National Report of China to ICC 2019

The Progress and Trend of Cartography and Geographic Information Engineering in China (2015-2019)

CHINESE SOCIETY FOR GEODESY,

PHOTOGRAMMETRY AND CARTOGRAPHY

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Photogrammetry and Cartography**

Abstract: Cartography as a discipline has made great progress in China in the past 70 years since 1949, from traditional cartography to digital and information cartography. Based on the development of cartography and geographic information technology in China since 2015, this report summarizes the achievement in theories of cartography and geographic information science, digital cartography and press techniques, updating of China's National Fundamental Geographic Information Database, geographic information technology and industrial development, geographic information applications and services, atlas compiling and publishing, and the next generation online map. Finally, the report offers some prospects for the developing trend of cartography and geographic information engineering in China.

Keywords: cartography and GIS, national report, achievement, developing trend

1. Introduction

With the rapid development of artificial intelligence, big data and mobile communication technology, the advancement of cartography and geographic information technology has also been accelerated and geographic information services have been extended to the national economy and people's lives. Cartography and geographic information technology become more and more closely related to social development, which have achieved rapid development and encouraging results.

2. The progress of cartography and geographic information engineering in China

2.1 Advances in theoretical research on cartography and geographic information science

Cartographic theory has remained the focus of the academia and industry of cartography in China. In the age of traditional cartography, the theoretical study of cartography focused on three aspects—map projections, cartographic generalization and map symbols (representing method). In the 21st century, cartography has entered the information era. The theories and methods of map projections and their transformations have been mature and widely used in map production practice etc. The research of cartographic generalization theory focuses on the intelligent process control and quality evaluation which is controllable, covering all factors and the whole process. As a kind of map language, map symbol system is used to study its grammar, semantics and pragmatic rules. Chinese scholars have made in-depth studies on map projections, cartographic generalization and spatio-temporal data models, and have made a series of new achievements.

Map projection is an important component of modern cartography, and involves a great deal of complicated mathematical analysis, such as the power series expansions of elliptic functions, differential of composite and implicit functions, elliptic integral and the operation of complex functions. Deriving these problems manually is not only time-consuming but also error-prone and sometimes even cannot be realized at all due to various reasons such as the unbearable complexity.

With the mathematical analysis of the Computer Algebra system, some typical mathematical analysis process in the field of map projection has been studied, including five aspects, i.e., the symbolic expressions of forward and inverse solution of ellipsoidal latitudes, the direct transformations between map projections with different distortion properties, expressions of Gauss projection by complex function, mathematical analysis of oblique Mercator projection, and polar chart projection with its transformation. A series of new formulas and algorithms for map projections have been derived and established, which are more theoretically rigorous with a simpler form and higher precision, making breakthrough innovation of map projections on some specific problems of mathematical analysis, and having enriched and improved the theoretical system of map projection.

Automated map generalization in a computer-based environment, a highly intelligent system essentially, is a process where knowledge is re-expressed and abstracted through lots of loops and automatic judgment to find a satisfactory solution under the support of the map generalization knowledge and so on, so as to finish the work of cartographic generalization. Cartographic generalization knowledge can be divided into five categories,—descriptive knowledge of geographical characteristics of the spatial features and the knowledge rules for action item selection, for algorithm selection, for specific geographic features and cartographic generalization, and for regional cartographic generalization. To realize automated map generalization, such methods of cartographic generalization as selection, simplification, merging and displacement, etc., should be transformed into a series of steps performable for computers. The more detailed and reasonable the process is disassembled, the easier the automated map generalization can be realized. Only by making full and reasonable use of all models, operators, algorithms and knowledge, etc. to form a scientific and systematic operation process, and by implementing intelligent control of the process, can the automated generalization system make a qualitative leap forward in its capability, which is called automated cartographic-generalization process-control. In the new era, spatial data generalization should not only focus on graphic generalization, but also combine traditional graphics-oriented cartographic generalization with spatial data mining and knowledge discovery. In the context of big data, the objects of cartographic generalization are more closely related to and more strongly contextually correlated with the specialized knowledge. Structural feature extraction, knowledge discovery and macro-level decision-making have become new map generalization tasks.

The advent of the era of informatization and spatio-temporal big data has posed new demands on cartographic representation and analysis. Chinese scholars have put forward the concept of geographical scene, which has added new research content and mode of expression to the development of cartography. Chinese scholars discussed the connotations and characteristics of geographical scene, and elaborated on the necessity and main technical approaches for transforming a map into a scene. He put forward a six-element representation model of geographic information, including “spatial locations”, “geometric forms”, “characteristics of attributes”, “relationship between elements”, evolutionary process, and sematic description. A unified GIS data model integrating the six elements based on geometric algebra, a new GIS data structure driven by geographical rules and interaction, and unstructured spatio-temporal data organization and storage have been designed in response to the integrated representation, systematic analysis and highly efficient management for the spatial distribution, temporal and spatial patterns, evolutionary process and interaction mechanisms of geographical phenomena.

2.2 The wide application of digital cartography and publishing technology

In the field of digital cartography, China has adopted the advanced database-driven cartographic technology and method, and has integrated geographic information updating with map symbolic publishing. Dynamic updates, incremental updates, cascading updates, and element updates of the multi-scale map database and the entity-based data model have been implemented. The cartographic production system for topographic maps driven by spatial database has realized the automatic optimization and configuration of cartographic element symbols, annotations and marginal representation, and can flexibly carry out cartographic editing and processing of graphic relations, having greatly improved the efficiency of cartography. By 2018, a map-database with integrated storage and management of the cartographic database of 1:50000, 1:250000 and 1:1000000 scale topographic maps has been built, and synchronous linked updates of topographic and cartographic data have been realized, with a nationwide topographic map at scale of 1:50000 being printed and published. On the basis of updating 1:250000 and 1:1000000 scale topographic database, the corresponding cartographic database is updated synchronously. By using the updated cartographic database, one can quickly print out the latest version of the standard topographic maps or customized maps as required.

Nowadays, the fusion of multi-source geospatial vector data is one of the main tasks for studying digital cartography. The data fusion technology of the multi-source geospatial vector data is an important way of and valid method for solving the problem of inconsistency between geometric positions and characteristics of attributes of the multi-source geographic data. By spatial datum transformation, data format conversion and the attribute encoding correspondence etc., the point positions, graphic shapes and contents with varying degrees of detail for geographic information data have been preliminarily unified and integrated. Then geometric and attribute matching of spatial data, and updating of information about geometric shapes and attributes are carried out to integrate and consistently process geometric information, attributes and spatial relationships and improve the quality of spatial data. With the emergence of volunteered geographic information, vehicle spatial-temporal trajectory contains rich geometric and semantic information of the roads, which has become an important way to obtain roads data and traffic status.

2.3 Update of China’s National Fundamental Geographic Information Database

The department responsible for surveying and mapping in China has launched the project of dynamically updating the national fundamental geographic information database since 2012. The key elements and associated elements of the 1:50000 national fundamental geographic database will be updated and published once a year. Then the updated 1:50000 database will be used for updating the1:250000 and 1:1000000 database. The total elements of the 1:50000 topographic database include such nine major categories as transportation, residential areas, boundaries, geographical names, pipelines, water systems, soil and vegetation, terrain features and control points, and more than 470 minor categories. The key elements refer to the six major categories, including transportation, pipelines, residential areas, geographical names and boundaries and 117 minor categories of elements which change frequently and have a great impact on economic and social development. The associated elements include two major categories—terrain features and soil and vegetation and 57 minor categories. From 2014 to 2018, total element renewal was carried out at the same time. About 50% of the key-element and total-element areas will be updated each year, so that the key elements can be updated once a year and the total elements can be thoroughly updated every two years. The change rate of key elements in 2018 is above 6%. After the update, China's 2018 version of 1:50000 topographic database has been built. The overall currency has reached no more than one year. The management and service of multi-temporal data have been realized. The data results have been comprehensively improved in terms of time-effectiveness, practicability, accuracy, and application value. By the end of 2018, the 1:50000 topographic mapping database has been updated for 6 rounds with the updating result of 1:50,000 database.

Since 2016, the dynamically updated incremental data results of 1:50000 database have been used annually for collaboratively updating the 1:250000 database so that its currency is consistent with 1:50000 database. After several rounds of updating, the elements and attributes of the 1:250000 topographic database have been enriched. The data set has been increased from 9 to 32. Minor categories of elements have been increased from 158 to 229. The data structure is more optimized and reasonable, which enables the coordination and correlation with 1:50,000 database. The currency has been comprehensively and continuously improved. Since 2016, the latest 1:250000 topographic database has been used annually to update 1:1000000 topographic database so that its currency is consistent with 1:250000 topographic database.

The completion of the above work lays a solid geospatial data foundation for constructing China’s digital earth, digital country, digital province, digital city, digital river and digital ocean, and provides timely and reliable geospatial data support for the national and regional economic planning, disaster prevention and mitigation, farmland water conservancy construction, post-disaster reconstruction, major engineering design and construction, and national defense construction.

2.4 Continuous development of geographic information technology and industry

China's geographic information industry has been developing from scratch for 40 years since the reform and opening up. The focus of industrial development has extended from the initial emphasis on software development and data processing to service and application. In recent years, the scale of China's geographic information industry continues to grow rapidly. In 2015, the annual output value of China's geographic information industry exceeded 360 billion yuan. By 2018, the annual output value of China's geographic information industry exceeded 620 billion yuan. The number of industrial units have been over 95000, among which more than 19000 enterprises have surveying and mapping qualifications. Many geo-information enterprises are listed at home and abroad and more than 220 geo-information enterprises have been listed on the NEEQ, with more than 1.17 million employees.

In the research and development of geographic information system, large numbers of GIS software are emerging. By 2018, China has had more than 1000 enterprises engaged in GIS software and application development, including software, hardware, training and education. Domestic GIS software continues to expand the market share, which has occupied most of the market now, with the output value of billions of dollars, widely used in urban planning and management and other fields. They have produced such excellent software as SuperMap (SuperMapSoftware), MapGIS (ZONDY CYBER), GEOWAY(GEOWAY) and GeoStar (Wuda Geoinformatics), some of which has successfully entered Japan, South Korea, India, Italy and other countries and regions, initiating the internationalization of GIS software in China. The technical level of domestic GIS platform software has been equivalent to that of foreign similar software, realizing the comprehensive localization of a new generation of geographic information platform software based on CPU, operating system and database.

Due to the rapid development of geographic information industry, various districts are actively building geo-information industrial parks or industrial incubation bases.in order to improve the geo-information industrial chain, enhance the overall scale and efficiency of the industry, and improve the level of independent innovation. According to statistics, more than 50 geo-information industrial parks or industrial incubation bases are under construction or have been built in China, each of which having its own characteristics. Among them, the permanent meeting venue of the high-level forum on United Nations Global Geospatial Information Management (UN-GGIM) is located at the Geospatial Information Industrial Park in Deqing, Zhejiang Province.

At present, under the influence of the national “Internet Plus” plan and big data strategy, the geographic information industry keeps pace with the times and has increasingly closer links with new technologies such as big data, artificial intelligence, Internet of Things, mobile Internet, cloud computing and blockchain. The progress of geographic information technology has greatly improved the efficiency of operation and greatly expanded the value of geographic information data.

In the future, with further deepening of the reform and opening up, the deep integration of surveying and mapping geographic information into natural resource management, the support of national industrial, scientific and technological innovation policies, and the continuous growth of global geographic information market, the development of China's geographic information industry will usher in a more brilliant tomorrow.

2.5 Application of geographic information in all walks of life

Over the years, the service field of China's geographic information industry has been expanding and has penetrated into all aspects of national economic and social development. The service path of geographic information industry is getting wider and wider.

Maps on Internet platforms provide mass mapping, business analysis and enterprise services to a wide range of users. With rich map modules, it allows users to generate various statistical maps based on tabular data, helps enterprises analyze potential customers, select logistics sites, network management, district management, sub-unit management, route planning and vehicle monitoring etc. Baidu Map has Eagle-eye Web with global trajectory tracking, storage, query, deviation correction, analysis and other functions, which can help each developer track more than 10 million terminals in real time. It has been widely used in logistics, ridesharing, on-board hardware, field service management and wearable device services, and has provided trajectory tracking and management services for a number of express delivery companies.

In the field of navigation electronic maps, more than 500 million users have used products and services such as vehicle-mounted navigation, mobile positioning and location query. Navigation electronic maps and navigation technology have driven the development of automobile, tourism and other related industries. Navigation electronic maps have more refined functions with: (1) more practical navigation map system; (2) more accurate navigation electronic map data; (3) well improved navigation map visualization; and (4) more extensive scope of navigation map application etc.

At present, as the foundation and support of navigation industry, navigation electronic map products have covered all highways, national roads, provincial roads, etc., realizing the uninterrupted guidance of all cities, counties and villages in the country. In 2017, NavInfo, AMAP, and EMG respectively occupied the top three positions in the market share of China's vehicle-mounted navigation electronic map. The market size of on-board navigation electronic map has been growing year by year, exceeding 2 billion yuan in 2018. In terms of navigation electronic map products and services, the application of map navigation has been extended to many fields including tourism, logistics, e-commerce, insurance and government affairs. Domestic electronic map products, such as Baidu Map, AMAP, QQ Map and Tianditu (or Map World), have launched some more professional navigation map products, combined with the location based service (LBS), artificial intelligence (AI), virtual reality (VR) and augmented reality (AR) technologies to promote the connotation of the navigation electronic map service. Among them, Baidu Map proposes to build an intelligent travel platform from artificial to automatic, plane to three-dimensional, static to real-time, and from fingertips to voice, providing AR walking navigation, intelligent recommendation of boarding point, personalized map and other intelligent services. AMAP has introduced new functions for AR real scene navigation and is working to create new applications that combine AR with LBS.

In the tourism industry, navigation and positioning services can provide tourists with brief introduction, geographical location, transportation route transfer, tourism strategy reference and other information about the tourist destination. In 2018, the number of domestic tourists reached more than 5 billion. The traditional tourism era has been gradually transformed and upgraded. Independent travelers have become the main consumers of scenic spots. During the tour, the use of navigation and positioning services in the tourism area can provide tourists with all kinds of surrounding tourism information, including text and voice introduction of tourist attractions, the best location for shooting, information about surrounding restaurants, accommodation, toilets, entrances and service points, etc. Location-based services can also push the most accurate destination and navigation service for tourists. Tourists can know, select and change the travel route by knowing their own location so as to realize self-guided tour. Through navigation and positioning, the management department can analyze the data of users' tourism activities in the park and optimize the tourism routes. When tourists are in danger, the personnel in the command center can also quickly locate people in the scenic spot through location service for search, rescue and evacuation, so as to avoid travel risks.

Navigation electronic map industry has also widely penetrated into online food delivery, housing, ridesharing, social networks, online games and other fields, making people's various life needs greatly facilitated.

In recent years, with the construction of large commercial centers, airports, sports venues and museums, people's demand for mobile positioning and navigation electronic map services has been expanded from outdoor to indoor, thus promoting the application and development of indoor navigation electronic map. The research mainly focuses on three aspects, including indoor map modeling method, indoor map representation, and indoor map positioning and navigation application.

2.6 Compilation and publication of atlas

In recent years, high-quality atlas products have constantly emerged in China, with the map market getting more prosperous. In terms of thematic maps and atlas, representative works include the first large-scale comprehensive atlas published domestically in China by SinoMaps Press, i.e. *Atlas of the World* It is composed of the introductory map, continent map, city map, country map and region map, ocean map, text description, gazetteer index and appendix. It includes such contents as world politics, economy, culture, nature and humanity, covers all countries and regions in the world, and records about 150000 geographical names. It will play an important role for China to implement the "go global" strategy and participate in international affairs, scientific, technological and cultural exchanges, and other aspects. *Atlas of Remote Sensing Images of the Environmental Changes in China*, compiled by Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences, under the guidance of the theories and methods of contemporary earth system science. With remote sensing images as the principal part, such basic characteristics as spatial distribution, spatio-temporal variation, structural characteristics, interconnection, dynamic development and cause analysis of various environmental topics, for instance, urbanization and urban expansion, environmental changes in lakes and wetlands, land desertification, natural disasters and their prevention and control, forest protection and restoration, and impacts from major projects have been represented on national, regional and local scales.. *Atlas of Sandy Deserts in China*, compiled by the former State Forestry Administration of China, using the monitoring data of desertification in China and integrating remote sensing images, thematic maps, field landscape photos and text descriptions, vividly analyzed the formation, distribution, regional environment, source of sand material, distribution of different dune types and the historical evolution of 11 deserts and 7 sandy lands in China. It is a large-scale academic literature which interprets the desert comprehensively and also a textbook of the desert in China. *Atlas of Remote Sensing Monitoring for Recovery and Reconstruction After Major Natural Disasters*, compiled by Institute of Remote Sensing and Digital Earth, Chinese Academy of Sciences, presented remote sensing monitoring results of post-disaster recovery and reconstruction of five major natural disasters since 2008, including the Wenchuan earthquake, Yushu earthquake, Zhouqu mudslide, Lushan earthquake and Ludian earthquake. The atlas named *Green Hills and Clear Waters on the Map*, compiled by SinoMaps Press of China, centered around the theme of new responsibilities, new missions and new tasks for natural resource management, collected, collated and refined the public survey and monitoring data in fields of natural resources such as land, mineral resources, forest, grassland, wetland, water and ocean etc. It shows the current situation of various natural resources in China and the remarkable achievements made in the field of natural resources since the reform and opening up 40 years ago. *Atlas of Natural Resources in China*, compiled by China Geological Survey, is divided into three series including national volume, provincial volume and thematic volume, and covers 8 categories including water, soil, mineral, forest, grass, wetland and ocean etc. Such contents as the quantity, quality, structure, ecology, current situation, potential and problems of natural resources in China have been systematically arranged, which provide systematic and detailed basic data for the new functions of natural resources management in China. *Atlas of Changes in Administrative Divisions of the People's Republic of China*, compiled by Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences, includes two volumes with time spans from 1949 to 1979 and from 1980 to 2017, respectively. With county administrative unit as the basic unit, it comprehensively, systematically and intuitively reflects the dynamic changes in administrative division since the founding of new China and the process of administrative division changes in different stages in China. Moreover, thematic maps, such as *Distribution Map of Active Faults in China and Its Adjacent Sea Area* and *Series Maps of Karst Environmental Geology in South China and Southeast Asia* also have important academic values.

On the basis of the first national geographic conditions census of China, Sichuan, Gansu, Guangxi, Shanxi, Hunan and some other provinces have compiled and published the atlas of the first census results in their own region, reflecting the current situation of geographical conditions within the province from multi-perspectives and in a profound and comprehensive way. It provides important basis for optimizing land space development and implementing natural ecological environment protection. Among them, the *Atlas Series of Geographical Conditions of Hunan Province* is the largest, including 1 provincial *Atlas of Geographic Conditions Census of Hunan Province*, with another 14 atlases of geographic conditions at municipal (including autonomous prefecture) level and 98 at county (city and district) level, and113 in total. The compilation and publication of the provincial historical atlas is of great value for inheriting history and propagating culture. *The Historical Atlas of Chongqing, Volume II, Changes in Administrative Divisions and Cities, Politics and Military*, compiled by Chongqing Urban Planning Bureau and Chongqing Survey Institute, is one of the representative works. The atlas includes a total of 254 maps from Xianba Era to 1997, which spans more than 3,000 years, showing the historical evolution process of Chongqing. *The Atlas of the Historical Evolution of Inner Mongolia* = compiled by the Bureau of Surveying, Mapping and Geographic Information of the Inner Mongolia autonomous region, with the unique language of historical maps, fully displays the political evolution of Inner Mongolia from prehistoric times, pre-qin period to the republic of China period. It clearly presents the contact and integration of multi-ethnic groups and the cultural exchanges between the north and the south under the space-time framework, and provides a spatial reference for the cultural construction, tourism development and territorial planning of the autonomous region. *The Historical Atlas of Shaanxi Province*, compiled by Shaanxi Provincial Cultural Relics Bureau, shows the historical evolution, changes in administrative division, geographical names and environmental changes of Shaanxi province in the development process of the Chinese nation.

Map products that meet the needs of the public and serve people's life still show a more personalized, thematic and artistic trend. Traditional publishing is further integrated with new technologies and new media. A series of new media map products were published, such as the AR version of the *Map of the People's Republic of China* and the *Map of the World*, Laoshan AR paper tour map, a variety of AR globes, and "talking" tour maps and so on. They expand the content representation of traditional paper map products, improve the interaction between people and maps, and endow traditional maps with new vitality. In 2018, the first session of the United Nations World Geospatial Information Congress was held in Deqing, Zhejiang. As an important part of the technology and application exhibition, the members of China Cultural Industry Association (CCIA) jointly organized the "Chinese map cultural exhibition", including the *Antique Chinese Maps*, outstanding maps, creative maps, children's hand-painted map works exhibition unit etc. The exhibition showcased the achievements of Chinese map culture and contemporary map development to domestic and foreign guests and media. By focusing on telling Chinese stories with maps, the exhibition has further enhanced the international influence of Chinese map culture.

2.7 Online maps being put into practical use

With the popularization of network map application and the development of new media map, some new modes of online map services, such as map mashups, crowdsourcing map and event map, have emerged. Combined with various sensors, the map-oriented multi-mode human-computer interaction mode was explored, including voice, handwriting, gesture, expression perception, etc., as well as the intelligent perception and service driver of position, orientation and speed. Also, new forms of maps like intelligent map and holographic map have been developed. Among them, map mashups seamlessly join together the interactive functions and Internet map contents of government cartographic departments, private software developers and volunteers. Its open map services allow users to share updates from other users. Crowdsourcing map adopts the crowdsourcing mode to build a map service with public participation. It can be either a way to provide map data or a way to make maps. It has been used in high-precision navigation data acquisition and update, indoor map data acquisition, and mapping services and so on. Event map is to superimpose various events on the map targets, including time, place, changing mode, and information about people or things involved. It can organize events into visual stories in a logical way with a clear theme and purpose. Event map, which has a stronger visual impact than static map, can more effectively arouse the reader's empathy and produce a kind of charisma that can change the reader's attitude or behavior. Intelligent map, combined with cloud computing, Internet of Things, mobile Internet, artificial intelligence and data mining technology, etc., by integrating the layer data with multi-source, multi-scale, multi-space-time and multi-structure elements and emphasizing on the dynamic integration between the human expert’s knowledge and maps, forms a new dynamic mutual-promoting and mutual-decision-making-support map mode. The intelligent map realizes the self-adaptive representation and intelligent map service based on the automatic detection of the change of people and environment. It can also provide efficient and flexible map service support for smart city, smart tourism, smart government and other applications.

Location-based holographic map realizes the correlation of multi-dimensional spatio-temporal dynamic information through location, and effectively links various spatial information, sensor network information, social network information, volunteered geographic information, and real-time public service information, etc. It is a kind of map form of personal centered pan-space information display and intelligent service.

3. The future development of cartography and geographic information engineering

3.1 Adjustment of future tasks and development direction of map and cartography

After nearly 70 years of rapid development, maps and cartography in new China have undergone a fundamental change from traditional manual surveying and mapping to complete digitalization and automation. The surveying and mapping of the national basic topographic map at a large scale has been completed, while 1:5000, 1:10000 and 1:25000 scale mapping in some key areas is still needed. Nationwide comprehensive scientific survey, investigations by various specialized departments, and general survey of various economic and social departments have also been completed. Therefore, the future tasks and development direction of maps and cartography should be timely adjusted according to the new demands of economic and social development in the new century.

(1) The national basic scale topographic map database is mainly updated with satellite remote sensing technology. Topography represented by contour lines in topographic maps generally does not change or rarely does, while changes in water systems, residential areas, road networks and some other elements can easily be updated using satellite remote sensing technology. Databases of different scales can be updated with images of corresponding resolutions respectively with no need to downsize according to the scale.

(2) The main task of thematic mapping is to serve disaster prediction and early warning, ecological protection, environmental governance, and urban and regional development planning. Besides the exploration and mapping of mineral and petroleum resources (including oil shale and combustible ice) and natural gas resources in key regions and sea areas, the main content of thematic mapping is the compilation of natural disaster prediction map, ecological environment map, disease medical map, city and regional planning map, population change map and comprehensive economic map. In the future, dynamic monitoring and mapping based on remote sensing and telemetry will be further developed, including dynamic monitoring and mapping of ecology and environment, monitoring and mapping of national geographical conditions, and dynamic monitoring and mapping of urban land use change.

(3) Existing thematic maps and atlases will be digitized and corresponding map databases be established. To meet the needs of information age, government departments, scientific research units, universities and colleges' demand for digital thematic maps, give full play to the various published maps and atlases, improve the utilization and social economic benefits of the existing thematic maps, it is necessary to have various thematic maps and atlases digitalized and establish the corresponding digital map database, so as to make it an important part of the country's natural, economic and environmental big data.

(4) The compilation of emergency maps will be further strengthened. At present, China has initially established various natural disaster databases, early warning information system and satellite remote sensing dynamic monitoring. However, it is still necessary to expand the network of ground monitoring stations and establish an emergency response system for emergencies, including the real-time remote monitoring using unmanned aerial vehicles. In this way, various

emergency maps can be generated in real time, including emergency maps to prevent various natural disasters (earthquake, landslide, mudslide, flood, drought, typhoon, and tsunami, etc.), various epidemic diseases, war and other emergencies. In addition, maps of damage assessment after emergencies and planning for post-disaster reconstruction should also be made to provide timely information to relevant departments as the scientific basis for disaster relief, project recovery and home reconstruction.

3.2 "Digital Earth" and "The Belt and Road" strategies providing new opportunities for the development of cartography

The "Digital Earth" strategy is highly valued and supported by China. The International Society for Digital Earth, initiated and organized by China in 1999, has become a permanent body of the council in Beijing. The International Symposium on Digital Earth has also become a regular biennial international academic conference. Since the first session of the symposium was held in Beijing and “Beijing Declaration on Digital Earth” was adopted, nine sessions have been held in succession, which have played an important role in promoting the development of the international digital earth. China's "Digital Earth" strategy has made great progress with the active support of central government departments and governments at all levels. More than half of China's provinces, cities, autonomous regions and 300 large and medium-sized cities, as well as the Yangtze River and Yellow River basins, have put forward and are implementing grand plans for "Digital Provinces and Regions", "Digital River Basins", "Digital Cities" and "Digital Communities". Various space information infrastructure construction, e-government, e-commerce, as well as the application of various departments have made great progress and notable results.

With the implementation of “The Belt and Road” initiative, the planning maps reflecting the strategic layout of “The Belt and Road” and the general maps and various thematic maps of countries along the route (maps of natural resources and natural conditions, economic development, infrastructure, ethnic religions, and maps of history and culture, etc.) should be brought to the agenda. This is bound to be a significantly important Internet cartographic task.

3.3 Opportunities and challenges for the development of maps and cartography in the era of big data, Internet and artificial intelligence

(1) China has accumulated many years of remote sensing data and has continuously acquired a large number of daily remote sensing and telemetric data. On this basis, various grid maps and vector maps have been generated constantly. There are nationwide digitalized topographic maps at all scales, general geographic maps and thematic maps, data from all kinds of national censuses (including population censuses, industrial censuses, tertiary industry censuses, economic censuses, agricultural censuses, and science and technology censuses, etc.), various economic and social statistics (total national economy, industry, agriculture, transportation, business, foreign trade, culture, public health, science and technology, and education, etc.) over the years, and observation

data accumulated over a long period at national meteorological and hydrological stations and so on. In addition, the location and dynamic information generated by each individual in mobile communication every day and the large amount of information brought by the Internet of Things make an extremely large data volume and a rich display of content. Data previously unavailable are now readily at hand, such as the real-time dynamic data of the daily flow of people, traffic, and logistics. The traffic management and control can be solved in time by compiling real-time status map of urban vehicle operation. Through establishing logistics maps for enterprises, the optimal route for goods distribution and delivery can be determined and distribution vehicles can be supervised in real time. A considerable part of big data comes from map data, while other spatial data are easily visualized on the basis of map. By visualizing the spatial pattern, regional differentiation and spatial-temporal dynamic changes of things and phenomena on the map, the process of analysis and evaluation, prediction and forecast, regional layout, planning and design, and management and control can be carried out.

(2) China's Internet has developed dramatically in the past decade. By the end of 2018, China has had 649 million netizens and 695 million mobile netizens. The proportion of Internet users surpasses that of some developed countries. China has really entered the Internet era. Internet has become the main platform for map compilation and application. Currently, map Internet is no longer limited to map query and retrieval, but also provides various services such as restoring virtual real world, customizing various maps on demand, realizing data visualization, media diversification, and other services. In addition to the conventional two-dimensional plane “real map form”, it can produce three-dimensional map, three-dimensional dynamic map, virtual reality map, and space-time dynamic map and so on. In the way of map compilation, big data is combined with geographic information system to provide online mapping platform for various organs, groups, enterprises and the public. People can obtain information directly on the net, use network service tools to make a map, and publish maps on the net. They can also obtain data on the net, mapping offline, and then publish the new map online. Thus maps become more popularized, personalized, intelligent, and practical, which can greatly improve the use of maps.

3.4 Future prospects

The key to the application of big data in the future is the fusion of all kinds of big data, spatial-temporal big data mining and knowledge discovery, as well as the establishment of various intelligent application models and the automatic generation of a variety of comprehensive evaluation, prediction and other thematic mapping software. Therefore, it is necessary to use the knowledge of earth science to analyze and understand the distribution characteristics, formation mechanisms and the rules of spatial-temporal dynamic changes of the natural and human phenomena. Therefore, the participation and cooperation of professionals from different disciplines are needed.

Cartography will develop forward with the pace of the times. At present the academic thought in the domestic cartographic academia is quite active. After a period of practice and discussion, we believe that a new theoretical system of cartography will be established in the era of big data, Internet and artificial intelligence. Virtual cartography, self-adapting cartography, intelligent cartography, holographic cartography, and Internet cartography may become new branches of cartography.

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