. Top 10 Key words frequency distribution

NO.	Key words	Frequency
1	Augmented reality	861
2	virtual reality	203
3	Mixed Reality	49
4	simulation	32
5	tracking	32
6	Visualization	31
7	Haptics	29
8	Artificial, Augmented, and Virtual Realities	28
9	COMPUTER VISION	28
10	Education	27

We use CiteSpace for clustering analysis. Fig. 5 shows the results of clustering. It displays cluster labels in abstract terms. We can see that the previous research mainly focused on #11(various technical approach), #5(natural feature), #3(registration problem), #7(rapid technological advancement). The timeline view of Citespace can show the time span and research process of each cluster (i.e. sub domain) evolution. As can be seen from Fig.6, the time span is from 1988 to 2018 and there are a series of important milestone results. It can also be seen that the recent research topics focus on #1(3d scene), #4(point cloud), #6(true per-pixel focal control).

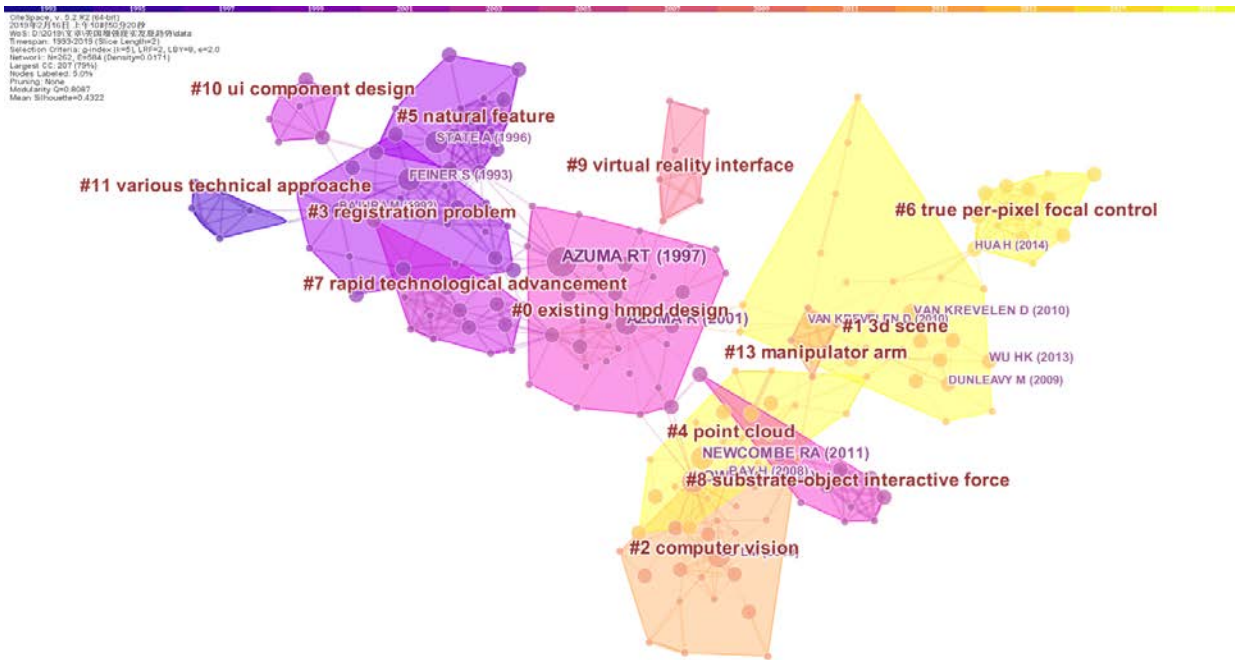


Fig.5. Label cluster with abstract terms

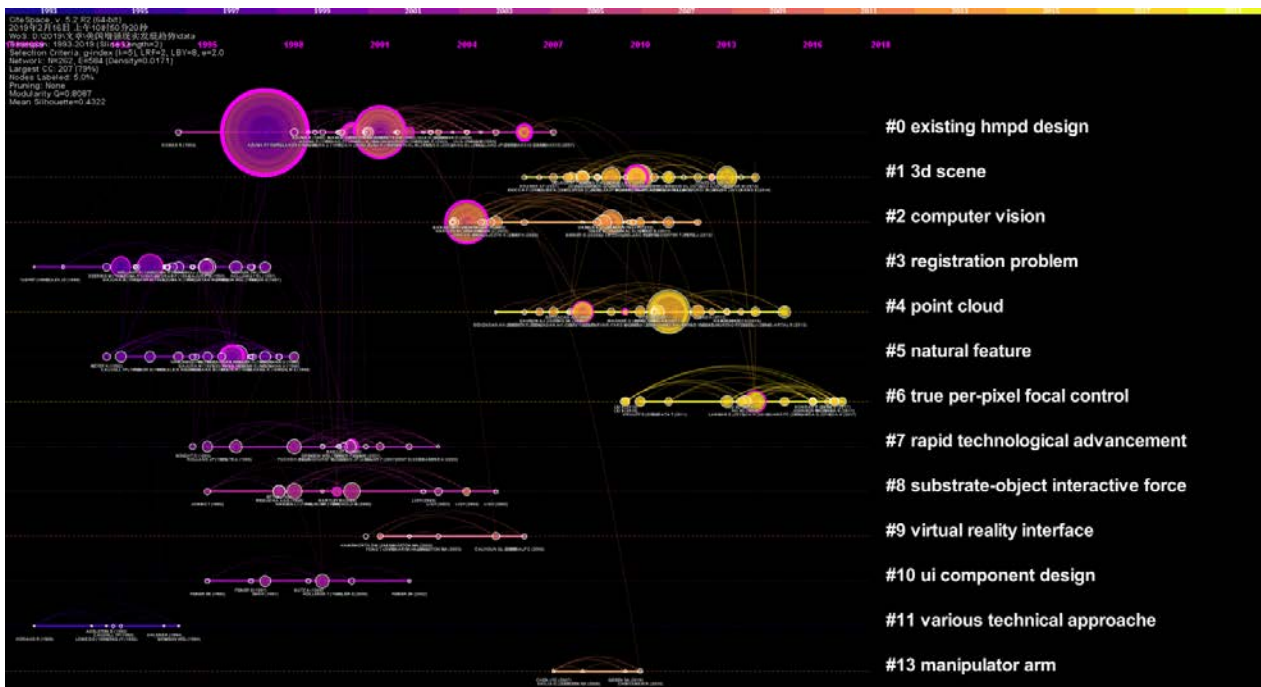


Fig.6. Timeline view of augmented reality

## 6. Summary

Through the data mining and analysis of augmented reality research papers in the United States, the following conclusions are obtained:

- (1) In 1993–2018, the number of research papers on augmented reality is on the rise.
- (2) The United States has the largest number of articles published in the world in the field of augmented reality. The largest number of articles published in the United States is University of California.
- (3) There are many subjects involved in the research of augmented reality technology, mainly Computer Science, Engineering, Imaging Science Photographic Technology and Optics.
- (4) According to the statistical analysis of high frequency keywords in literature, augmented reality, virtual reality, mixed reality, simulation, tracking, visualization have higher frequency words,

more than 30 times.

(5) The main hot spots of augmented reality are 3d scene, point cloud, true per-pixel focal control, etc..

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