

# Development Status and Prospects of Digital Creative Technology in China

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**Abstract:** As one of the strategic emerging industries identified in the 13th Five-Year Plan of China, the digital creative industry has entered the digital and networking era, focusing on culture, content, and copyright, and driving the development of surrounding industries through integration and penetration. The key to developing the digital creative industry is digital creative technology and creative design; however, China has certain weaknesses and does not have a clear development path. In this paper, by analyzing industrial data, we systematically describe the current development status of digital creative technology in China, including enabling, application, and end-user device technologies, and summarize the problems and weaknesses of China in terms of ultra-high definition (UHD) video, 3D audio, virtual/augmented reality, and software for digital content generation and creative design. The results of our investigation suggest that the development of digital creative technology in China can be promoted by establishing key national science and technology projects and national engineering research centers on digital creative technology, improving the quality of talented researchers working on digital creative technology, and actively dissipating international cooperation thereby increasing the influence of Chinese culture.

**Keywords:** digital creativity; cultural creativity; creative design; ultra-high definition (UHD) video; virtual reality

## 1 Introduction

The digital creative industry is an emerging industrial cluster in the digital and networking era, which is supported by technology and design and is centered on culture, content, and copyrights, and is driving the development of surrounding industries through integration and penetration [1,2]. The digital creative industry covers many areas, including the ultra-high definition (UHD) video industry, virtual/augmented reality (VR/AR), design, media, gaming, digital copyrights, living-environments, culture and museum, fashion, toy, sporting and health, and tourism industries. The digital creative industry integrates modern information technology with the cultural and art fields, promotes cultural and artistic innovation and business model innovation, and promotes the mutual penetration and transformation of traditional manufacturing, cultural, and creative industries, as well as the design and service industries, thereby creating new economic growth and commercial models.

At the end of 2016, the State Council affirmed the key position of the digital creative industry as a national emerging strategic industry in the *13th Five-Year National Strategic Emerging Industries Development Plan*, and proposed that the digital creative industry should become one of the five new pillar industries with an output value of 10 trillion yuan by 2020. This shows that developing a digital creative industry is an important strategic plan for China. In the digital creative industry, digital creative technology provides basic support capabilities, representing all forms of information and communication generated in the digital environment, and represents all forms of deep integration and application of new-generation information technology and creative industries. Digital creative

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technology includes three categories: enabling technology, application technology, and end-user device equipment technology [2].

Enabling technology refers to general basic information technology, including artificial intelligence (AI), big data, cloud computing, human-computer interaction, humanoid audiovisual technology, spatial and emotional perception technology, Internet of Things, and 5G network technologies. These technologies are prerequisites for digital construction in various industries and provide support for the development of their own applications in the digital creative industry. Application technology refers to the realization of technologies in various professional technical fields, such as integrated broadcast-broadband (IBB), digital content processing software, home entertainment software, game engine technology, interactive entertainment engine development, digital art presentation technology, media convergence broadcasting technology, and digital processing technology of cultural resources. Application technology is a core tool for improving the quality of content and innovative service models in various professional fields of the digital creative industry. Only when a breakthrough is made at the level of application technology can the quality of the content products be improved. End-user devices are the carriers of content consumption by users, including hardware and their embedded application software, such as 4K/8K UHD TVs, naked-eye 3D TVs, immersive audio devices supporting 3D audio, VR/AR devices, data gloves, game controllers and other sensing terminals, film and television recording equipment, laser projection equipment, and holographic projection equipment. End-user devices directly improve user experience, and their advanced level directly determines the presentation method of digital content and the using experience of audiences.

Previous papers have described some of these technical fields, including AI technology [3], big data technology [4], cloud computing technology [5], UHD video technology [6], and VR technology [7]. However, to the best of our knowledge, no studies have systematically and comprehensively introduced the field of digital creative technology in China. Meanwhile, most existing papers have described general technologies, but have not emphasized the role of these technologies in the digital creativity industry. To this end, in the present study, key technology sub-fields were selected and the development of digital creative technology in China is introduced in detail herein. Specifically, we will introduce enabling technologies, including artificial intelligence, big data, cloud computing, and future network technologies; application technologies including IBB, digital content processing, game engine software, and digital processing technologies for cultural resources; and end-user device technologies, including 4K/8K UHD video, 3D audio, VR/AR, and holography technologies, as shown in Fig. 1.

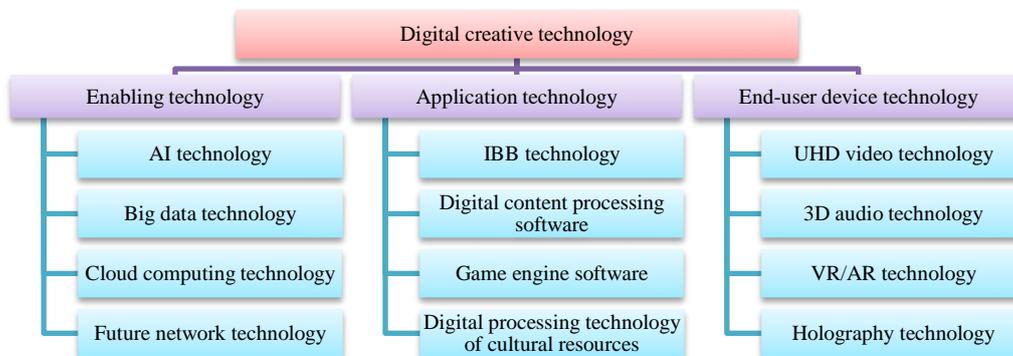


Fig. 1. Digital creative technology classification introduced in this article.

## 2 Development status of digital creative technology in China

### 2.1 Enabling technology

#### 2.1.1 AI technology

AI is a new technical science for researching and developing theories, methods, technologies, and application systems for simulating and extending human intelligence [8]. Its main purpose is to understand the essence of human brain intelligence and produce a new intelligent machine that can react in a similar way as human intelligence. The main development stages of AI are computational intelligence, sensing intelligence, and cognitive intelligence. We are currently in the transition stage from sensing intelligence to cognitive intelligence. AI has become a new field of international competition and is a strategic technology that is leading to future developments. An increasing number of countries have adopted the development of AI as a major strategy to enhance national competitiveness and maintain national security. They are introducing emergency plans and policies, and strengthening the deployment

around core technologies, top talent, and standards, among other factors, aiming at leading international technological competition. Among them, China and the United States are ahead of the world in the fields of computer vision, natural language processing, and intelligent robots. According to data from the Qianzhan Industry Research Institute [9], it is expected that the size of China's AI market will reach 64.4 billion yuan in 2019 and achieve significant development potential (Table 1).

At present, China has many products that apply AI technology to the digital creative industry. For example, Dreamwriter, launched by Tencent, generates news reports based on text rules. Luban AI designers developed by Alibaba can produce 8000 poster designs per second and can produce 40 million posters per day. It can be seen that AI will play an increasingly important future role in the digital creative industry.

**Table 1.** AI, big data, and cloud computing market size in China, 2015–2019 [10–12].

Technology domain	Scale	2015	2016	2017	2018	2019
AI	Market size (100 million CNY)	112	142	237	416	644
	Year-over-year growth (%)	–	26.8	66.9	75.5	54.9
Big data	Market size (100 million CNY)	2940	3700	4800	6170	8080
	Year-over-year growth (%)	–	25.9	29.7	28.5	31.0
Cloud computing	Market size (100 million CNY)	387	510	692	963	1291
	Year-over-year growth (%)	–	31.8	35.7	39.2	34.1

### 2.1.2 Big data technology

Big data is a technology that can calculate and analyze large amounts of data by virtue of its powerful storage and computing capabilities and provides powerful guidance for forecasting. Big data have “4V” characteristics, i.e., volume, variety, velocity, and value [10]. The main areas of interest in big data research include e-commerce big data, social network big data, transportation big data, and video big data. At present, big data in China are playing an important role in the fields of industry solutions, computing and analysis services, and storage services, among other areas. Meanwhile, high-speed development is being maintained at the industrial level and will penetrate all industries of big data. According to a survey and calculation conducted by the China Commerce Industry Research Institute [11], it is expected that the size of the big data market in China will reach 808 billion yuan in 2019 with a year-on-year increase exceeding 30% (Table 1).

China has a 5000-year history and thus owns many cultural resources such as artworks and cultural relics, and has an intangible cultural heritage as well as many public cultural institutions such as public libraries, museums, and art galleries. During the digital processing of such cultural resources, a large amount of data will be generated. The final forms of the data include text, images, audio, and video. Ways to effectively store, retrieve, and apply these cultural data require the use of big data technologies. At present, China has built many big data platforms in the fields of culture and art, including the China Cultural Resources Cloud Platform in Gansu Province, the Big Data Platform for Museums in Beijing, and the Digital Relic Library in the Forbidden City.

### 2.1.3 Cloud computing technology

Cloud computing is a computing model that obtains the required services (e.g., hardware, platform, and software) in an on-demand and easily scalable manner through a network. The growth of the global cloud computing market has stabilized. The global public cloud computing market represented by infrastructure as a service (IaaS), platform as a service (PaaS), and software as a service (SaaS) reached 962.46 billion yuan in 2018, with a growth rate of 23%. The fastest area of growth during the past few years has been in IaaS. Although SaaS has slowed, it will still occupy the largest share of the global public cloud computing market in the next few years [12]. The United States is an early innovator in the field of cloud computing and currently takes the lead in global cloud computing services. The cloud computing services began late in China. For China, although the global cloud computing market share is small, the growth momentum is obvious. According to the *White book of China's Cloud Computing Industry* [12] released by the Institute of International Technology and Economy in October 2019, the market size of the cloud computing industry in China is expected to reach 100 billion yuan in 2019 with a growth rate of 34.1% (Table 1).

Cloud computing provides a computing and storage platform for digital creativity. At present, China has already applied cloud computing to digital creative products. For example, the cloud-editing function provided by Aliyun allows video creators to conduct a series of operations in the cloud, such as cutting and splicing, mixing, and applying subtitles, picture overlays, occlusions, and transition effects, effectively addressing the lack of local computing power of video creators.

### 2.1.4 Future network technology

5G technology is a representative future network technology. According to the “Global Race to 5G” report released by the Cellular Telecommunications Industry Association (CTIA) in April 2019, China and the United States ranked first in the world in the number of 5G commercial deployment plans [13]. In terms of the number of required patents for 5G standards (Fig. 2), the total number of patent declarations of three companies in China is 3542, accounting for 30.3% of the total declarations, ranking first. The 5G R&D in China has been recognized as a leading echelon globally.



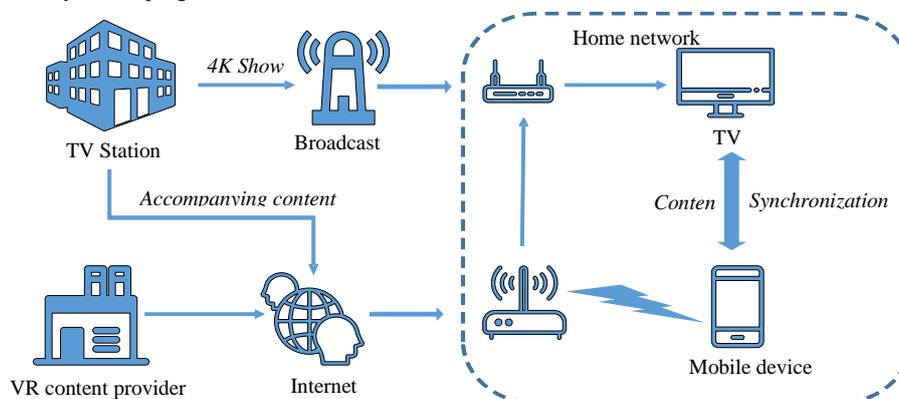
**Fig. 2.** Number of 5G standard patents declared by various countries according to the European Telecommunication Standardization Association (as of December 28, 2018) [14].

In addition, 5G technology enriches video transmission methods and provides a strong transmission capacity support for the development of the UHD and VR industries. On January 13, 2019, China Mobile, China Central Radio and Television Station, and Huawei successfully carried out 5G network 4K TV transmission tests in Shenzhen, Guangdong, and successfully realized the transmission of 4K UHD Beijing landscape signals to the main station in the Shenzhen branch. In addition, a 4K UHD OB van displayed real-time signals.

## 2.2 Application technology

### 2.2.1 IBB technology

IBB technology takes advantage of both broadcast and broadband networks to deliver TV programs and applications through broadcast networks and the Internet, and presents them on the user’s TV and mobile devices in an integrated manner, thereby providing a comprehensive experience of broadcasting and interaction [15]. The core concept of IBB technology is to use broadcast channels and Internet channels to display the same TV program. Whereas users watch traditional TV programs through a broadcast network, business-related applications made by TV stations or third-party application service providers can be delivered to users simultaneously through a broadband network, which can be viewed by the users as a page embedded into the users’ TV screens. At the same time, such information can also be pushed to mobile devices such as mobile phones, pads, and laptops (Fig. 3). At present, the standardization and application products of the IBB system have been deployed in many countries around the world. China is currently developing its own IBB standards.



**Fig. 3.** Application scenario of IBB technology.

### 2.2.2 Digital content processing software

Digital content processing is a service that processes information such as pictures, text, video, and audio using digital technology. The specific technical issues include two levels. The first level is digital content enhancement technology [16]. For example, in 2019, the Baidu AI development platform applied deep-learning image processing technology to conduct defogging, lossless enlargement, and contrast enhancement for low-quality images. The SenseAR software product developed by Sensetime combines AR technology to realize body shaping functions in cameras. The second level is digital content understanding technology [17]. The preliminary understanding of digital content such as images, audio, and video through AI technology, together with text descriptions, can greatly help users intelligently retrieve or detect information, thereby saving significant manpower and material resources. Typical examples include Iflyrec software developed by Iflytek, which can effectively convert audio into text in multiple languages.

### 2.2.3 Game engine software

In the field of animation and games, the engine refers to the core components of certain editable animation game systems or interactive real-time image-processing tools. These systems provide basic tools for game designers. The purpose is to allow game designers to make game products easily and quickly without having to start from scratch. Game engine technology includes the rendering engine (i.e., the “renderer,” which includes a 2D image render engine and 3D image render engine), physics engine, collision detection system, sound effects, script engine, computer animation, AI, network engine, and scene management [18]. Good game engines can allow game designers to efficiently create excellent products. Currently, China mainly uses foreign game engines, such as Unity.

Domestic companies have developed several engines either independently or in cooperation with foreign companies. However, China still lacks technical strength in game engines overall, and the gap with foreign countries is obvious. With improvements in the independent research and development of domestic enterprises, an increasing number of companies are committed to the localization of engine technology, and China is expected to narrow the gap with the development level of world-class games.

### 2.2.4 Digital processing technology of cultural resources

China has rich cultural resources such as artworks, cultural relics, and intangible cultural heritage as well as many public cultural institutions such as public libraries, museums, and art galleries. These cultural resources are the cornerstone and source of the digital creative industry in China. To extensively spread these rich cultural resources with the help of Internet technology, China urgently needs to digitize these cultural resources. The earliest start of digital processing technology of cultural resources in China can be traced back to August 1998 when Henan Museum set up its own Internet website. Subsequently, with the advancement of Chinese science and technology, museums around the country also began to build their own Internet sites, and the scope of digital technology applied to cultural resources gradually developed. In 2001, the State Administration of Cultural Heritage of China began a project titled “Relics Investigation and Database Management System Construction” in China, unifying the digitization of museums across the country. Nowadays, new digital technologies such as VR, live broadcasting, 3D printing, and mobile client development have greatly contributed to the development of our culture. Some new culture-domain technologies include VR display technology, cultural relics protection and restoration technology, museum management technology, and museum education technology. For example, the Forbidden City uses the mobile app “Daily Forbidden City,” launched in the form of a calendar, “One Forbidden Collection per Day,” allowing users to enjoy collections anytime and anywhere. At the same time, the “Forbidden City Museum Digital Relic Library,” “Panorama Forbidden City,” “Forbidden City Famous Paintings,” “Digital Duobao Pavilion,” and many other digital products launched by the Forbidden City have expanded the influence of its cultural relics.

## 2.3 End-user device technology

### 2.3.1 UHD video technology

Video is the main carrier of information presentation and dissemination as well as the main content form of the digital creative industry. Currently, video technology is undergoing an evolution from high definition to 4K ultra high definition, and then to 8K ultra high definition. The resolution of 4K UHD video is  $3840 \times 2160$ , which is four-times the resolution of full-HD video at  $1920 \times 1080$ . The resolution of 8K UHD video is  $7680 \times 4320$ , which is 16-times the resolution of full-HD video at  $1920 \times 1080$  [6]. UHD video technology has been one of the hottest technical topics in the global broadcast and television field in recent years, and various countries are actively deploying and promoting UHD technology.

The core components of UHD video equipment mainly include photosensitive devices, memory chips, codec chips, image chips, processor chips, and display panels. With the continuous improvement of system integration, memory chips, decoding chips, and processor chips have been integrated into SoC chips. In 2019, because Huawei's HiSilicon chips are applied to Skyworth TV, we will gradually take control in this area. In addition, China has many independent intellectual property rights in LCD and OLED panels.

### 2.3.2 3D audio technology

Audio technology has gone from mono audio, two-channel stereo audio, 5.1 surround sound, and 7.1 surround sound, to the development of 3D audio, which is a sound with a 3D sense of space and sense of position, which enables the listener to not only locate the position and direction of the sound source during the listening process, but also to hear the movement trajectory of the sound source, which can bring an environment immersion to audiences [19]. Currently, the existing 3D audio technology is mainly from other countries, including mature MPEG-H and Dolby 3D audio technology. In 2016, CCTV led the Academy of Broadcasting Science and other organizations to establish a 3D Audio task force, completed the "3D Audio Radio and TV Industry Standard Technology Collection" and began to formally collect proposals. In 2017, each party formally submitted the final proposal, and the 3D audio test and evaluation team began to test the submitted proposals, and the standard test verification was completed in October 2017. At present, 3D audio technology in China is still in the research and development stage. In addition, 3D audio codec technology and 3D audio pre-processing and post-processing technology need to be substantially improved as do 3D audio production technology standards and 3D audio quality evaluation systems.

### 2.3.3 VR/AR technology

VR generates a three-dimensional virtual world by using a computer or other intelligent computing device to provide users with simulated feelings regarding vision, hearing, touch, and other senses. VR technology only shows a virtual world [7]. AR is the seamless integration of real-world information with virtual world information, as well as physical information (e.g., visual information, sound, taste, and touch) that is difficult to experience within a certain time and space of the real world. Computers and other scientific technologies are superimposed after simulation, and virtual information is applied to the real world, which is perceived by human senses, so as to achieve a sensory experience beyond reality [20].

For the VR/AR industry, in terms of industrial policy, China has increased the development of its VR industry to a national level. Thus far, nearly 20 provinces, cities, and regions in China have developed VR industries. In terms of the richness of the supply of digital creative consumer services, VR applications have developed rapidly in the fields of VR education books, VR film and television, VR game entertainment, and VR government exhibitions. Virtual content resources continue to grow. VR live broadcasts have been conducted in major events such as the Spring Festival Gala, national celebrations, and international conventions and exhibitions, and high-quality content with a strong VR experience has begun to take shape. Regarding the industry standard of VR, China has initiated the standardization of VR head-mounted display devices. However, we also found that mainstream VR/AR equipment is still dominated by products from foreign manufacturers such as Oculus, HTC, and Microsoft. China is still a certain distance back in terms of VR/AR equipment manufacturing technology.

### 2.3.4 Holography technology

Holography is a method of reconstructing all information of an object by collecting the light waves reflected by the photographer, such that the content of a flat object can be displayed in 3D stereo, giving people the enjoyment of stereo vision, and can be observed more intuitively from different angles [21]. With the development and improvement of modern AI technology, some products using holography technology have already spread throughout the globe. The use of high-tech holographic image technology to create realistic stage stereoscopic projection effects and achieve immersive stereoscopic effects makes the content expression form more specific and richer. For example, in 2016, director Zhang Yimou used holography technology to guide a difficult performance at the G20 summit, i.e., a staging of "Swan Lake" on the water of West Lake in Hangzhou, which was breathtaking for audiences.

## 3 Problems in the development of digital creative technology in China

Currently, the support of innovation in the field of digital creative technologies in China, such as UHD video technology, 3D audio technology, VR/AR technology, digital content production, and innovative design software is insufficient. China still has a certain gap in these areas with developed countries such as the United States, the United Kingdom, Japan, and South Korea.

### 3.1 UHD video technology

In general, UHD video technology in China is still in its early stages of development. Although certain results have been achieved, many challenges and problems still remain.

#### 3.1.1 Insufficient investment in research and development of UHD technology and basic devices such as cameras

Cameras are an indispensable component for shooting UHD video content. The camera industry in China has only penetrated the low- and mid-end markets. High-end markets, such as radio and television, still have to import foreign cameras. The advent of 4K and 8K UHD faces more severe technical challenges including the challenge of losing top professional talent. Thus, large investments into research and development are still required.

#### 3.1.2 Industry testing standards are lacking

The national and industry standards that have been promulgated thus far have mainly focus on the fields of source codecs and terminal reception and displays. However, an end-to-end UHD video standard system, including channel, interface, security, and application systems, has not been fully established. Inconsistencies in the technical standards and a lack of certification standards have caused the existing UHD video technologies to be uneven, which is not conducive to a high-quality experience and affects the future popularity and healthy development of the industry.

#### 3.1.3 Layout of key industry patents is lagging, and there is a hidden danger of hurting economic growth

In terms of ultra-high definition, China has not yet formed a patent layout that supports the development of the industry. As a consequence, TV manufacturers still mainly use internationally mature technologies and need to pay royalties.

#### 3.1.4 Serious lack of UHD content

China does not have sufficient video content that strictly conforms to the 4K or 8K standards, which has become a key bottleneck to the development of the UHD video industry. Problems such as high content production costs, long output return periods, and incomplete copyright protection have greatly reduced the willingness of content production companies to produce UHD video content.

### 3.2 3D audio technology

The 3D audio technology in China is still in the initial research and development stage, and the technology used in related products is still mainly based on foreign technologies, including MPEG-H and Dolby 3D audio technology. Specifically, China needs to improve its codec technology, front-end and back-end processing technology, production technology standards, and quality evaluation systems in 3D audio technology. With the development of future technology, China is expected to improve its relevant technical level.

### 3.3 VR/AR technology

#### 3.3.1 Insufficient systematic research and development capabilities

In the VR/AR industry, China is pursuing one-sided performance parameters of software and/or hardware such as chips, sensors, display devices, and optical devices, while ignoring the improvements to the overall system performance. How to solve the problems in practical VR/AR applications, how to expand the penetration of VR/AR viewing devices from large-sized head-mounted devices to small-sized tablets and smartphones, and how to systematically improve the VR/AR experience still require significant efforts.

#### 3.3.2 Insufficient high-quality content

At present, the VR/AR industry in China is still dominated by hardware. In 2018, the hardware revenue of the virtual reality industry in the country accounted for 70% [1]. In the field of content applications, although China has conducted live VR broadcasts at major events such as the Spring Festival Gala, national celebrations, and international conventions and exhibitions, the scale of high-quality content is still insufficient. High-quality content is the core of enhancing the VR/AR user experience. Only when sufficient high-quality content is guaranteed will users be willing to purchase VR/AR products and spend time on consumption. China needs to vigorously develop VR/AR applications and apply VR/AR to key vertical industries such as education, healthcare, e-commerce, and industrial production.

#### 3.3.3 Industrial ecological chain is imperfect

At present, VR/AR enterprises in China are mainly small- and medium-sized enterprises, and most of their

products are aimed at certain hardware and software components in the industry. Overall, China does not have a complete VR/AR industry chain. It is necessary for China to address the industry defects of VR/AR and build a complete end-to-end industrial chain from hardware equipment to software applications in the vertical field.

### **3.4 Digital content production and innovative design software**

For the production of digital creative content, digital content processing software support in China is insufficient. A large number of industrial design software programs mainly rely on imports, including 3D Studio Max, Maya, and AutoCAD. High-end digital content production and innovative design software, including VR content production, industrial design software, and game engine software are also lagging, and the domestic contribution rate of such software programs is not high. Reliance on foreign digital content production and processing software technology will inevitably bring about constraints to the digital creative industry in China. China should increase its R&D efforts, develop reward mechanisms, and organize relevant technical personnel to develop this type of software, as well as strive for independent research and development to eventually replace foreign software.

## **4 Suggestions for accelerating the development of digital creative technology in China**

### **4.1 Establish key national science and technology projects for digital creative technology**

It is recommended to set up key national digital science and technology projects on digital creative technology to catch up with international technologies and industries more quickly. China needs to increase the research and development of key technologies, key components, high-end products, innovative applications, software platforms, and tools in the field of digital creative technology, as well as solve the problems and break the bottleneck of key technology shortcomings. Through the implementation of key research projects, China can form an internationally competitive high-tech R&D and innovation system in the fields of digital cultural creative technology equipment, digital content innovation, and innovative design, and play an important role in the development of the global digital creative industry.

### **4.2 Establish national engineering research centers on digital creative technology**

The digital creative industry is a highly cross-integrated industry that involves AI, big data, cloud computing, VR, super perception, and many other fields. It is a typical high-tech industry. At present, there are problems in the field of digital creative technology, such as a weak independent innovation capability, insufficient system integration capability, and a lack of depth in the application of new technologies. China needs to organize its universities, scientific research institutions, and enterprises with strong research and development strengths to build national engineering research centers for the development of digital creative technologies. Such research centers can conduct engineering research and verification on key technologies, equipment, and intelligent design systems of digital creativity. It can also establish a mechanism conducive to the transformation of technological innovation and achievement. By building a bridge between industry and scientific research, these research centers are expected to vigorously promote the technological progress and core competitiveness of the digital creativity industries in China.

### **4.3 Establish resource share platforms for digital cultural content**

On one hand, the development of digital creative industries can create new economic growth. On the other hand, it can also inherit and vigorously promote Chinese culture. To this end, China needs to build a cross-department, cross-region, cross-industry digital content resource big data platform, and a sharing platform to realize the digitization of cultural artwork nationwide, with the help of VR/AR, UHD video, 5G, and other new-generation information technologies. At the same time, China needs to actively participate in international cooperation and exchanges, spread the nation's excellent culture, learn from foreign experience, and absorb the essence of foreign culture and art. Going a step further, the relevant digital platforms and products constructed and developed in China and the breadth of participation in international cooperation will greatly promote the accumulation and inheritance of human cultural and artistic knowledge.

### **4.4 Improve the quality of talent working on digital creative technology**

The digital creative industry involves many new-generation information technologies and is a typical high-tech industry. Technical innovation is an important foundational force for the development of digital creative industries. However, there is currently a serious shortage of talent in digital creative technology in China. China needs to

actively set up digital creative technology majors, develop relevant disciplines, implement major first-class construction demonstration projects of digital creative technologies, and improve the quality of talent training in this field.

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