Advances in Computer, Signals and Systems (2023)
Clausius Scientific Press, Canada

DOI: 10.23977/acss.2023.070606
ISSN 2371-8838 Vol. 7 Num. 6

Construction of Public Security Rapid Response Communication and Command System Based on Spatiotemporal Big Data

Chang Liu[1,a,*]

[1]*Chaoyang District Public Security Bureau, 645 West Minzhu Street, Changchun, Jilin, 130000, China*

[a]*50059766@qq.com*

[*]*Corresponding author*

Keywords: Spatiotemporal Big Data, Public Security Rapid Response, Communication Command, System Construction

Abstract: Spatial and temporal big data is one of the most important types of big data, and spatiotemporal big data is the foundation for accurately measuring and extracting the value of data content. The disadvantage of traditional data representation is that it cannot cope with the rapidly growing amount of data, and its most important attribute is its global ability to represent big data. In the era of big data, data has complex relationships, and the main value of spatiotemporal big data lies in the relationships between time, space, and things. However, the complexity of spatiotemporal big data and the dynamic evolution between them make it difficult to represent and calculate relationships. The value of spatiotemporal big data lies in discovering and utilizing the hidden laws behind it. The unique value of spatiotemporal big data lies in that, unlike local data, it contains information about significant large-scale events that are particularly difficult to understand due to their large spatial scope, complex measures, and behaviors.

1. Introduction

The Public Safety Command Center adopts advanced technologies such as computer network, program control exchange, wireless communication, and image processing, and achieves high integration through operating interfaces and communication networks, digitizing and computerizing the line of sight. Through wireless integrated dispatch, police response is faster and more accurate, enhancing the ability of public security departments to respond to emergencies and combat crime.

Scholars have long conducted relevant research on the design of communication systems. Hassan M H utilized intermediate relays between transmitters and receivers as an effective technique to combat channel attenuation and improve system performance. Collaborative systems have some drawbacks, such as high latency and not ensuring diversity order. In order to alleviate the negative impact of these factors, a relay selection protocol has been adopted in the cooperative communication system to improve the performance of the entire cooperative system. Relay selection in cooperative systems enables signal sources to collaborate with a single relay node, rather than multiple relay nodes that ensure diversity order [1]. Chen, Y. A demonstrated a high-precision satellite ground integrated quantum communication network at the University of California, Los Angeles, USA, which integrated over 700 optical fibers and two free spaces. By adopting a reliable relay architecture, ground-based fiber optic communication over 2000 km can be achieved, ensuring its safety, reliability, and long-term stability under non ideal conditions. In a typical satellite transmission process, the satellite ground quantum sub key distribution reaches an average key distribution rate of 47.8 K bits per second, which is more than 40 times the previous rate. This combines fiber optic and Quantum Key Distribution (QKD) links in free space, expanding the QKD network to over 2600 kilometers and allowing any user on the network to communicate with another user over a total distance of 4600 kilometers [2]. Zappone, A discussed the application of emerging deep learning technologies in future wireless communication networks. It indicates that data-driven methods should not be replaced, but should supplement traditional design techniques based on mathematical models. A comprehensive survey of literature on deep learning in wireless communication networks was conducted, followed by a detailed description of several new case studies on why deep learning based on artificial neural networks can become an indispensable tool for future wireless communication network design and operation. The use of deep learning has been proven to be very useful for network design [3]. Although the above literature has conducted relevant research on communication functions. However, the technology is relatively traditional and lacks innovation.

Spatiotemporal big data includes traditional spatiotemporal data and new spatiotemporal big data created by the development of sensors and communication technologies. Traditional spatiotemporal data includes Earth observation data, socio-economic data, etc. For example, remote sensing data is a typical big data, and national remote sensing data can reach the PB (petabyte) level and can continue to grow over time. The three major data sources of the Internet, social networks, and sensors have also created a large amount of spatial big data. Spatial dimension is a type of accurately measurable and high-precision spatial information that requires a set of measurable and high-precision spatial datasets. The rapid response communication command of public security based on spatiotemporal big data can greatly improve the efficiency of communication.

2. Spatiotemporal Big Data and Communication Systems

2.1 Spatiotemporal Big Data

The spatiotemporal big data can be divided into five categories: Earth observation big data, socio-economic big data, Internet of Things big data, and social network big data [4].

Specific technical roadmap for spatiotemporal big data construction.

To fully utilize spatiotemporal big data, it is necessary to fully utilize the achievements of digital construction and conduct comprehensive research from different levels such as models, data, platforms, and applications. To continuously improve the initial digital urban management system to meet the requirements of smart city development, investment in existing environmental systems should be conditional on the effective implementation of digital urban management construction achievements [5-6]. The existing data and the data to be collected are divided into six stages: data collection, update, data processing, data generation, data management and analysis, and data release [7].

1) Data collection and update

Municipal spatial data is updated by collecting, adding, and updating geographic address data, oblique image data, 3D model data, urban image data, geodetic data, and navigation data. The functional modules include analysis and measurement, simulation and estimation, data mining, and data management [8].

2) Data aggregation

For different types of data, a data sharing method based on spatial aggregation and publishing systems, network services, and big data service sharing platforms is adopted to achieve unity and aggregation of previously collected data and data [9].

3) Data processing

Municipal spatial data is updated by collecting, adding, and updating geographic address data, oblique image data, 3D model data, urban image data, geodetic data, and navigation data. The functional modules include analysis and measurement, simulation and estimation, data mining, and data management [10].

4) Data database building

Under the framework of data quality control, data that meets human database standards is loaded into corresponding databases according to different data organization methods, forming the main geographic information database, orthophoto database, geographic address database, 3D model database, urban landscape database, public object database, knowledge perception database, and spatial planning database [11]. The functional modules include analysis and measurement, simulation design, big data mining, and big data management [12-13].

5) Data management

Various types of data in the database are managed and analyzed, including functional modules such as dynamic data collection, data management, analysis and measurement, simulation and inference, big data extraction, and big data management.

6) Data sharing

According to the spatial data application needs of different government agencies, a spatial data exchange system supported by cloud platforms and the external sharing of a large amount of spatiotemporal data are provided.

Big Data

There is no unified definition of “big data”. Big data refers to a collection of data that can be collected, stored, processed, queried, analyzed, extracted, and presented in large quantities. The characteristics of big data are large data volume, multiple types, high processing speed, and rich content. If big data is not statistically analyzed and extracted, it can become scattered data and cannot be effectively “utilized”. Big data has the characteristics of huge scale, diverse types, fast processing speed, and rich content. Without the statistical analysis and mining of big data, big data is just a pile of data, and it is impossible to extract “value-added” effective knowledge. Therefore, in order to achieve the core value of big data - “prediction”, it is necessary to fully leverage its role.

Spatiotemporal data is a rigorous scientific term that refers to a dataset of geographic features or phenomena based on a single spatiotemporal dataset with key features such as spatial dimension (S), attribute dimension (D), and temporal dimension (T), with the Earth (or other celestial bodies) as the object.

Spatial dimension is a type of accurately measurable and high-precision spatial information that requires a set of measurable and high-precision spatial datasets. Attribute dimension is a collection of related information (attributes or target information) with a large number of dimensions, which urgently requires a scientific classification system and standardized coding system. The time dimension refers to geographic information with precise three-dimensional (S-XYZ) spatial location or distribution characteristics, requiring measurable and highly accurate spatial datasets; Attribute dimension refers to various relevant information (attributes or attribute information) that can be loaded into the spatial dimension, with multi-dimensional features that require scientific classification schemes and standardized coding schemes; The time dimension refers to the temporal nature of geographic information and requires precise time reference.

Characteristics of Spatiotemporal Big Data

Spatiotemporal big data not only includes a large amount of spatial data generated according to standard specifications for mapping and geographic information such as DLG, DOM, DEM, and DRG, but also includes a large amount of spontaneous data in physical and virtual spaces such as text, images, audio, and video. As the most important big data, spatiotemporal big data has its own characteristics and also has the commonalities of big data. According to domestic experts and researchers, spatiotemporal big data mainly has the following characteristics:

(1) Spatiotemporal big data includes spatial, temporal, and semantic correlations between objects, processes, and events.

(2) Spatiotemporal big data has the characteristics of timeliness, spatiality, dynamism, and multidimensional evolution. Objects, processes, and events can be measured in both time and space, and the process of change can be described by events.

(3) Spatiotemporal big data has certain scale attributes. Starting from the spatiotemporal evolution attributes of spatiotemporal big data, it is transformed into scales, and the correlation between multiple dimensions such as objects, processes, and events is reconstructed to conduct multi-dimensional correlation analysis of spatiotemporal big data.

(4) The spatiotemporal changes of big data have the characteristics of multiple types, scales, dimensions, and dynamic correlations. It is able to classify and sort related feature oriented constraints, and establish mechanisms for selecting, reconstructing, and updating related feature oriented constraints.

(5) A large amount of spatiotemporal data has the characteristics of spatiotemporal dimensions, and can be extracted and combined with spatiotemporal correlation constraints to establish a state model based on spatiotemporal correlation constraints for event detection, understanding, and prediction.

2.2 Communication and Command System

Due to the strong potential of global positioning system technology in public safety operations, it plays an important role in preventing and controlling crime, as well as maintaining social security [14]. Therefore, it is possible and necessary to establish a rapid response system that covers the entire city, province, and even the whole country. The system should be based on wireless data networks to locate, automatically track, monitor, and guide vehicles and other moving targets throughout the city, province, and even the country. It should also provide services for relevant businesses of fire, road, border, and security departments [15]. Some public safety command centers are integrated with 110 (bandit police), 119 (fire alarm), and 122 (traffic accident) alarms, achieving the sharing of hardware equipment, information, and personnel resources, fully realizing social and economic benefits.

The control center, as the brain of various levels of public security organs, is playing an increasingly important role [16]. In addition to traditional police recruitment and equipment, command and dispatch, police situation statistics and analysis, and decision support, they also undertake more complex functions, such as monitoring the security situation on the surface of the city and video control of command posts, as well as multi police merger operations. They have become the central system for promoting all police agencies and police forces in all cities [17-18]. However, when it comes to the management and supervision of public safety, the most important thing is to narrow the “information gap” between the front and rear, so that the two can cooperate in a relatively fair competitive environment and maximize the efficiency of the police. However, at present, public security command systems around the world still focus on centralization and information visualization, emphasizing visualization, integration, centralized command scheduling and decision support, rather than fully realizing in-depth command scheduling integration on the battlefield from the perspective of the battlefield [19].

The implementation of the police crisis management system in public security organs is not only necessary to adapt to changes in the situation, but also to serve the needs of national economic development and social stability.

Firstly, it meets the practical requirements of high security and reliability for police communication protection. The digital fleet system not only has rich frequency resources, but also has efficient and safe backup functions, greatly improving the reliability and stability of the system. The confidentiality and security of the communication management system also provide strong guarantees for daily work such as public safety, emergency management, police management, and other special tasks. At the same time, the system has high capacity and scalability. In the event of emergencies or major regional special operations, personnel from different regions and departments can effectively integrate through this system and collaborate through common channels.

Secondly, the system can meet the constantly increasing needs of the police force. The traditional simulation cluster has drawbacks such as low usage frequency, small system capacity, single function, and inability to be developed for the second time. It cannot meet the needs of current public security work and hinders the development of diversified, advanced, and unified public security work. In addition, the increase of police tasks has accelerated the transformation of police informatization from analog information technology to Digital transformation. Replacing simulated vehicles with communication management can not only improve the overall efficiency of police management, but also promote the fundamental transformation of local police models, providing preliminary technical support for the reform of public security institutions [20].

Thirdly, it needs to adapt to different needs. With the progress and development of communication technology, more and more functional modules have emerged in different application fields. Especially, they are becoming increasingly comprehensive and being used for police communication tasks. The digital highway system is no longer limited to simple conventional communication instructions. They ensure uninterrupted high-quality voice calls, continue to develop and implement functions such as remote control, WAP queries, GIS positioning, and data transmission, effectively solve practical problems such as flat commands, and provide accurate, fast, flexible, and real-time communication for public security services at all levels.

3. Path Retrieval Experiment Based on Traditional Algorithms and Spatiotemporal Big Data

Based on the current research status of relevant algorithms and spatiotemporal big data, in order to simultaneously solve the problem of low matching accuracy between urban road networks and trajectory points, and effectively and reasonably reduce the number of trajectory points. In the urban road network and track point matching problem, the experiment converts the track matching problem into the problem of finding the optimal path in the weighted urban road network. The experiment requires initialization of the road network. According to the urban road network, a weighted network topology model and a data table are established, and data values are added such as road section number, road section start table, road section end table, and road weight. Road segments are used as edges in the topology network, road intersections as network nodes, and road segment length as the initial weight of the edges. The algorithm flowchart is shown in Figure 1.

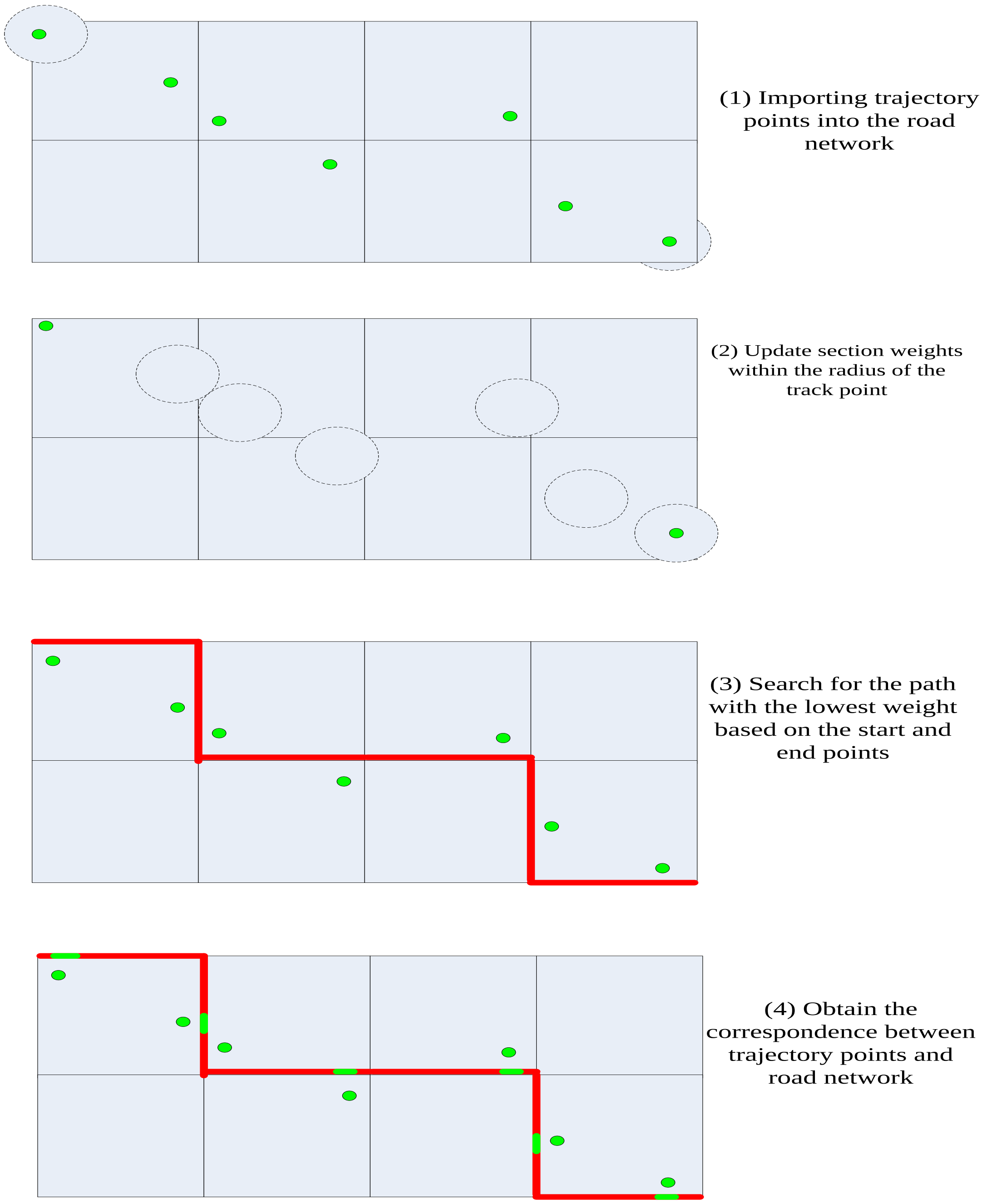

Figure 1: Flow chart of the road network trajectory matching algorithm steps.

At the same time, in order to ensure the success and accuracy of road network trajectory matching, the time segment T is taken as 10 minutes, and the trajectory points of the target vehicle can be defined and expressed in a new way based on road network information, thereby reducing data storage. The original trajectory points are represented as:

$$Trajpoint = \{id, lon, lat, time, speed, status\} \tag{1}$$

The representation method of its trajectory segment is:

$$subTraj = \{Trajpoint_1, Trajpoint_2, \ldots, Trajpoint_n\} \tag{2}$$

The information obtained from the road matching can be combined with the trajectory points to obtain a new RoadTraj expression for the trajectory segment.

$$RoadTraj = \{id, roadpoint, time\} \tag{3}$$

In the formula, roadpoint is the number of the road network road intersection, the roadpoint information value includes the longitude and latitude information of the road intersection, and time is the time of passing through the roadpoint. Among them, roadpoint=[pointlon, pointlat], pointlon, pointlat are the longitude and latitude of the location where the roadpoint is located. Through this method, the number of information points in the trajectory segment is effectively reduced.

By extracting the target vehicle trajectory points from the trajectory dataset and conducting experimental analysis on the algorithm, the matching information of the matching mechanism under different intercepted segments T is compared, and the relationship between the success rate, accuracy rate, data storage, and intercepted segment T of urban road network road matching is analyzed. Through this matching positioning algorithm, the trajectory algorithm reduces the amount of data storage for trajectory data. After matching the trajectory segments based on the urban road network path matching positioning algorithm, the results are shown in Figures 2 and 3.

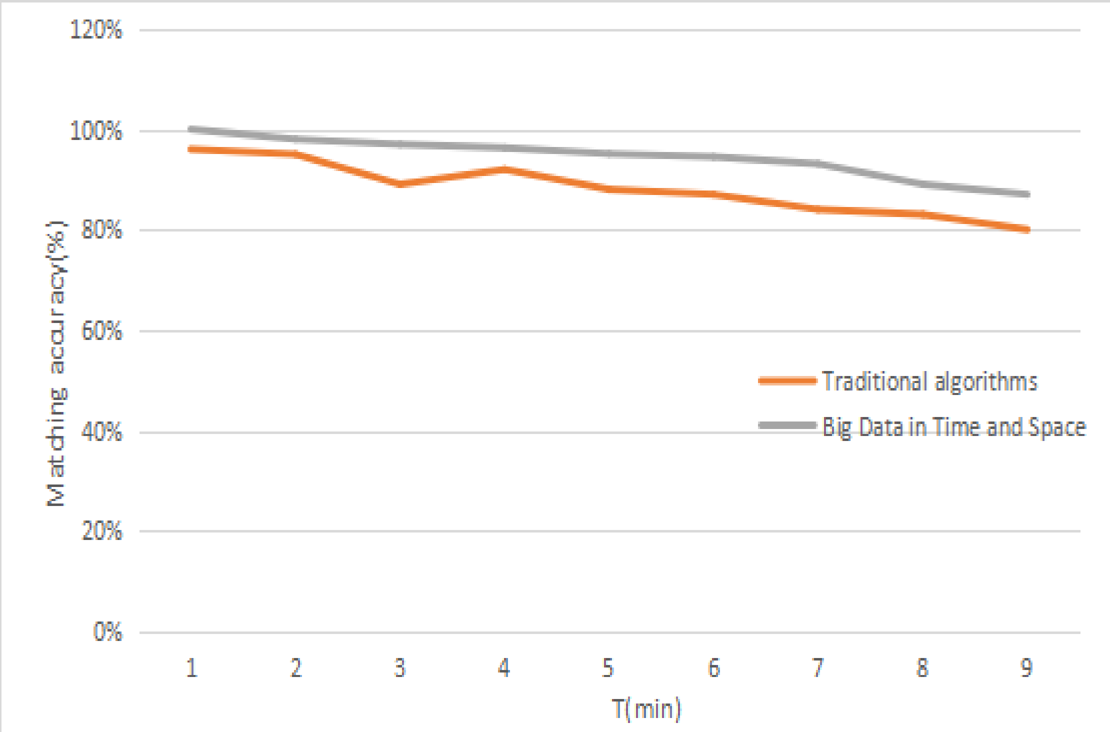

Figure 2: Analysis of the accuracy of road network trajectory matching.

As shown in Figure 2, the accuracy of traditional algorithm matching trajectories is not significantly different from that of spatiotemporal big data matching trajectories, but the overall accuracy of spatiotemporal big data matching trajectories is higher than that of traditional algorithms.

As shown in Figure 3, the success rate of road trajectory matching in traditional algorithms rapidly increases when time segment T is between 1 and 5 minutes, and then stabilizes after 7 minutes in time segment T. Although the trend of spatiotemporal big data is roughly the same, the curve of spatiotemporal big data is still higher than traditional algorithms, that is, the success rate of road matching based on spatiotemporal big data is higher.

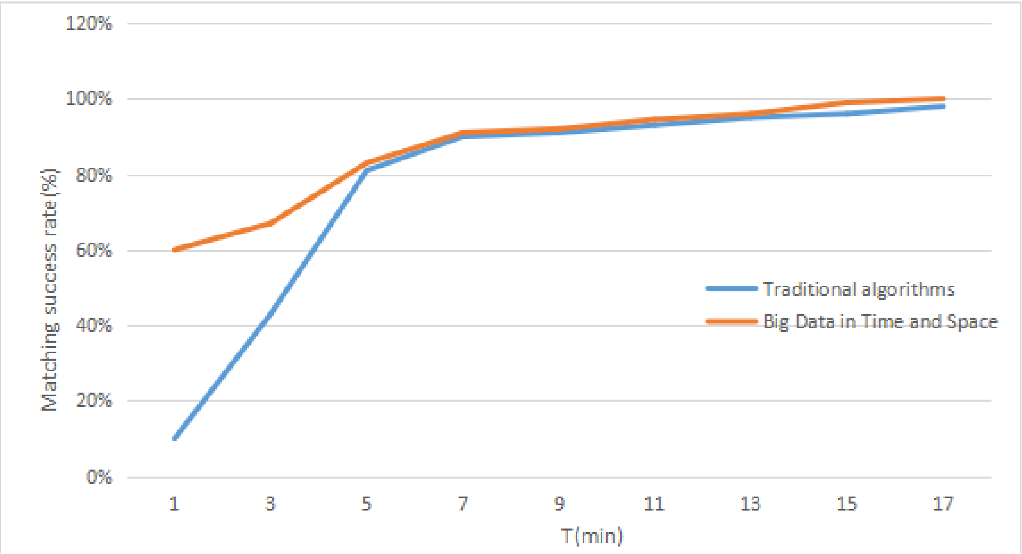

Figure 3: Analysis of the success rate of road network trajectory matching.

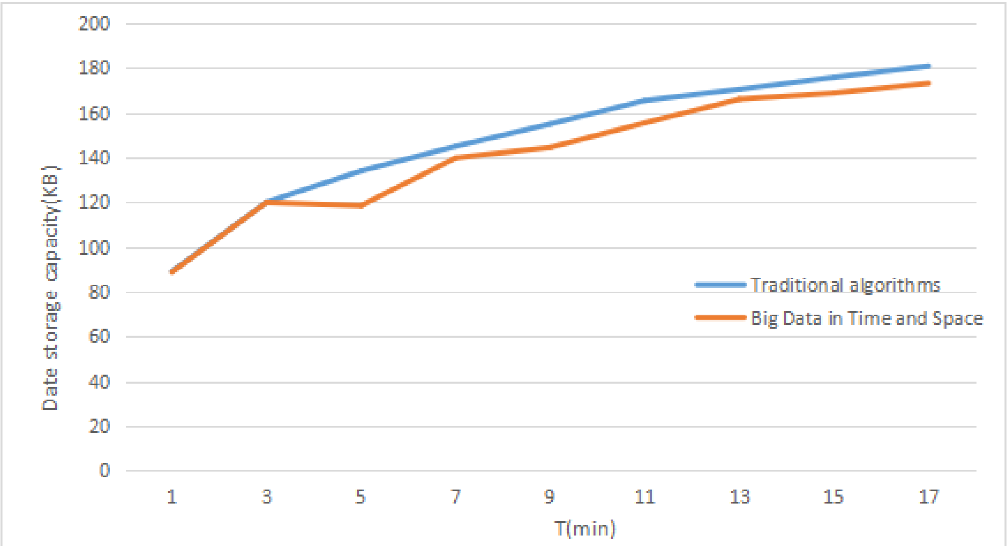

Figure 4: Analysis of the data storage capacity for the operation of road trajectories in the road network.

As shown in Figure 4, the data storage capacity of road trajectory operation based on traditional algorithms increases with the increase of time segment T, but is higher than that of road trajectory operation data storage capacity based on spatiotemporal big data. Therefore, communication command systems based on spatiotemporal big data have lighter data storage compared to communication systems based on traditional algorithms.

4. Conclusions

The spatiotemporal big data can be applied to the public security rapid response communication command system, which can efficiently improve the accuracy and success rate of communication response, and has less data storage compared to traditional algorithms. This technology can effectively help police respond quickly to police situations, thereby better maintaining social order. This article first provided a detailed analysis of the concept of spatiotemporal big data, and then introduced the application of spatiotemporal data and its application in building a police rapid response command system. Finally, the experiment proved that the accuracy, success rate and data storage capacity of path matching based on spatiotemporal big data were compared with traditional algorithms, which verified the progressiveness of spatiotemporal big data.

References

[1] Hassan M H, Jubair M A, Mostafa S A. Analyzing bit error rate of relay sensors selection in wireless cooperative communication systems. Bulletin of Electrical Engineering and Informatics, 2021, 10(1):216-223.

[2] Chen Y. A., Zhang Q., Chen T. Y., Cai W. Q., Liao S. K., Zhang J.,... & Pan J. W.. An integrated space-to-ground quantum communication network over 4,600 kilometres. Nature, 2021, 589(7841), 214-219.

[3] Zappone A., Di Renzo M., & Debbah M. Wireless networks design in the era of deep learning: Model-based, AI-based, or both? IEEE Transactions on Communications, 2019, 67(10), 7331-7376.

[4] Huang B., & Wang J. Big spatial data for urban and environmental sustainability. Geo-spatial Information Science, 2020, 23(2), 125-140.

[5] Shashidharan A, Chandola V, Vatsavai R R. The 9th ACM SIGSPATIAL International Workshop on Analytics for Big Spatial Data (BigSpatial 2020): November 3, 2020. SIGSPATIAL Special, 2021, 12(3):15-16.

[6] Shashidharan A, Chandola V, Vatsavai R R. The Eighth ACM SIGSPATIAL International Workshop on Analysis for Big Spatial Data: Chicago, IL, USA - November 5, 2019. SIGSPATIAL Special, 2020, 11(3):38-39.

[7] Eken S, Sayar A. A MapReduce-Based Big Spatial Data Framework for Solving the Problem of Covering a Polygon with Orthogonal Rectangles. Tehnicki Vjesnik, 2019, 26(1):36-42.

[8] Sabek I, Mokbel M F. Machine learning meets big spatial data. Proceedings of the VLDB Endowment, 2019, 12(12):1982-1985.

[9] Martinez-Alvarez F, Morales-Esteban A. Big data and natural disasters: New approaches for spatial and temporal massive data analysis. Computers & Geosciences, 2019, 129(AUG):38-39.

[10] Sivakumar K. Spatial Data Mining: Recent Trends in the Era of Big Data. Journal of Advanced Research in Dynamical and Control Systems, 2020, 12(SP7):912-916.

[11] Jo J H. A Sampling Approach for Visualization of Spatial Big Data. Journal of Korean Society for Geospatial Information Science, 2020, 28(4):89-97.

[12] Yi C. Directional Difference of the Residential Relocation among the Age Groups Using Spatial Big Data Analysis. Journal of Korea Planning Association, 2020, 55(1):98-111.

[13] Yu S C, Dong B S, Ahn J W. A Study on Spatial Analysis of Greenhouse Gas Emissions in Building Sector Used by the Spatial Big Data in case of Seoul. Journal of Korean Society for Geospatial Information Science, 2019, 27(4):11-19.

[14] Bello R W, Talib A, Mohamed A. A Framework for Real-time Cattle Monitoring using Multimedia Networks. International Journal of Recent Technology and Engineering, 2020, 8(5):974-979.

[15] Kumar J, Ammar M, Kantilal S A, et al. Advanced Data Storage Security System for Public Cloud. International Journal of Fog Computing, 2020, 3(2):21-30.

[16] Kim K K. A Survey on the Recognition of Field Police Officers on the Uniform Autonomous Police System. Korean Police Studies Review, 2020, 19(4):3-20.

[17] Park D K, Lee H J. A Study on Introduction of Municipal Police System in Korea. Korean Police Studies Review, 2019, 18(1):55-92.

[18] Hoon K S. A Study of Two Korea's Police Integration Based on Local Municipal Police System. Journal of Peace and Unification Studies, 2019, 11(2):399-446.

[19] Xu R, Nikouei Y, Nagothu D, et al. BlendSPS: A BLockchain-ENabled Decentralized Smart Public Safety System. Smart Cities, 2020, 3(3):928-951.

[20] Snyder A. Fitting Into the. Public safety communications, 2019, 85(1):36-37.