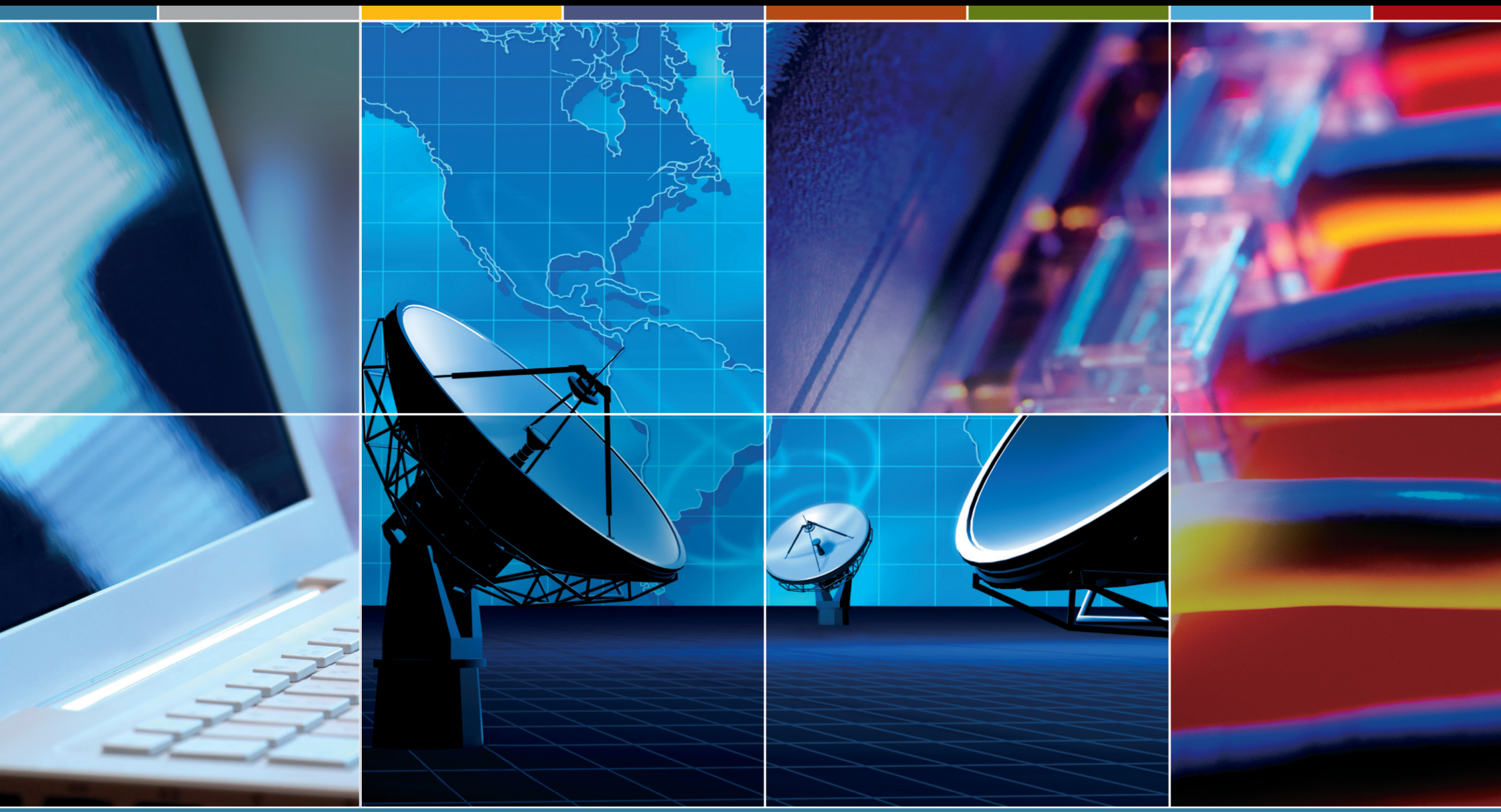
Journal of Computer Networks and Communications

The Future of Wireless Communications Systems: 5G and Beyond

Lead Guest Editor: ARVIND KUMAR
Guest Editors: Ayman A. Althuwayb and Divya Chaturvedi



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Research Article

Graphene-Based Full-Duplex Antenna for Future Generation Communication in THz Frequency Range

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A proximity-coupled graphene patch-based full-duplex antenna is proposed for terahertz (THz) applications. The antenna provides a 10 dB impedance bandwidth of 6.06% (1.76 – 1.87 THz). The input ports of the proposed design are isolated from each other by −25 dB. The aspect ratio of the graphene-based radiating patch and the physical parameters of the antenna is selected for obtaining the single-mode operation. The dimensions (length and width of graphene) of the proposed antenna have been opted to operate in two higher-order orthogonal modes, and these modes remain intrinsically isolated. The utilization of the graphene material provides flexibility in tuning the antenna response. Graphene-based patch exhibits good electrical conductivity, electrical conductance controllability, and plasmon properties. The graphene-based antennas perform better than their metallic counterparts, especially in the THz frequency range. The radiation properties of the graphene material are more prominent due to no-ohmic losses. Moreover, its chemical potential may be altered by applying a bias voltage to its surface conductivity, which modifies the surface impedance value of graphene. Therefore, with a small footprint, graphene acts as an excellent radiator at extremely high frequencies.

1. Introduction

With the advancement in high-speed data communication, terahertz (THz) components have been investigated for the present and future through innovative processes and technologies. Antennas in the THz frequency ranges (0.1 to 10 THz) have been extensively investigated and engineered for different applications. Expanding compact transceiver subsystems of data transmission at low power with ultrafast speed and superbroad bandwidth-like features are desirable for future generation communication [1–6]. Microwave and millimetre wave communication systems use metallic antennas/radiators in transceiver systems. However, they display poor conductivity at higher frequencies or the THz range [7–9]. Consequently, it is required to discover the replacement of metallic radiators in different devices operating in THz frequencies. Switching carrier frequencies to the terahertz band is a natural substitute for meeting future-generation needs, i.e., high-speed data communications [10–12]. However, compared to lower frequency antenna systems, the THz antennas have specific characteristics, including higher transmission path loss and additional molecular losses due to the absorption of the radiation energy [13]. In recent times, to combat this, many strategies have been employed. The highly directional antennas have been suggested to overcome path loss issues and to improve the channel capacity [14]. On the other hand, conventional radio frequencies (RF) and optical transceivers have numerous shortcomings, such as their bulky size, design complexity, and energy consumption [15, 16]. These constraints have prompted researchers to investigate novel nanomaterials as the foundation for next-generation electronics beyond silicon. Graphene is one of the most promising substitutes [17–26].

Graphene exhibits good electrical conductivity, electrical conductance controllability, and plasmon properties. In case graphene is integrated into antenna systems, it shows improved radiation properties than typical counterparts in metal antennas at extremely high frequencies. This is due to its good conductivity and the fact that its chemical potential may be altered by applying a bias voltage to its surface conductivity, which varies the value of the surface impedance of graphene. Moreover, its conductivity can be tuned either by doping during manufacturing or by applying an external electrostatic direct current (DC) voltage [14, 27–29]. Recently, several graphene-based antenna designs have been reported for different applications. A graphene-based antenna was reported for the ultrashort range impulse communication and biosensing applications in [30, 31], respectively. The graphene material was loaded in the realization of plasmonic antennas [32]. A mathematical model was computed for a planar graphene antenna with a triangular-shaped radiator [33]. As mobile communications evolve into the fifth generation, to offer a high-speed data rate and reduced latency, multi-input-multioutput (MIMO) antenna systems were investigated. Various MIMO antennas operating in microwave, millimetre wave (mmWave), and THz frequency ranges were reported in [26, 34–36].

A full-duplex antenna system is required to deal with practical wireless communication connectivity. In general, a full-duplex antenna system comprises two indispensable components, i.e., duplexers and antennas. Traditionally, they are designed independently and integrated with the help of a suitable transmission line. However, incorporating these components increases the system complications in limited space and leads to colossal power consumption due to a massive number of radio-frequency chains. In addition, such configuration increases the complexity and is less favourable in array extension. Hence, the concept of a self-duplex antenna was introduced in recent research [37–43]. These antennas allow a more straightforward solution to enhance the performance of a two-way communication system. The main concern of THz antennas is their low gain and radiation efficiency. This enforces exploring a suitable way to implement THz antennas with duplexing (filtering) functionality. To the authors' knowledge, no work has been reported for full-duplex design in the THz communication range. Here, a graphene-based full-duplex antenna for THz communications is introduced. A single graphene patch is excited with the help of a proximity-coupled two-port feeding mechanism. The design maintains the simple configuration of the planar feeding technique. The graphene has proven capability to exhibit good radiation characteristics, owing to the absence of Ohmic losses and surface waves. These attractive features of graphene make it a preferred choice over a metallic antenna, especially at the THz frequency range.

The difference in the architecture of the conventional and the self-duplex antenna for dual-band operation is illustrated in Figure 1. The duplex antenna is a radio-frequency component that supports the separation or combination of two frequency channels (bands) and allows them to operate on a single antenna module. Duplex antennas are provided with low-frequency and high-frequency ports. The idea can be further extended as N-frequency with N-input ports. Here, N is the number of frequency channels.

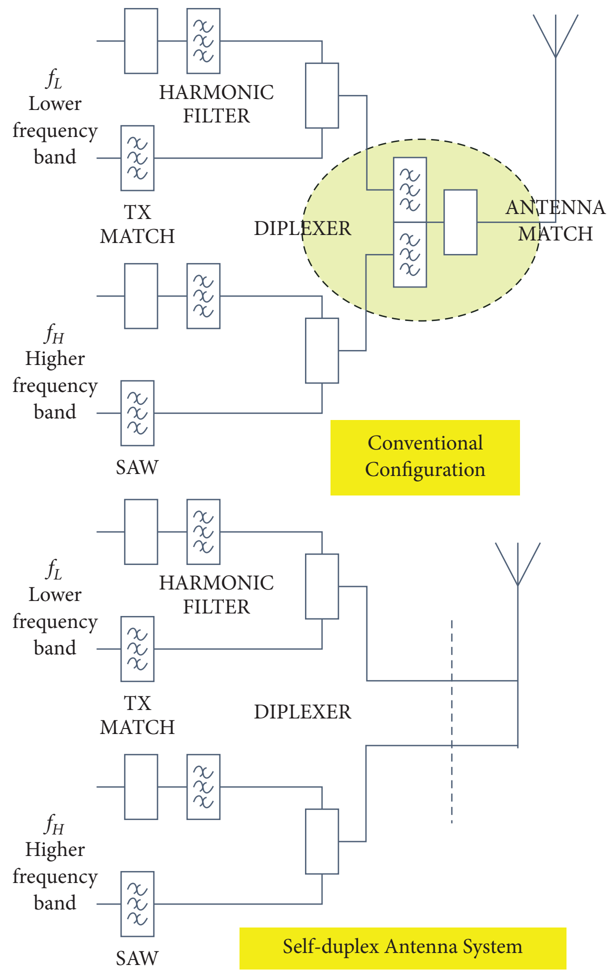

Figure 1: Architecture of self-duplex antenna system.

2. Graphene-Based Full-Duplex Antenna Modelling

The geometrical view of the proposed graphene-based self-duplex antenna is shown in Figure 2. This configuration contains a layered structure of two substrates with proximity-coupled feeding systems. The silicon dioxide is used as a dielectric substrate with a permittivity of 3.8. The substrate of height ($h1$) is placed just above the perfect electric conductor (PEC). Another substrate-2 of height ($h2$) is placed just above it. The PEC-based 50 Ω microstrip feed lines are sandwiched between these two silicon-based dielectric substrates. A thin film of the graphene material is polished on the top layer of the dielectric substrate-2. The thickness of the graphene film is optimally chosen as 0.001 mm. This film acts as a radiator when it is excited by proximity-coupled feeding. To realize the full-duplex functionality, an orthogonal feeding system is used. The aspect ratio of the proposed design is maintained in such a way that both microstrips feed excite the orthogonal higher-order modes. Moreover, the resonant frequency corresponding to the excited feed can be controlled by changing the corresponding dimension of the rectangular patch. The impedance-matching characteristics of the patch

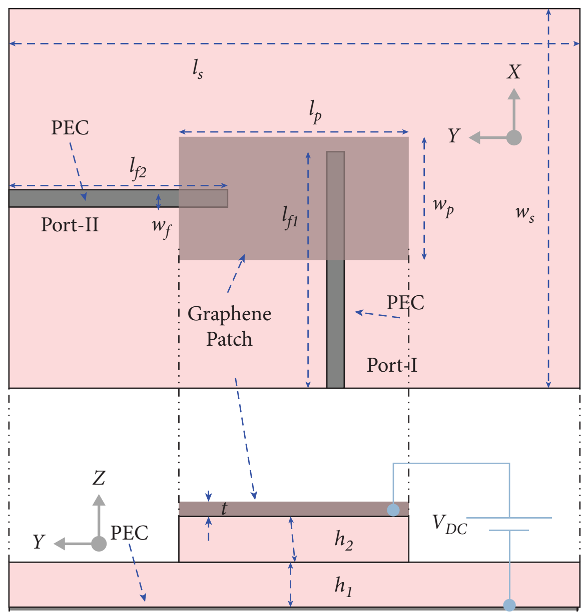

Figure 2: Configuration of the proposed graphene-based full-duplex antenna.

can be optimised by changing the length of the microstrip line. Also, the resonance of the patch can be tuned by changing the length of the microstrip line, as it controls the magnitude of the coupling energy with the graphene patch.

The graphene patch is modelled by adopting the mechanism explained in [25]. The parameters of the graphene layer, including its thickness (t) and relaxation time (τ), are opted such that the antenna can be realized physically. These parameters are designated in such a way that a suitable positive value of the external electrostatic DC voltage is required for the tuning of chemical potential (μc) and the surface conductivity (σg) of graphene material. In the antenna structure, a metal gate layer is implanted at the top of the graphene patch for applying the DC gate voltage. The length and width of the metallic gate layer are kept equal to the graphene patch so that its Fermi level can be maintained uniformly when the external voltage biasing is performed. The surface conductivity of graphene varies with radian frequency (ω), scattering rate ($\Gamma = 1/\tau$), temperature (T), applied magnetostatic bias field (Bo), and μC. The chemical potential is a function of the applied electrostatic field (Eo). Kubo's formalism reports that σg is a combination of Hall's and diagonal conductivity [25]. The Hall's conductivity of graphene becomes zero for Bo = 0, as given in [6]. Thus, σg is only due to Eo, which is generally called diagonal conductivity. The diagonal conductivity of graphene is the composition of interband and intraband transitions [1–4]. Thus, σg is only due to the intraband contribution in the operating frequency band of the designed two-port antenna.

3. Working Principle and Result Analysis

The dimensions of the proposed design are provided in Table 1. The length and the width of the patch antenna are optimised in such a way that the antenna offers the two distinct frequency bands for simultaneous transmitting and receiving channel operation in the frequency range of THz frequency applications.

Table 1: The dimensions of the antenna structure.

l_s	w_s	l_p	w_p	l_{f1}	h_1	h_2	t	w_f	l_{f2}
60	40	25	13	25	1.6	1.6	0.001	1.8	23

All dimensions are in millimetres (mm).

Finally, the optimised design operates at a lower frequency band of around 1.8 THz and a higher frequency band of about 2.0 THz frequency. Furthermore, the tuning of the antenna response is possible by varying the chemical potential of the graphene material, a feature available in CST MWS. Figure 3 shows the electric field distributions at the operating frequencies at Port-1 and Port-2. It can be clearly evidenced that the antenna operates in higher-order modes. As shown in Figure 3(a), the electric field shows three half-wave variations along the length of the graphene patch. On the other hand, it offers two half-wave variations when Port-2 is on. It is observed that the incident field is radiated through the appropriate aperture without being transmitted to another port. Thereby, input port isolation is enhanced and maintained. Finally, the optimised design with parameters is shown in Table 1. The lower resonant frequency occurs at 1.83 THz and is generated when Port-1 is excited, and the antenna radiates along the broader side of the rectangular graphene patch. Similarly, the resonance at upper resonant frequency is generated from Port-2 when it is excited along the narrower side of the rectangular graphene patch. The length of the radiating patch is chosen to be much larger than half of the guide wavelength at the resonant frequencies, so it shows functionality at higher-order modes corresponding to Port-1 and Port-2.

The frequency response of the proposed design in terms of S-parameters is shown in Figure 4. The design shows that the coupling of the energy from Port-1 to Port-2 and vice versa is below −20 dB. The same can be inferred from Figure 3 that the resonant frequency of each channel can be tuned without affecting the other channel by maintaining the same level of port isolation. Also, it operates in different high-order modes. The 3D far-field radiation pattern at the resonant frequencies is shown in Figure 5. The proposed design shows unidirectional radiation patterns due to the large ground plane at the bottom. The peak directivity of the antenna in the broadside direction is noted as 2.44 and 2.79 dBi at 1.83 and 2.06 THz, respectively. Moreover, the proposed THz design has a compact structure and simple design procedure, which would make it attractive to choose for upcoming communication systems. The proposed design offers the flexibility of using one device and one board layout to cover dual-frequency bands and substitutes the conventional design mechanism.

3.1. Future Applications of THz Technology. THz range of the electromagnetic spectrum has increasingly been used in numerous sectors for practical purposes, and research on the use of THz technology in communications, radar, imaging, sensors, and other areas has been reported in recent years.

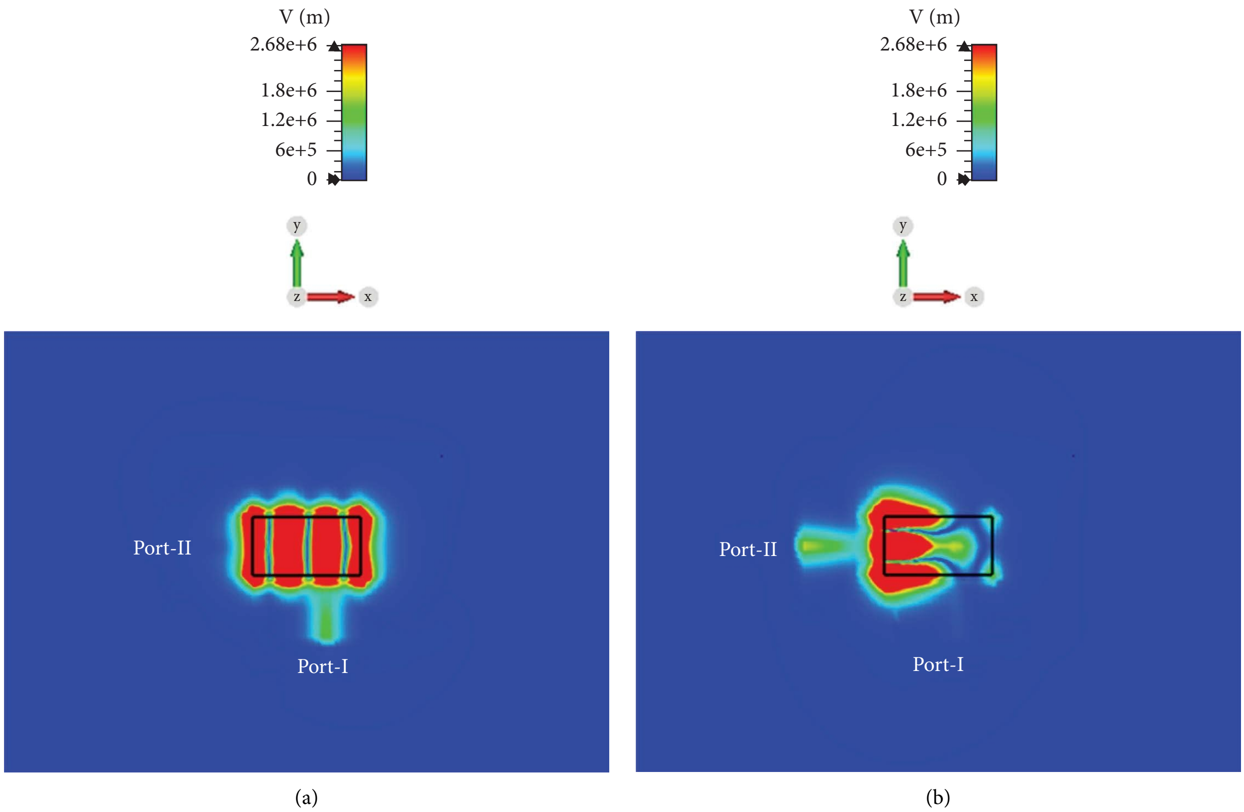

Figure 3: Field distributions: (a) at 1.83 THz, when Port-1 is excited. (b) At 2.06 THz, when Port-2 is excited.

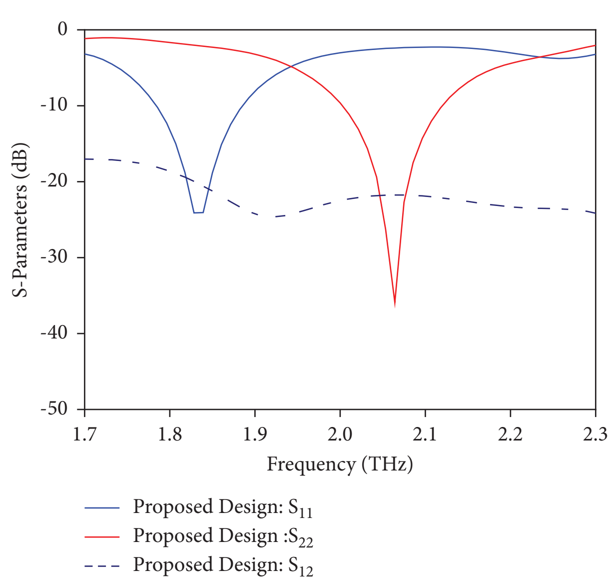

Figure 4: Simulated S-parameters of the proposed design.

The need for a wide bandwidth has prompted research into the THz frequency spectrum and THz communication components. Terahertz (THz) radiation is receiving increasing attention for its very diverse range of applications in both technology and science, including areas such as information and communications technology (ICT), non-destructive sensing and imaging, strong light-matter coupling, physics, and biology.

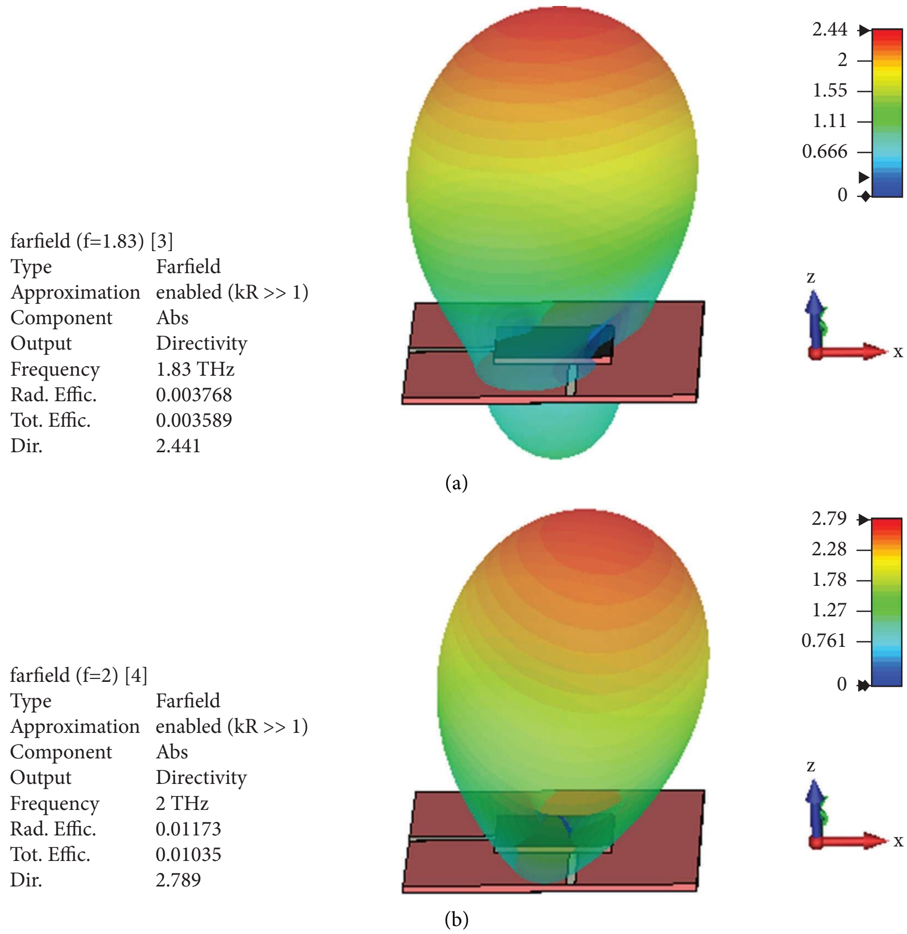

Figure 5: Radiation patterns: (a) at 1.83 THz, when Port-1 is excited. (b) At 2.06 THz, when Port-2 is excited.

4. Conclusion

A proximity-coupled graphene patch-based two-port duplexing antenna is realized for simultaneous transmitting and receiving channel operation in the frequency range of THz frequency applications. The physical parameters of the antenna can be selected for desired operating frequency. The operating frequency maintains a small frequency ratio, and the same can be manipulated further. The antenna maintains isolation better than 20 dB between input ports which helps to realize duplexing functionality and radiation characteristics as a single unit. The proposed design offers the flexibility of using one device and one board layout to cover dual-frequency bands and substitutes the conventional design mechanism. The proposed design possesses an overall compact footprint, which makes this design extremely useful for applications in forthcoming wireless communication systems.

Data Availability

No data were used to support the findings of this study.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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Research Article

Analysis of 5G Smart Communication Base Station Doppler-Smoothed Pseudorange Single-Point Geodesic Positioning Accuracy

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With the continuous development of mobile communication and satellite navigation technologies, the positioning requirements of 5G smart communication base stations are becoming higher and higher. With the opening of GNSS raw observation data, research on the positioning of a 5G smart communication base station has become a research hotspot in the surveying and mapping disciplines. In this paper, based on the GNSS observation data of the 5G smart communication base station, the quality of the original GNSS observation data of the 5G smart communication base station is studied and analyzed. A method based on Doppler smoothing pseudorange solves the problem that the original pseudorange observation values of the 5G smart communication base station are noisy and prone to multipath errors due to the limitations of the base station chips and processes, which makes the traditional data processing methods unable to meet the demand for higher accuracy positioning. This method uses Doppler observations to smooth the pseudorange and determines the Doppler smoothing strategy and closure values to improve the data quality. The experimental data show that Doppler smoothing pseudorange can improve data quality and positioning accuracy by 67.9% in the *E* direction, 64.8% in the *N* direction, and 65.5% in the *U* direction. The future world will develop in the direction of intelligence, and the wireless network 5G technology used to support the construction of this intelligent system will become the core driver for the development of a leading intelligent society. 5G network signals have higher reliability and lower latency and can meet the specific needs of smart manufacturing, autonomous driving, and other industrial applications. This new base station product can meet the construction needs of future 5G base stations, adapt to the future intensive, miniaturized, intelligent station construction mode, and realize safe and fast station construction, providing the necessary hardware support for 5G network coverage.

1. Introduction

Currently, the global navigation satellite system (GNSS) technology is developing rapidly, providing all-weather, high-precision navigation and positioning services to different members of society. The successful launch of the 55th BeiDou navigation satellite marked the full deployment of the BeiDou navigation satellite system (BDS) constellation in China [1, 2]. With the continuous development of mobile communication and satellite navigation technologies, mobile intelligent terminals have been widely used in the fields of location sharing, engineering measurement, pedestrian navigation, firefighting, and disaster mitigation. In daily life, how to obtain real-time and high-precision geographic location information through mobile smart terminals has become a popular topic, and people have an increasing demand for smart terminal positioning [3, 4]. Especially since 2016, Google has provided interfaces to obtain raw GNSS observations (such as C1 pseudorange observation, and L1 carrier phase observation, D1 Doppler observation) in its Android Nougat 7.0 and above operating system for mobile devices, but due to the influence of the smart terminal chip process and antenna, the observation noise and multipath error are large when positioning at the base station [5, 6]. However, due to the influence of the smart terminal chip process and antenna, the observation noise and multipath error during base station positioning are large, resulting in low positioning accuracy, so how to improve the positioning accuracy of smart devices has become a research hotspot in recent years [7, 8].

Doppler observation has better observation accuracy and is not easily disturbed by multipath errors [9, 10]. The study [11] analyzed the difference between multipath errors in 5G smart communication base station and geodetic receivers. A study [12] showed that using Doppler combined with pseudorange observation for localization is better than using pseudorange observation alone. The study [13] investigated the feasibility of Doppler smoothing pseudorange. The study [14] used Doppler observations for pseudorange smoothing to improve the accuracy and stability of localization. Since the antennas of 5G smart communication base stations are different from those of geodetic receivers, 5G smart communication base stations are more likely to track satellite signals, but the signal-to-noise ratio is lower than that of geodetic receivers, and the multipath effect of 5G smart communication base stations is an order of magnitude higher than that of geodetic receivers [15, 16]. This is one of the main reasons for the poor positioning accuracy of 5G smart communication base stations, and these research works have been done by many scholars and will not be discussed here [17, 18].

To address the problem of low positioning accuracy of 5G smart communication base stations, this paper makes full use of the feature that Doppler observations are not affected by multiple paths to carry out research on the application of Doppler observation smoothing pseudorange for smart terminals, carries out research on coarse difference rejection and broad value setting in the process of Doppler smoothing, and preprocesses measurement data according to the analysis results to achieve the purpose of improving positioning accuracy [19, 20].

2. Doppler Positioning Architecture

The target positioning method of a single satellite is as follows: acquire the coordinates of the satellite's hypostasis; acquire the incoming wave direction angle of the target and the zenith angle from the satellite to the target; establish the first spherical triangle on the Earth's surface with the hypostasis, the target, and the pole as the vertices; the pole is the South Pole of the Earth or the North Pole of the Earth; determine the coordinates of the target B and the pole N based on the relationship between the sides and angles of the first spherical triangle. Based on the coordinates of the first spherical triangle, the coordinates of the substar point A, the incoming wave direction angle, and the sky bottom angle, the position of the target B and the pole N are determined. Based on the position of the target B and the pole N, the coordinates of the target B are determined. When the satellite flies over the target radiation source, the single-satellite positioning process is carried out, and its radius l acceleration changes continuously during the motion. Based on the correspondence between the radial acceleration and the target position, the radial acceleration of the target is measured at several moments, and then combined with the constraint of the target position on the Earth, the coordinates of the radiation source position can be located (see Figure 1).

STK (Satellite Tool Kit), or Satellite Simulation Kit, was developed by AGI, USA, to quickly and effectively analyze missions in complex environments such as land, sea, and air, and to support the whole process of space missions, including design, test, launch, operation, and mission. Therefore, it is widely used in the aerospace industry and in science and technology fields. In this paper, we choose the STK version 10 environment and build a motion scenario including a ground radiation source, motion satellite, and on-board receiver with the powerful and realistic analysis capability of STK. The communication simulation module of STK is used to analyze the reception of ground radiation source signals by the on-board receiver. The simulation flow of single-star passive positioning is shown in Figure 2.

Positioning based on Doppler information mainly refers to the use of Doppler frequency and Doppler frequency change rate to determine the positioning surface, multiple measurements to obtain multiple positioning surfaces, and intersection position as the target's positioning point. Generally, the target is on Earth's surface or at a relatively low height, and two-dimensional plane analysis is used. As shown in Figure 3.

3. Coarse Difference Detection and Doppler Smoothing Algorithm

GNSS pseudorange observations contain various errors caused by observation equipment, propagation paths, relativity, satellite ephemeris, etc. Therefore, the single-point positioning results are affected by satellite ephemeris errors and atmospheric refraction errors. Due to the influence of the 5G smart communication base station itself, the measurement results are not as stable as those of earth-based receivers, and the observations contain large, coarse differences. By using pseudorange observations for real-time dynamic positioning, we can avoid the problems of resolving ambiguity and dealing with circular jumps, and the accuracy of the obtained positioning results can meet the single-solution needs of most navigation users. However, pseudorange observation is susceptible to multipath effects, nonvisual distance, and signal occlusion, which makes dynamic localization using pseudorange in complex scenarios less effective. Due to the effect of the duty cycle, it is difficult for intelligent terminals to obtain ideal carrier phase observations, so Doppler observations can be used to smooth the pseudorange and improve the satellite positioning accuracy of intelligent terminals. When there is no duty cycle limitation, the smoothed pseudorange of carrier phase observation can obtain more reliable satellite positioning results from the smart terminal. In this paper, we detect ephemeris elements containing coarse differences by calculating quadratic differences between ephemeris elements, removing the ephemeris elements, and restarting the smoothing calculation.

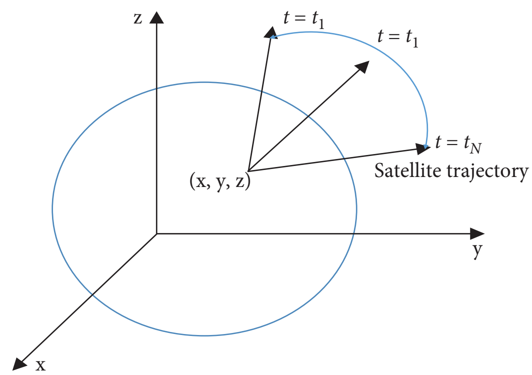

Figure 1: Schematic diagram of a single-star passive positioning model.

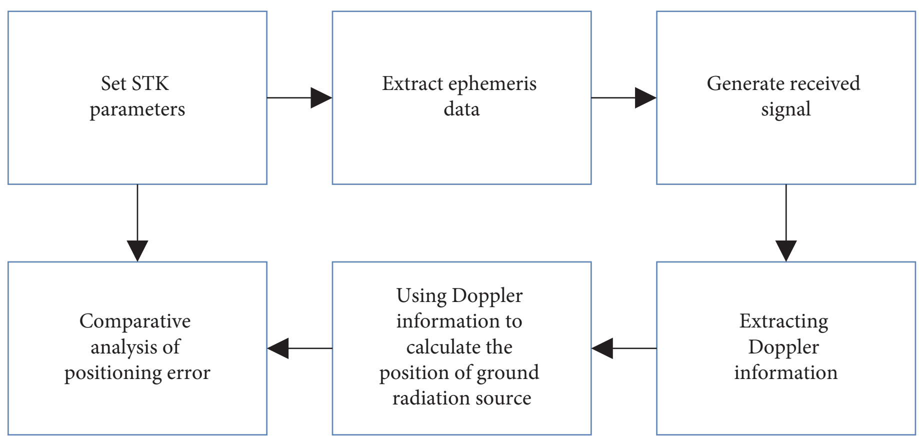

Figure 2: Single-star passive positioning simulation flow chart.

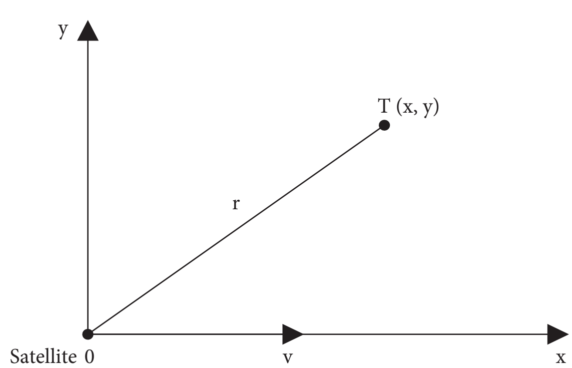

Figure 3: Schematic diagram of a planar motion scene.

For the calendar element k, the pseudorange observation equation can be expressed as the following equation:

$$\rho_k^s = R_k^s + c\delta t_k - c\delta t_k^s + \delta\rho_{k,\mathrm{trop}}^s + \delta\rho_{k,\mathrm{ion}}^s + \delta\rho_{k,\mathrm{rel}}^s + \delta\rho_{k,\mathrm{sagnc}}^s + \varepsilon_{\rho,k}^s. \tag{1}$$

where s is satellite number; c is the speed of light; ρ_k^s is the pseudorange observation; R_k^s is true satellite ground distance from the receiver; δt_k is the receiver clock difference; δt_k^s is the satellite clock difference; $\delta\rho_{k,\mathrm{trop}}^s$, $\delta\rho_{k,\mathrm{ion}}^s$ are tropospheric delay error and ionospheric delay error; $\delta\rho_{k,\mathrm{rel}}^s$ is the relativistic effect; $\delta\rho_{k,\mathrm{sagnc}}^s$ is the Earth's rotation error; $\varepsilon_{\rho,k}^s$ is the unmodeled error such as multipath and measurement noise.

The single difference between epoch $k + 1$ and epoch k of (1) can eliminate or weaken the effects of tropospheric delay error, ionospheric delay error, relativistic effect, and Earth rotation error. Since the satellite clock is more stable, the single difference between pseudorange ephemeris elements is a smooth curve when no large jump occurs in the receiver clock. Then, the double difference between the ephemeris is a straight line tending to 0. According to error theory, (an error is an experimental scientific term that refers to the extent to which the measurement results deviate from the true value. Mathematically, the measured value or other approximate value and the difference between the true value of the error. The error theory is the study of the error in the experiment of a theory; error theory is the test technology, instrumentation, and engineering experiments and other fields' indispensable and important theoretical basis; it plays an important role in science and production practice.) Three times, a medium error is selected as the limit difference for coarse difference rejection.

Because of the increased more week-hopping of 5G smart communication base station carrier phase observations, the pseudorange smoothing effect is not good, so this paper uses Doppler smoothing pseudorange, which is not affected by week-hopping and whose algorithm is more efficient, and base station Doppler smoothing pseudorange is derived from carrier phase smoothing pseudorange.

For the calendar element k, the carrier phase observation equation can be expressed as the following equation:

$$\begin{aligned}\varphi_k^s &= R_k^s + c\delta t_k - c\delta t_k^s + \delta\rho_{k,\mathrm{trop}}^s - \delta\rho_{k,\mathrm{ion}}^s \\ &\quad + \delta\rho_{k,\mathrm{rel}}^s + \delta\rho_{k,\mathrm{sagnc}}^s - \lambda N^s + \varepsilon_{\varphi,k}^s,\end{aligned} \tag{2}$$

where φ_k^s is the carrier phase observation; λ is the corresponding carrier wavelength; N^s is the whole-period ambiguity; $\varepsilon_{\varphi,k}^s$ is the unknown carrier phase measurement noise; rest parameters have the same meaning as equation (1).

In the initial epoch, let the initial smoothing pseudorange be equal to initial epoch pseudorange observation, i.e., $\overline{\rho}_k = \rho_k$, then the conventional equation of carrier smoothing pseudorange is in the following equation:

$$\overline{\rho}_{k+1} = \omega_{k+1}\rho_{k+1} + \left(1 - \omega_{k+1}\right)\left(\overline{\rho}_k + \varphi_{k+1} - \varphi_k\right), \tag{3}$$

where the first coefficient on the right side of the equation $\omega_{k+1} = 1/(K+1)$ is usually called the weighted smoothing factor, which is equivalent to the following equation:

$$\overline{\rho}_{k+1} = \omega_{k+1}\sum_{i=1}^{k}\rho_i + \omega_{k+1}\sum_{i=1}^{k}\left(\varphi_{k+1} - \varphi_i\right). \tag{4}$$

Combining equations (2)–(4), it can be seen that the use of carrier smoothing pseudorange is independent of whole-period ambiguity, and the result obtained from $\varphi_{k+1} - \varphi_k$ is a high-precision pseudorange change rate, while a high-precision pseudorange change rate can be directly obtained in the 5G smart communication base station.

According to a white paper published by the European GNSS Agency (GSA), Doppler observations are derived from pseudorange rates of change, and the relationship is given in the following equation:

$$\mathrm{PsdR} = -\alpha \times \mathrm{Dopplershift}, \tag{5}$$

where PsdR denotes the pseudorange variation rate, whose value can be obtained from Google's open GNSS raw data API interface; α is a constant, which can be expressed as $\alpha = c/f_i$; c is the speed of light; f_i is the central frequency of the signal (e.g., $L1 = 1575.42\mathrm{e}6$ Hz); and Doppler shift is the Doppler observation value.

Because Doppler observations have better observation accuracy and are not disturbed by multipath errors, the relationship between pseudorange change rate and Doppler observations can be known from equation (5), and pseudorange change rate PsdR is used instead of $\varphi_{k+1} - \varphi_k$ for pseudorange smoothing in cell phone Doppler smoothing pseudorange, which can be expressed as the following equation:

$$\overline{\rho}_{k+1} = \omega_{k+1}\rho_{k+1} + \left(1 - \omega_{k+1}\right)\left(\overline{\rho}_k + \mathrm{PsdR}\right). \tag{6}$$

4. Results

Due to the high power consumption of GNSS modules in long-term continuous operation, 5G smart communication base station manufacturers have introduced a "duty cycle" mechanism within the base station to ensure the low power consumption of the GNSS module, which causes discontinuous carrier phase tracking, resulting in circular jumps in the phase observations of the front and rear ephemeris. The base station can turn on the option to force full tracking of GNSS measurements to eliminate the effect of the "duty cycle." Table 1 shows the fields of raw observations available for 5G smart communication base stations.

Before pseudorange smoothing, data are first preprocessed to detect jumps between Doppler and pseudorange observations by making a primary difference between observed Doppler and pseudorange values and then a second difference between epochs to determine a reasonable reading value. Table 2 shows an error in the double-difference value of an observable satellite.

From Table 2, we can see that the Doppler observation data are relatively stable, and the double difference can reflect that some satellites contain coarse differences while the pseudorange observation data vary more through the double difference, so it is easy to find the coarse differences through the double difference and eliminate them. Obviously, G11 and G32 are normal observations because the observation epoch of the G11 satellite is relatively small, so satellite 32 is selected as a reference, and 0.9 Hz (3 times the medium error) is set as the reading value of the Doppler double difference and 15 m (3 times the medium error) is set as the ranking value of the pseudorange double difference.

The satellites G11, G32, G22, and G23 are selected for detailed analysis, where G11 and G32 are normal observations without jump, and the single and double differences of the observed satellite Doppler and pseudorange observations are observed and calculated by epoch elements, and the comparison results are shown in Figure 4.

Figure 4 shows single and double differences between Doppler and pseudorange observations of the G11 satellite, calendar element by calendar element. It can be seen that Doppler observations contain small jumps, while pseudorange observations do not have jumps. 99.5% of the absolute values of single differences between Doppler observations are within 2 Hz, and 985% of the absolute values of double differences between ephemerides are within 1 Hz. The single difference between calendar elements of the pseudorange observation value varied smoothly, and the absolute value of the double difference between calendar elements did not exceed 15 m. Figure 4 reflects variation rate of Doppler and pseudorange variation when a 5G smart communication base station tracks satellites normally, which provides data support for setting coarse difference rejection broad value.

Figure 5 shows single and double differences between Doppler and pseudorange observations of the G32 satellite, calendar element by calendar element. It can be seen that Doppler observations contain small jumps, while pseudorange observations do not have jumps. 99.9% of the absolute values of single differences between Doppler observations and double differences between ephemerides are within 2 Hz, and 98.6% of the absolute values of double differences between ephemerides are within 1 Hz. The single difference between the ephemerides of pseudorange observations

Table 1: The main observations are available for the 5G smart communication base station.

Name	Attribute	Describe
GNSS Clock	Class	Clock class, used to calculate pseudorange observations
Accumulated delta range meters	Observed value	Carrier phase observations
Cn0Db (Hz)	Observed value	Signal to noise ratio
Carrier frequeney (Hz)	Observed value	Carrier frequency
Pseudorange rate meters per second	Observed value	Pseudorange change rate

Table 2: 5G smart communication base station observation double difference error statistics.

Satellite	Doppler double difference (Hz)	Pseudorange double difference (m)
G3	0.562	4454.335
G7	0.507	310.468
G8	0.317	4890.355
G9	0.315	4367.548
G11	0.316	3.344
G14	0.381	4305.128
G16	0.307	3690.258
G21	0.753	4498.947
G22	0.362	26.222
G23	0.411	3698.558
G25	1.138	37.135
G26	0.306	3691.353
G27	0.308	3965.124
G29	0.505	82.488
G31	0.306	3690.334
G32	0.292	5.055

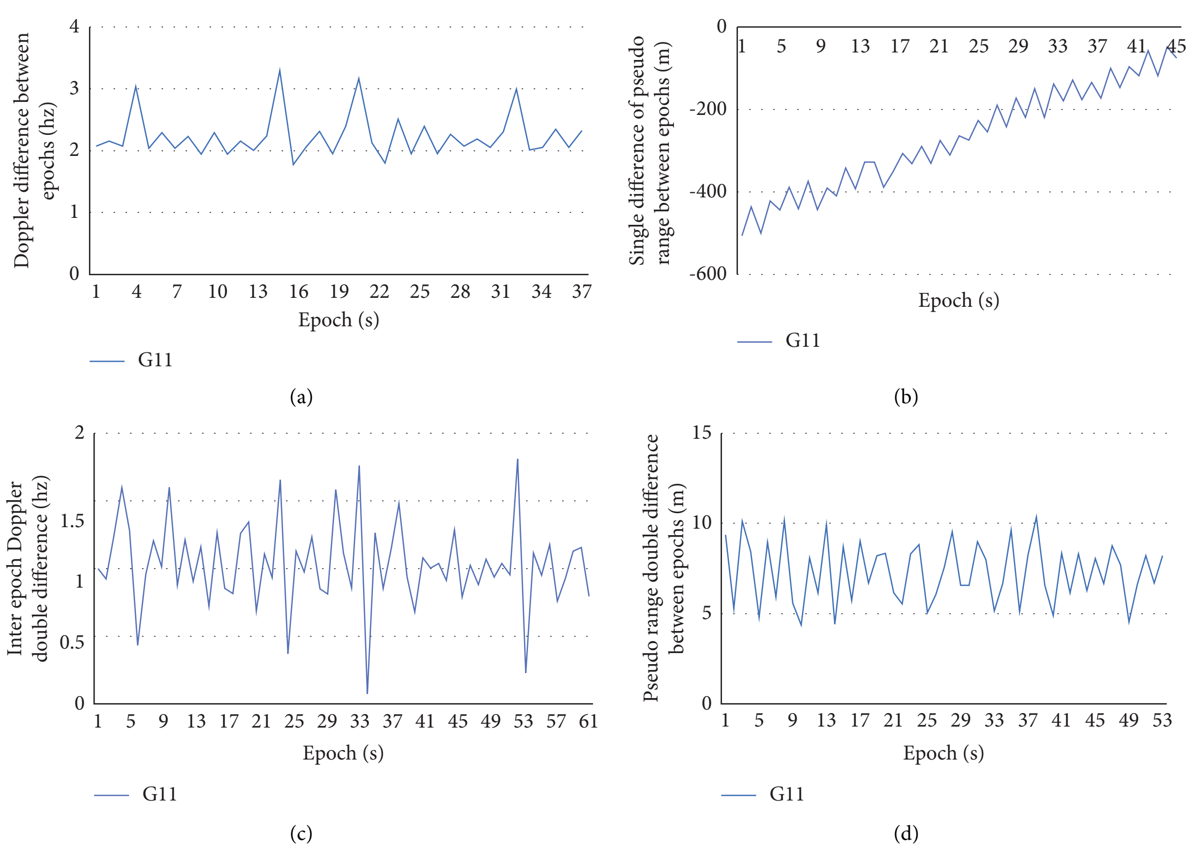

Figure 4: Doppler difference and pseudorange difference between ephemeris elements of the G11 satellite. (a) Doppler single difference. (b) Pseudorange single difference. (c) Doppler double difference. (d) Pseudorange double difference.

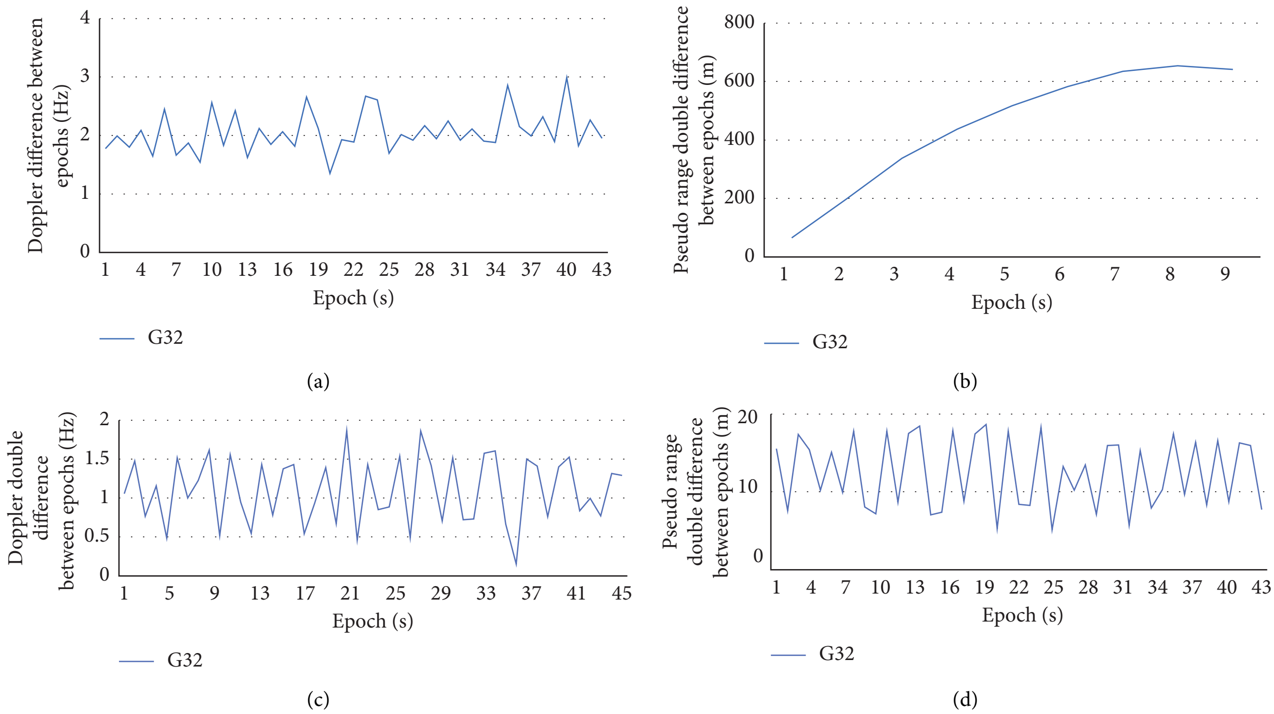

Figure 5: Doppler difference and pseudorange difference between ephemeris elements of the G32 satellite. (a) Doppler single difference. (b) Pseudorange single difference. (c) Doppler double difference. (d) Pseudorange double difference.

varied smoothly, and the absolute value of the double difference between the ephemerides did not exceed 25 m.

Figure 6 shows single and double differences between Doppler and pseudorange observations of the G22 satellite, calendar element by calendar element. It can be seen that there is no jump in Doppler values; 99.9% of the absolute values of single differences between Doppler values are within 2 Hz, and most of the absolute values of double differences between ephemerides are within 1 Hz. For most of the pseudorange observations, the single difference between ephemerides varied smoothly, but there were frequent jumps between 1000 and 3000 ephemerides, and the absolute value of the double difference between ephemerides exceeded 200 m, which was larger than the broad value.

Figure 7 shows single and double differences between Doppler and pseudorange observations of the G23 satellite on an ephemeris-by-ephemeris basis. It can be seen that there are seven Doppler single differences greater than 2 Hz between 7000 and 11000 epochs and many double differences greater than 2 Hz between 10 000 and 11 000 epochs, while pseudorange observations have a large coarse difference of 300 km jumps between 8000 and 9000 epochs.

The GPS L1 single-frequency data were smoothed with a satellite cut-off altitude angle of 15° and a signal-to-noise ratio reading of 30 dB-Hz, and smoothing windows of 50, 100, 120, and no smoothing were selected for comparison. After the test, accuracy was significantly improved, and the test results are shown in Table 3.

As can be seen from Table 3, RMS values of smoothed single-point localization results become smaller in all directions, and the accuracy of smoothed window 100 improves by 11.0% in the E direction, 10.0% in the N direction, and 4.0% in the U direction over smoothed window 50 results; the accuracy of smoothed window 100 improves by 67.9% in the E direction, 64.8% in the N direction, and 65.5% in the U direction over unsmoothed results. Although the solution accuracy of smoothed window 120 is improved over that of smoothed window 100, improvement is limited.

As can be seen from Table 4, pseudorange observations contain coarse errors when data are not preprocessed, which leads to no results in data solution, and after star picking, the data solution rate reaches 100%, which verifies the necessity of coarse error removal before smoothing pseudorange. In summary, it is especially important to remove the Doppler jump and deal with the pseudorange observation jump before Doppler smoothing pseudorange, and Doppler jump and the pseudorange jump are not related, so they should be handled separately in coarse error rejection. If the wrong value is introduced, it will affect smoothed pseudorange observations and continue to affect subsequent localization results on an epoch-by-epoch basis. Based on the abovementioned analysis, 0.9 Hz is selected as the reading value for the double difference between Doppler ephemeris elements, and 15 m is selected as the reading value for the double difference between pseudorange ephemeris elements.

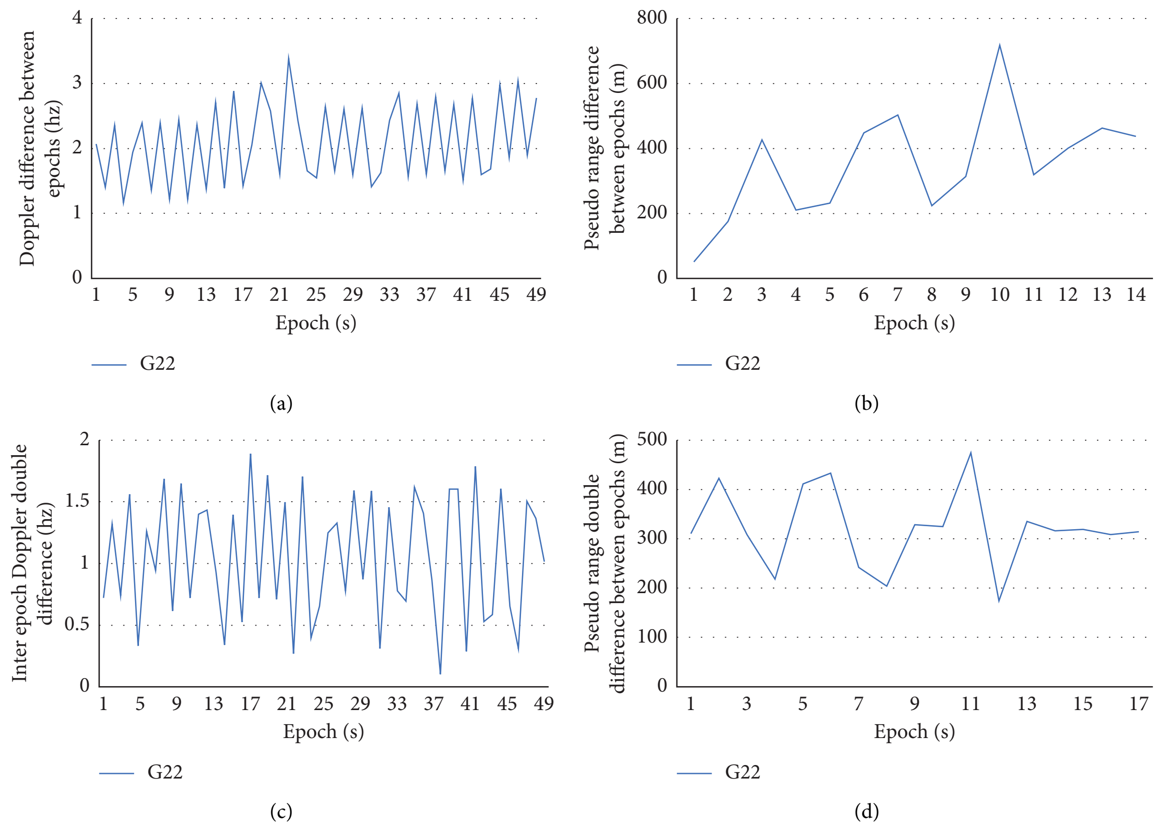

Figure 6: Doppler difference and pseudorange difference between ephemeris elements of the G22 satellite. (a) Doppler single difference. (b) Pseudorange single difference. (c) Doppler double difference. (d) Pseudorange double difference.

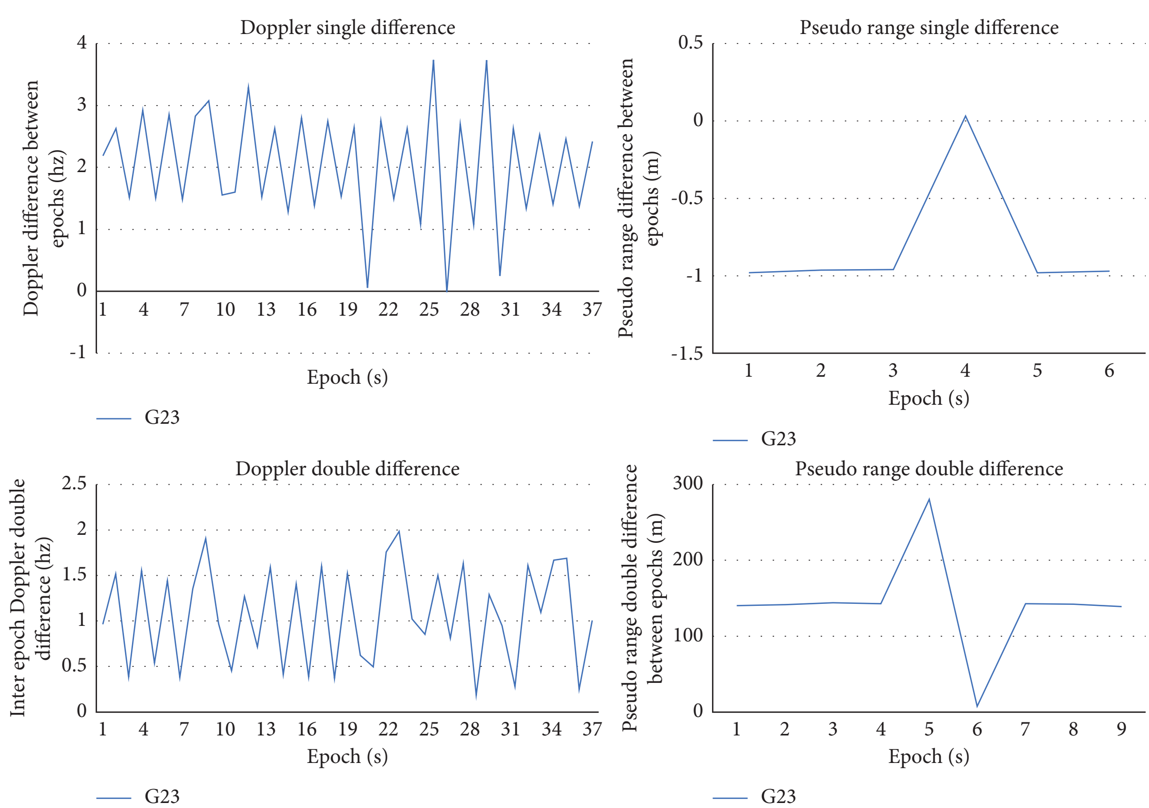

Figure 7: Doppler difference and pseudorange difference between the ephemerides of the G23 satellite. (a) Doppler single difference. (b) Pseudorange single difference. (c) Doppler double difference. (d) Pseudorange double difference.

Table 3: 5G smart communication base station smoothing pseudorange positioning outside conformal accuracy (RMS) statistics.

RMS	N (m)	E (m)	U (m)
Unsmoothed	2.28	1.95	4.44
Smooth window 50	0.83	0.77	1.72
Smooth window 100	0.72	0.69	1.54
Smooth window 120	0.71	0.66	1.49

Table 4: Statistics of data solving rate.

Smooth window	Primitive epoch	Solve epoch	Solution rate (%)
Unsmoothed	13200	13185	99.88
Smooth window 50	13200	13200	100
Smooth window 100	13200	13200	100
Smooth window 120	13200	13200	100

5. Conclusion

This paper first introduces the principle of GNSS pseudorange single-point positioning, then introduces carrier phase smoothing pseudorange and Doppler smoothing pseudorange according to the poor quality of smartphone pseudorange observations, and compares and analyzes the three strategies of pseudorange single-point positioning, pseudorange single-point positioning after carrier phase smoothing, and pseudorange single-point positioning after Doppler smoothing. The experimental results show that Doppler smoothing pseudorange can improve the positioning accuracy. When the smoothing window is 100, the pseudorange single-point localization strategy with carrier phase smoothing improves the localization results by 67.9% in the E direction, 64.8% in the N direction, and 65.5% in the U direction compared with the pseudorange single-point localization strategy without carrier phase smoothing. The original pseudorange observations with carrier phase and Doppler smoothing can effectively reduce the noise effect and thus improve accuracy.

Data Availability

The experimental data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Acknowledgments

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Research Article

Improved Convolutional Neural Image Recognition Algorithm based on LeNet-5

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Convolutional neural network (CNN) is a very important method in deep learning, which solves many complex pattern recognition problems. Fruitful results have been achieved in image recognition, speech recognition, and natural language processing. Compared with traditional neural network, convolutional weight sharing, sparse connection, and pooling operations in convolutional neural network greatly reduce the number of training parameters, reduce size of feature map, simplify network model, and improve training efficiency. Based on convolution operation, pooling operation, softmax classifier, and network optimization algorithm in improved convolutional neural network of LeNet-5, this paper conducts image recognition experiments on handwritten digits and face datasets, respectively. A method combining local binary pattern and convolutional neural network is proposed for face recognition research. Through experiments, it is found that adding LBP image information to improved convolutional neural network of LeNet-5 can improve accuracy of face recognition to 99.8%, which has important theoretical and practical significance.

1. Introduction

An image is a visual form that describes state of objective world or transforms energy into a two-dimensional plane. Image recognition is based on image recognition algorithm, which is a technology for computer to analyze specific types of objects contained in images [1]. Image recognition is used in many fields, such as biomedical pathological diagnosis, military dangerous environment reconnaissance, and intelligent portrait recognition in field of life services. Images contain a lot of useful information for human beings [2]. Effective image recognition is of great significance to progress of whole society.

Image data not only contains information about human beings but also brings huge profits to companies that master image data. The technology giant Google Inc. used data to bring about $54 billion in revenue in the United States in 2009. This makes people see importance of mining information from images. With rapid development of modern industries, image data has exploded and accumulated at an unprecedented speed. How to extract information from images has become a problem worthy of study. With deepening of information mining, more and more algorithms are used to mine information in images [3]. Machine learning is known for its efficient mining ability, adaptive ability, and learning ability. It is an algorithm with excellent performance suitable for image processing and big data. The convolutional neural network algorithm is an excellent deep learning algorithm specially designed to process image data.

2. Related Work

The idea of neural network is to let machine learn way of human thinking to simulate way that humans obtain information from nature to deal with problems. Based on this, scientists put forward artificial neural network theory (artificial neural network for short ANN) [4, 5] proposed back propagation (BP) algorithm of artificial neural network. The

BP algorithm was applied to shallow forward neural network model, and a hidden layer was added to solve XOR gate problem that perceptron could not solve [6]. The computational complexity of optimization problem is reduced, and the algorithm becomes most basic algorithm of neural network. From then on, research and application of neural network began to recover. In the 1860s, concept of convolutional neural networks was proposed. Reference [7] found that visual image of a small area in cat's visual cortex is only processed by one neuron, which is receptive field. Reference [8] proposed that this is first prototype of a convolutional neural network, in which visual system is modeled and can be recognized when objects are displaced or even slightly deformed. The neurocognitive machine proposed by scientists contains two types of neurons, one neuron S-cells extract features to filter convolution kernel of convolutional neural network, and other neuron C-cell is antideformation for convolutional neural network. Activation function and pooling: convolutional neural networks are developed on basis of multilayer perceptrons. Reference [9] proposed to be derived based on an efficient BP training method and first achieved success in field of English handwriting recognition. Convolutional neural network is the first artificial neural network that has been successfully trained in deep learning [10]. Subsequently, various aspects of convolutional neural network have been continuously improved, making it a most potential and successful model. Convolutional neural network is widely used. There are applications in face recognition, pedestrian detection, natural language processing for robot navigation, medicine discovery, disaster climate discovery, and even Go AI programs [11]. At present, there are many research studies on convolutional neural network in world, mainly aiming at improving the structure of convolutional neural network. Domestic research is still in its infancy.

Image recognition is the basis of image classification and detection, and correct image classification results are of great significance to development of computer vision. Image recognition is a research that analyzes image categories by extracting feature information of images. Because image information is very complex, it is particularly important to select effective features [12]. Although algorithms for feature extraction are continuously proposed, traditional algorithms are difficult to meet performance and efficiency requirements of massive images. After more than 50 years of development in image recognition, a large number of excellent machine learning algorithms have emerged [13]. Shallow neural network algorithms such as artificial neural network (ANN), support vector machine model (SVM), Gaussian mixture model (GMM), and conditional random field (CRF) are correct in classifying a series of objects such as fruits, rock formations, and peanuts rate of more than 90%. The shallow neural network also has problems in obtaining good classification [14]. For example, if you need to manually select features, training effect after deepening number of layers is not ideal [15]. Deep learning is a deep network algorithm that automatically learns image features [16]. Deep learning is divided into supervised learning (Supervised Learning) and unsupervised learning (Unsupervised Learning) according to whether there are labels [17].

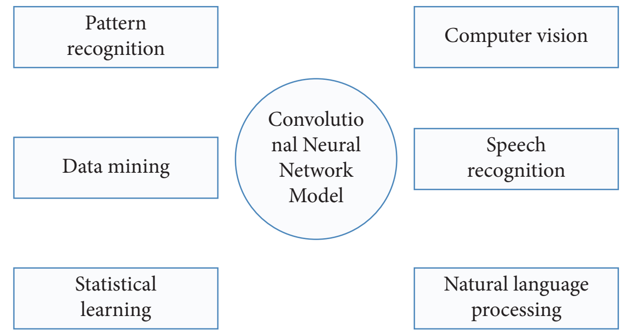

Figure 1: Deep learning application areas.

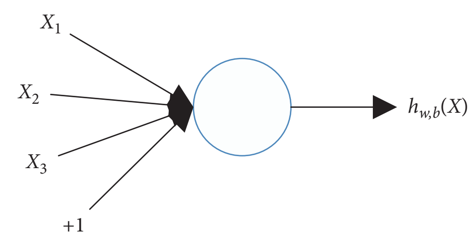

Figure 2: Neuron model.

2.1. Convolutional Neural Network Model. More and more scholars in various countries have joined in the research of machine learning and various high-tech companies. Machine learning is becoming more and more intelligent and has made outstanding achievements in various fields, and its results are continuously applied in practice. Figure 1 shows the application of deep learning in various fields.

Neuron is a basic processing unit of neural network, generally has multiple inputs and one output. The basic structure model is shown in Figure 2.

The convolution operation has two excellent properties: sparse connection, that is, in convolution operation, one input neuron is only connected to corresponding part of output neurons, and one output neuron is only connected to corresponding part of input neurons. Figure 3(a) shows the sparse connection method of convolution, and Figure 3(b) shows the full-connection method. It can be clearly seen that each output neuron is connected to all input neurons in the full-connection method, while in convolution sparse connection method, an output neuron is only connected to corresponding part of input neurons, for example, output neuron s_3 is only connected to input neurons x_2, t_3, and x_4.

Parameter sharing, that is, parameters of each part of convolution operation are shared. Figure 4(a) shows the convolution operation, and Figure 4(b) shows full-connection operation. It can be seen that weight parameters of each connection in full-connection operation are different. Therefore, when the number of input and output neurons is 5, the required number of parameters is 25. In convolution operation, because of the nature of parameter sharing, such as

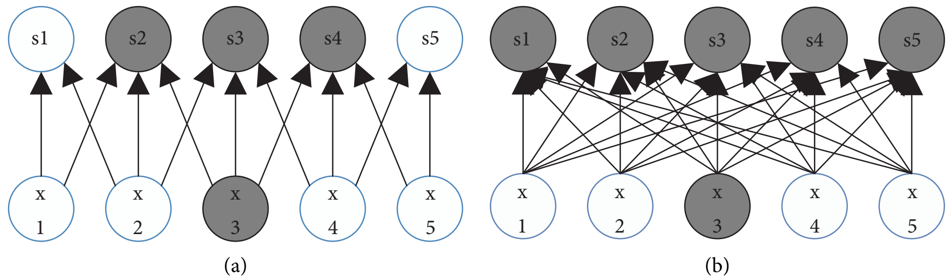

FIGURE 3: Sparse connection and full connection ((a) convolution and (b) full connection).

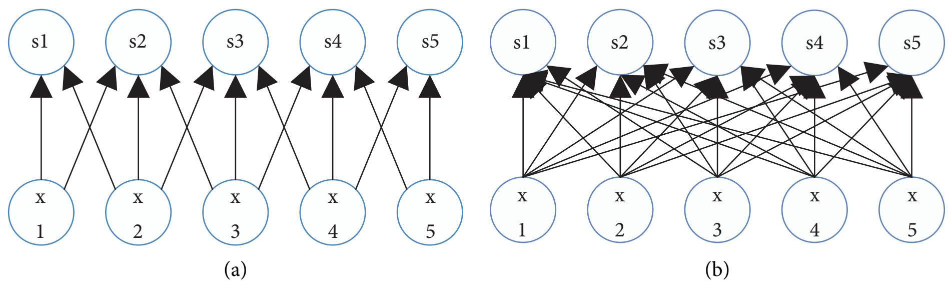

FIGURE 4: Parameter sharing ((a) convolution and (b) full connection).

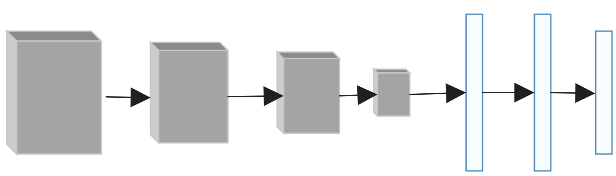

FIGURE 5: Schematic diagram of convolutional neural network node connection.

weight parameters of x and s, connection is same, so when the number of input and output neurons is 5 and size of convolution kernel is 3, the number of parameters required is 3.

The convolutional neural network inputs an image, and when image is only black and white, the image can be abstracted into a two-dimensional matrix in space. When image is color, there are three color channels, and nodes of each layer of neural network are composed of three RGB vectors, which can abstract image into a three-dimensional matrix in space. Figure 5 is a schematic diagram of connection of convolutional neural network nodes. It can be seen from figure that multiple nodes in the upper layer of convolutional neural network are connected to a single node in the lower layer of neural network.

3. Softmax Algorithm

In softmax, what needs to be solved is a multiclass problem (assuming k classification problem), so value range of class label y is k different integer values, and different values represent different classes. For training set $\{(x^{(1)}, y^{(1)}), \ldots, (x^{(m)}, y^{(m)})\}$ with m samples, there are $y^{(i)} \in \{1, 2, \ldots, k\}$, of which $i \in \{1, 2, \ldots, m\}$. Given a sample $(x^{(i)}, y^{(i)})$, we can use hypothesis function to calculate probability value $p(y^{(i)} = j|x^{(i)})$ that sample belongs to each category j, that is, estimate sample $x^{(i)}$ for each category probability of outcome. So, suppose output of function is a k-dimensional numeric vector (the vector element values sum to 1), where i component of vector represents estimated probability value of sample belonging to i class. Suppose function is of the following form:

$$h_\theta\left(x^{(i)}\right) = \begin{bmatrix} p\left(y^{(i)} = 1|x^{(i)}; \theta\right) \\ p\left(y^{(i)} = 2|x^{(i)}; \theta\right) \\ \vdots \\ p\left(y^{(i)} = k|x^{(i)}; \theta\right) \end{bmatrix} = \frac{1}{\sum_{j=1}^{k} e^{\theta_j^T x^{(i)}}} \begin{bmatrix} e^{\theta_1^T x^{(i)}} \\ e^{\theta_2^T x^{(i)}} \\ \vdots \\ e^{\theta_k^T x^{(i)}} \end{bmatrix}, \quad (1)$$

where $\theta_1, \theta_2, \ldots, \theta_k \in R^{n+1}$ is a model parameter. If a $k \times (n+1)$ matrix is used to represent parameter θ, there are following: $\theta = \begin{bmatrix} \theta_1^T \\ \theta_2^T \\ \vdots \\ \theta_k^T \end{bmatrix}$.

The cost function of softmax algorithm is as follows:

$$J(\theta) = -\frac{1}{m}\left[\sum_{i=1}^{m}\sum_{j=1}^{k} 1\left\{y^{(i)} = j\right\} \log \frac{e^{\theta_j^T x^{(i)}}}{\sum_{l=1}^{k} e^{\theta_l^T x^{(i)}}}\right], \quad (2)$$

where $1\{\cdot\}$ is an indicative function. For minimization problem of $J(\theta)$, there is no closed-form solution, and generally an iterative optimization algorithm (such as gradient descent method) is used. After derivation, gradient formula is as follows:

$$\nabla_{\theta_j} J(\theta) = -\frac{1}{m}\sum_{i=1}^{m}\left[x^{(i)}\left(1\left\{y^{(i)} = j\right\} - p\left(y^{(i)} = j|x^{(i)}; \theta\right)\right)\right]. \quad (3)$$

In the gradient descent method, each iteration needs to be updated as follows: $\theta_j = \theta_j - \alpha\nabla_\theta J(\theta)$, $(j = 1, \ldots, k)$.

Usually, softmax cost function will add weight attenuation term [18], which can solve numerical problem caused by parameter redundancy of softmax. The cost function with weighted attenuation term is as follows:

$$J(\theta) = -\frac{1}{m}\left[\sum_{i=1}^{m}\sum_{j=1}^{k} 1\left\{y^{(i)} = j\right\}\log\frac{e^{\theta_j^T x^{(i)}}}{\sum_{l=1}^{k} e^{\theta_l^T x^{(i)}}}\right] + \frac{\lambda}{2}\sum_{i=1}^{k}\sum_{j=1}^{n}\theta_{ij}^2, \quad (4)$$

where $\lambda > 0$ is the weight attenuation coefficient. Its gradient is calculated as follows:

$$\nabla_{\theta_j} J(\theta) = -\frac{1}{m}\sum_{i=1}^{m}\left[x^{(i)}\left(1\left\{y^{(i)} = j\right\} - p\left(y^{(i)} = j \mid x^{(i)};\theta\right)\right)\right] + \lambda\theta_j. \quad (5)$$

Suppose a labeled sample set $\{(x^{(1)}, y^{(1)}), \ldots, (x^{(m)}, y^{(m)})\}$ contains M samples. The following equation describes the use of batch gradient descent method to solve neural network model. For a single sample (x, y), cost function is given as follows:

$$J(W, b; x, y) = \frac{1}{2}\left\|h_{W,b}(x) - y\right\|^2. \quad (6)$$

Then, cost function of whole m samples is defined as follows:

$$J(W,b) = \left[\frac{1}{m}\sum_{i=1}^{m} J\left(W,b;x^{(i)},y^{(i)}\right)\right] + \frac{\lambda}{2}\sum_{l}\sum_{i}\sum_{j}\left(W_{ji}^{(l)}\right)^2$$
$$= \left[\frac{1}{m}\sum_{i=1}^{m}\frac{1}{2}\left\|h_{W,b}\left(x^{(i)}\right) - y^{(i)}\right\|^2\right] + \frac{\lambda}{2}\sum_{l}\sum_{i}\sum_{j}\left(W_{ji}^{(l)}\right)^2. \quad (7)$$

The gradient descent method updates parameters w and B according to the following formula:

$$W_{ij}^{(l)} = W_{ij}^{(l)} - \alpha\frac{\partial}{\partial W_{ij}^{(l)}} J(W, b),$$
$$b_i^{(l)} = b_i^{(l)} - \alpha\frac{\partial}{\partial b_i^{(l)}} J(W, b), \quad (8)$$

where α is the learning rate, and the most critical step is to calculate partial derivative. Let's introduce effective calculation method of partial derivative: back-propagation algorithm.

4. Results

We trained five different convolutional neural networks, and relationship between loss value and the number of iterations during training process is shown in Figure 6. In order to clearly see difference of each curve, we discard selection process of first 1000 times because their loss value is relatively large. The figure depicts training process from 1000 to 10000 epochs. It can be seen from the figure that when the number of generations reaches 3000, the loss value of network training has achieved a better effect. Among all networks, LeNet-E network can achieve lowest loss value, indicating that in case of fitting, parameters learned by its network structure can better express image features, that is, deeper network structure can better fit data features. It can be found from the figure that network loss value of LeNet-D and LeNet-E networks is very unstable during training. It shows that although dropout strategy helps to improve recognition rate of network, it affects stability of network training.

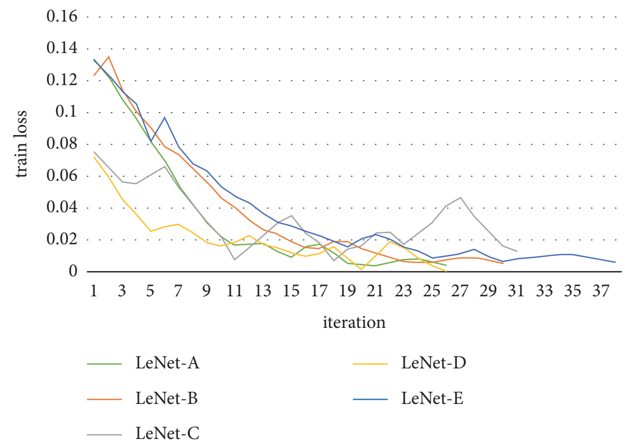

Figure 6: Training loss value vs. number of iterations.

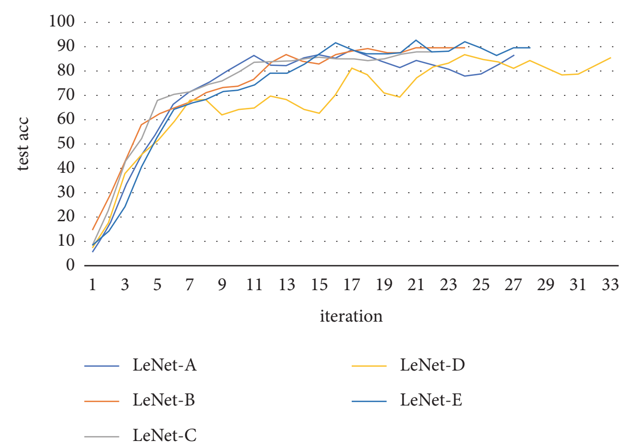

Figure 7: Test accuracy vs. iterations.

We also plot the relationship between test accuracy and number of iterations, as shown in Figure 7. It can be found that LeNet-D and LeNet-E networks have higher recognition rates than other three networks, indicating that the depth of network and dropout strategy have a greater impact on recognition rate. From the curve of LeNet-A, it can be found that with the increase of number of generations, recognition accuracy has a downward trend, which may be overfitting. When the width of network is not enough to represent characteristics of input data, the recognition rate of test set will decrease with the increase of number of network selections.

5. Conclusion

Convolutional neural network is a very important feature learning model in machine learning. It has strong representation ability in image recognition and has been widely used in the field of pattern recognition. This paper conducts in-depth research on convolutional neural networks, introduces in detail network structure of convolutional neural networks and specific operations of convolution and pooling, and introduces back-propagation algorithm used in network optimization. Based on LetNet-5 network model, five different network structures are constructed for handwritten digit recognition. The effects of network depth, number of hidden layer convolution kernels, and feature dimension on recognition accuracy are tested. The experimental results show that deeper and wider network structure is more conducive to improvement of recognition rate, larger feature dimension, and better recognition rate. Finally, a face recognition method based on local binary pattern and convolutional neural network is proposed, which uses stitching of original input image and local binary pattern image as the input of convolutional neural network, so that convolutional network not only learns the global features of face but also local structural features of face. Through experiments, it is found that added LBP information helps to further improve face recognition rate.

Data Availability

The experimental data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declared that they have no conflicts of interest regarding this work.

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Research Article

Optimal Management of Computer Network Security in the Era of Big Data

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As the "new oil of the future," big data is becoming the leading industry of the new economy, the core asset of the country and enterprises, the "new blue ocean" to be pursued, and the national strategy to be developed by all countries. The development of big data and its related technology supports and promotes a new round of technological innovation, making a new generation of information security technology reform and innovation, bringing opportunities and challenges to optimize, and consolidating national information security. In the era of big data, what kind of challenges and impacts will information security face? and is it crucial to explore the response strategies? At present, China has risen to become the world's largest number of Internet users and the largest number of people using smartphones, but because China's information security is the initial stage, involving information security, especially national information security laws and regulations are not much, the national social supervision and monitoring mechanisms are not much, the application level of science and technology content is relatively backward, the core technology has a patent technology not much, resulting in the flood of network data nowadays. Therefore, the underground illegal "data industry chain" activities are rampant. Therefore, this paper proposes a security-aware model based on the combination of distributed data analysis technology and data features. The model uses data features to dynamically generate a library of situational anomalies, effectively solving the problem of analyzing and processing rapidly and dynamically generated data streams, increasing the detection rate to more than 98%, effectively reducing the possibility of false detection, and having good results on large-scale datasets.

1. Introduction

In the twenty-first century, new technologies such as the Internet, the Internet of things, and cloud computing are developing rapidly, and the amount of data generated by modern society is growing at an unprecedented rate; we are now living in the age of big data [1]. The power of data allows people to make decisions directly without thinking about the causes, which is why big data has caused major disruption in the world [2]. In 2011, a study by the McKinsey Global Institute found that data are gradually becoming an important factor of production and is permeating all McKinsey Global Institute found in 2011 that data are becoming an important factor of production and that big data is permeating all industries and businesses, that the use of big data heralds a new wave of productivity growth and consumer surpluses [3], and that "big data" is "the next frontier for innovation, competition, and productivity improvement" [4].

In the late twentieth century, Hollywood actor King Carey starred in the surrealist film The Truman Show, in which the main character Truman is trapped from birth in a giant studio full of cameras while people around the world watch his reality show[5]. In the age of big data, it has long been unnecessary to monitor your behavior through cameras, the products you searched for on Taobao, the videos you watched on Youku, the food you ordered on Meituan, and so on. Even if you are not connected to the web, the server records all transactions made via computers, tablets, mobile phones or smart wearables. Your shopping habits, your heart rate, or your credit rating become part of big data [6]. Analyzing big data allows us to make many smart decisions: for example, whether razors and nappies sell better together or whether a typhoon boosts sales of vanilla-flavored ice cream, etc., but the security of our data is invisibly compromised [7].

China is currently in a period of rapid development, the external and internal environment is changing rapidly, and the issue of information security is attracting a lot of public attention [8]. In the era of big data, information security in the new era is not only threatened by attacks from cyber hackers but also by low-security awareness among citizens, a backward security education system, etc. The reasons for this are many and include various factors such as the government, society, universities, and the public itself [9]. The increasing number of phone scams, pornographic photo documents, data leaks, portal server crashes, and other incidents in recent years have revealed the low level of security awareness in China and the lack of skills to cope with the consequences of security incidents and highlighted the lack of adequate security training for Chinese university students. Information technology in China started to develop late, and since the beginning of the new century, information technology in China has been developing very rapidly. While the relevant regulations are not stable, the security assurance system is not perfect, and the lack of security awareness and the backwardness of information technology have together become the limiting factors affecting information security in China [10].

Therefore, it is necessary to analyze the current situation of information security education in China, identify the reasons for its insufficiency, and propose countermeasures for improvement in order to improve the level of information security protection in China and ensure the security of personal data, property, privacy, and other aspects of the public. The security and stability of universities and society can only be ensured if the security of public information is guaranteed. Only when the environment is stable and its security is guaranteed can citizens focus on their work and studies and contribute to the country and society.

People have always looked for ways to make science and technology serve people better, and in the age of big data, this proposal that people have fought for has come back to us. While we are reaping the benefits of big data, we are also facing a hitherto unknown impact on information security. With frequent media coverage of information security incidents and increasingly complex threats to information security, systematic and effective information security education is becoming increasingly important. The rapid development of the masses' awareness and skills in information security protection is also an issue that information security education in China needs to address urgently [11].

These are the best of times

but also the worst of times.

2. Related Work

Big data has been a hot research topic in recent years, both at home and abroad, but there is no single definition of big data. According to Wikipedia, big data is information so vast that it cannot be collected, managed, processed and organized into valid information in a short time by using conventional software tools [12]. The McKinsey Global Institute, in its article, "Big Data: the next frontier for innovation, competition and productivity," defines big data as data that are beyond the ability of traditional database software tools to collect, store, manage and analyze [13]. "According to "Steve" (IBM's "digital gatekeeper"), the era of networked big data is characterized by the full integration of the triple world of people, machines and things, unprecedented growth in the amount of data, and the sheer complexity of data patterns—the hallmarks of the era of networked big data [14]. McAfee, the world's largest professional security technology company, views big data as an intelligent activity aimed at turning big data insights into business advantage and a prerequisite for analytics [15]. Schoenberg's definition is more concise and clear: big data is a large amount of data [16].

Cybersecurity is a 5 v characteristic of volume, variety, veracity, velocity and, value [17]. The study [18] of network data is characterized by large scale, burstiness, and suddenness, which makes it difficult for researchers to assess and predict its changing state. The study [19] can only make good use of data if the data flow is controlled. The study [20] proposed a requirements analysis model for data quality that considered many candidate metrics and selected the required metrics according to the needs. The study [21] addressed the issues of how to reduce storage costs, fully utilize computational power, improve throughput, and support distributed nonlinear selection algorithm optimization. The study [22] pointed out that data analysis tends to use fewer fields, so the column storage rate is high, and popular databases in the industry (Bigtable, HBase) are implemented based on column storage. The study [23] proposed a hybrid row-column data storage structure that solves the problem of fast loading, querying, and efficient storage of data. Research [24] develops an advanced, highly scalable, petabyte-scale distributed data storage framework while optimizing the distributed storage structure for data layout to reduce cost and improve efficiency, thus realizing a highly available data distributed storage system. Researchers [25] use computing technology to mine and analyze data, discover the knowledge contained in it, and study the environment, change patterns, and development trends, which are the main ways to explore the deep value of data and realize computable behavior. With the advent of the data era, the complexity and scale of data have grown exponentially, leading to serious bottlenecks in the practicality and performance of traditional mining and computing methods. As a result, data processing techniques have become an important research topic. Divide and conquer strategies are often used to process data, i.e., decompose the data problem into smaller subproblems and combine the solutions of the subproblems to obtain the final solution [26].

In conclusion, data analysis is the core of data processing, and data-based security-awareness research uses data analysis as an effective method for sensing various anomalous behaviors in networks. Currently, there are some problems with security-aware models, such as low accuracy of security-aware results, poor prediction accuracy, coarse

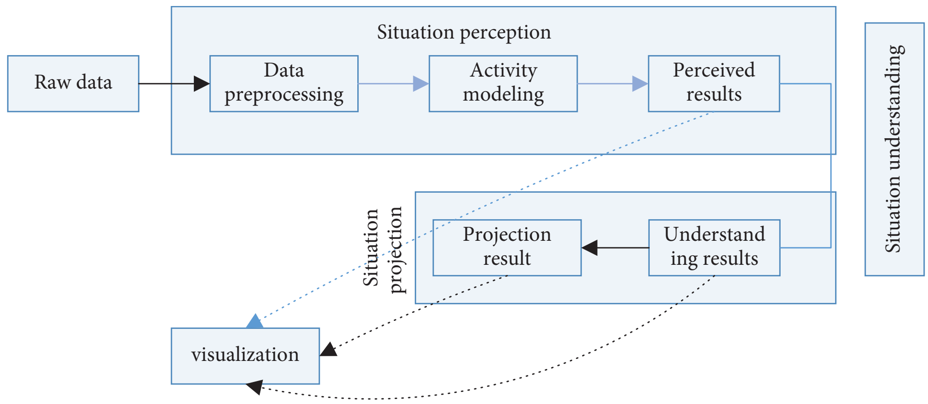

Figure 1: Security situation awareness model.

evaluation granularity, and low perception performance and efficiency. Therefore, our proposed model integrates data preprocessing in perception and performs association rule analysis based on datasets in the situation understanding process. As a result, the performance and efficiency of the model are improved in the security situational awareness process.

3. Network Security Architecture

Network security situational awareness refers to extracting relevant elements in the environment within a certain space and time range, understanding these elements and predicting their possible impacts. Security situational awareness is the cognitive process of system security status. It is generally believed that the first stage is security situation awareness; the second stage is security situation understanding; and the third stage is security situation projection. (Figure 1.

Figure 2 shows that the first stage of situational awareness is carried out at the root node at the top; then, the results of situational awareness are judged to enter the second stage of situational understanding; finally, in the third layer, the situation projection of the third stage is carried out, and the final result of the security situation is obtained.

Figure 3shows that situational awareness and situational understanding are carried out in the peripheral module; then, the results of situational understanding are transmitted to the core module for situational projection.

4. Improved Random Forest Correlation Algorithm

The introduction of decision trees is in the following section, through the decision tree algorithm, to further understand the random forest algorithm.

The calculation formula of entropy is shown in formula (1):

$$E(Y) = \sum_{t=1}^{N} -\frac{Y_t}{\mathrm{Sum}(Y)}\log_2\left(\frac{Y_t}{\mathrm{Sum}(Y)}\right)\lim_{x\longrightarrow\infty}. \quad (1)$$

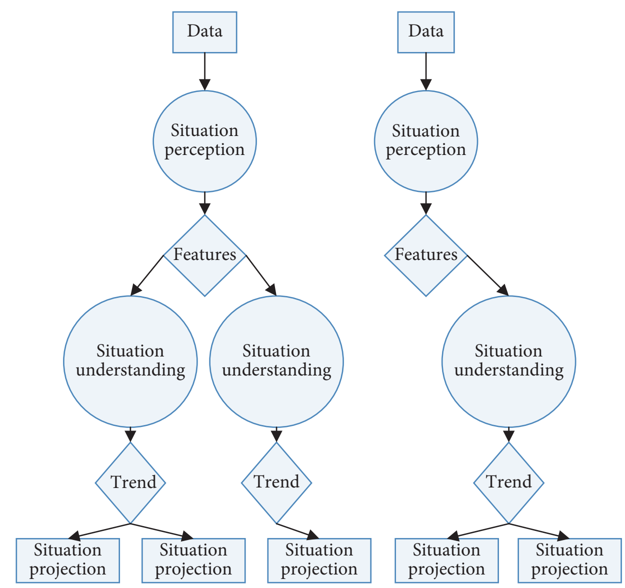

Figure 2: security situation awareness model based on a random forest.

Among them, Y_t represents T rd value of category Y, Sum(Y) represents the total number of records of category Y, and N represents a total of Y values of category N.

Next, we find gain of attribute x. Assuming that attribute X can take a total of M values, value of X_j for one of attributes of x is shown in formula (2):

$$E(X_j) = \sum_{t=1}^{N} -\frac{Y_t}{\mathrm{Sum}(X_j)}\log_2\left(\frac{Y_t}{\mathrm{Sum}(X_j)}\right), \quad (2)$$

where Sum(X_j) is number of records containing X_j in data set and Y_t is number of records classified as Sum(X_j); gain of attribute Y_t is shown in the following formula (3):

$$E(X) = \sum E(X_j) = \sum_{j=1}^{M}\sum_{t=1}^{N} -\frac{Y}{\mathrm{Sum}(X_j)}\log_2\left(\frac{Y}{\mathrm{Sum}(X_j)}\right). \quad (3)$$

Bayes' theorem is shown in formula (4):

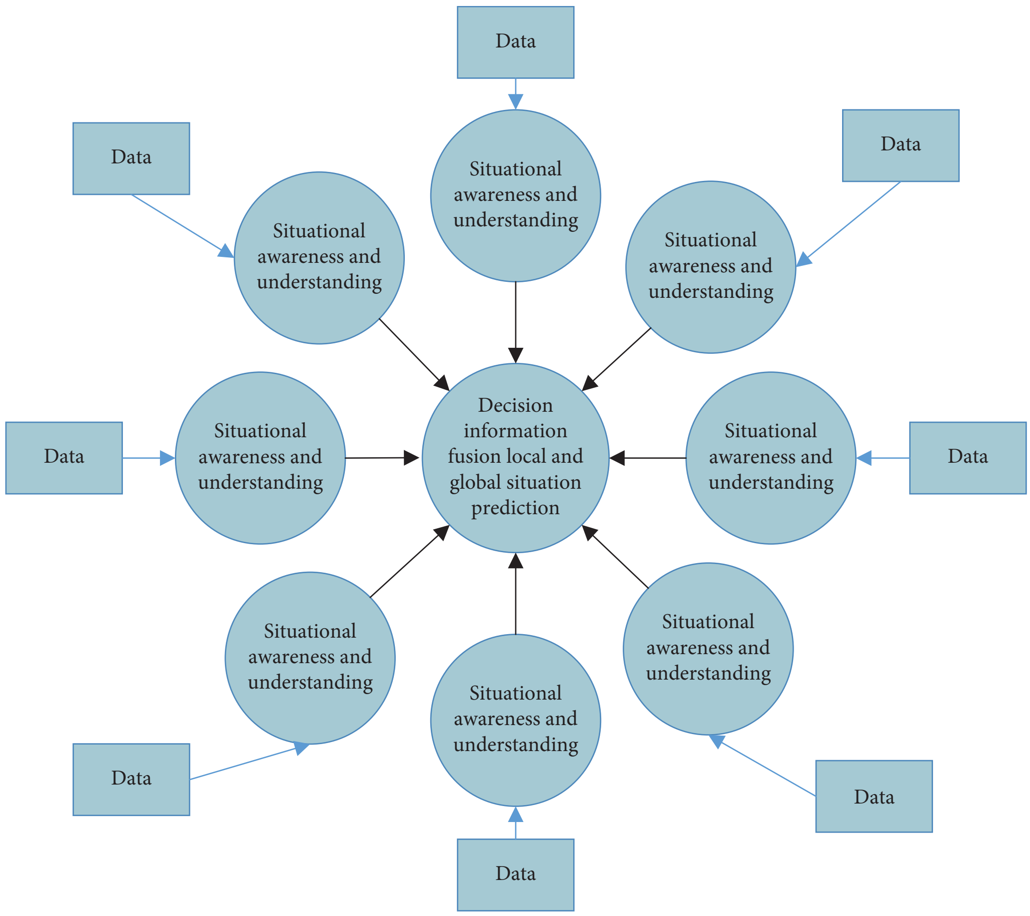

Figure 3: security situation awareness model based on a star structure.

$$p(H|x) = \frac{p(x|H)p(H)}{p(x)}. \quad (4)$$

If number of categories in a given dataset is M, the Naive Bayes algorithm can be used to predict whether a given value belongs to category with largest posterior probability, that is, when x is predicted to belong to a certain class C_t by the Naive Bayes classification algorithm, if and only if.

$$p(C_t|x) > p\left(C_j|x\right) 1 \le j \le m, \quad j \ne t. \quad (5)$$

If $p(C_t|x)$ is maximized at this time, then category C_t with largest $p(C_t|x)$ is called maximum a posteriori hypothesis. According to Bayes' theorem,

$$p(C_t|x) = \frac{p(x|C_t)p(C_t)}{p(x)}. \quad (6)$$

For all categories $p(x)$ are equal, and only largest $p(x|C_t)p(C_t)$ can be calculated. When predicting classified samples x of unknown classes, by estimating value of $p(x|C_t)p(C_t)$ corresponding to each class C_t, then sample x belongs to class C_t if and only if.

$$p(x|C_t) > p(C_t)\frac{1s}{s_m}, \quad j = i. \quad (7)$$

Therefore, Bayesian classification methods are mostly used to classify scenes.

The algorithm compresses data into memory in process of building a book, so that the data set only need to be scanned twice, which greatly reduces the overhead of $I/0$, so it has great advantages when dealing with large data.

In order to better describe the whole process, the following symbols are defined, S_{mtn} represents support degree.

$$S = \frac{\operatorname{count}(x \cup y \cup z)}{n}. \quad (8)$$

Formula (8) is the calculation formula of support degree, in which $\operatorname{count}(x \cup y \cup z)$ represents number of data records containing the attribute of x, y, z. Suppose there are 5 data records, each containing the following attributes:

$$\begin{aligned} R_1 &= \{a, c, d, f, g, t, m\}, \\ R_2 &= \{a, b, c, f, l, m, o\}, \\ R_3 &= \{b, f, h, j, o\}, \\ R_4 &= \{b, c, k, s, p\}, \\ R_5 &= \{a, f, c, e, l, p, m, n\}. \end{aligned} \quad (9)$$

Suppose $S_{mtn} = 3$. The process of mining association rules for the aboveentioned data records is as follows:

(1) Scan data for the first time and then generate a 1-dimensional frequent itemset as follows:

$$\begin{aligned} R_1 &= \{c, f, a, m, p\}, \\ R_2 &= \{c, f, a, b, m\}, \\ R_3 &= \{f, b\}, \\ R_4 &= \{c, b, p\}, \\ R_5 &= \{c, f, a, m, p\}. \end{aligned} \quad (10)$$

(2) Using 1-dimensional frequent item sets to generate FP-tree, generated complete FP-tree

(3) Mining association rules in generated FP-tree and obtain frequent item sets formed by each attribute that meets minimum support threshold. Since some of generated frequent item sets contain redundant repetitions, simple redundancy removal is performed

The final data record after dimensionality reduction is as follows:

$$\begin{aligned} R_1 &= \{a, c, f, m\}, \\ R_2 &= \{a, c, f, m\}, \\ R_3 &= \{\varnothing\}, \\ R_4 &= \{c, p\}, \\ R_5 &= \{a, f, c, m\}. \end{aligned} \quad (11)$$

In order to better describe the data matching process based on the dynamic time warping algorithm, the following symbols are defined for further explanation. Assuming the reference template is $R = \{r_1, r_2, r_3, r_4, r_5, r_6\}$, r_m represents the mean of 6 attributes and r_6 represents their standard deviation. Likewise, the test template is $T = \{t_1, t_2, t_3, t_4\}$, with t_m representing the mean of 4 attributes and t_3 representing their standard deviation.

The specific process of template matching is as follows:

$$\begin{aligned} r_i^* &= \frac{r_t - r_m}{r_s} i \in, \\ t_j^* &= \frac{t_j - t_m}{t_s} j \in . \end{aligned} \quad (12)$$

5. Results

Included in the CAIDA dataset is anonymized passively monitored traffic from the University of Chicago's Equinix high-speed Internet backbone. The experimental results are shown in Figure 4.

The same experimental environment was used with the same data set and the same four algorithms included in the model. The results of the experiments are shown in Figure 5. In the first method, only the distributed parallel clustering algorithm was used to analyze the experimental data; in the second method, the data were clustered after adding a

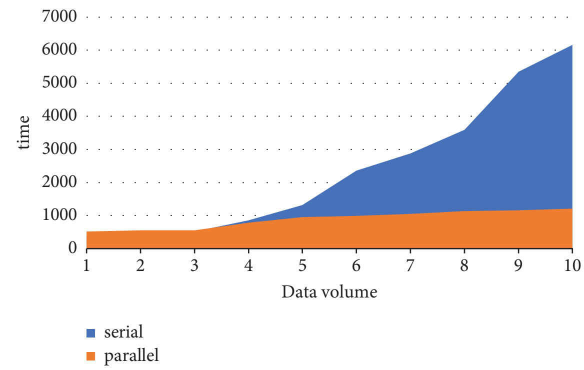

Figure 4: Comparison of parallel and serial time.

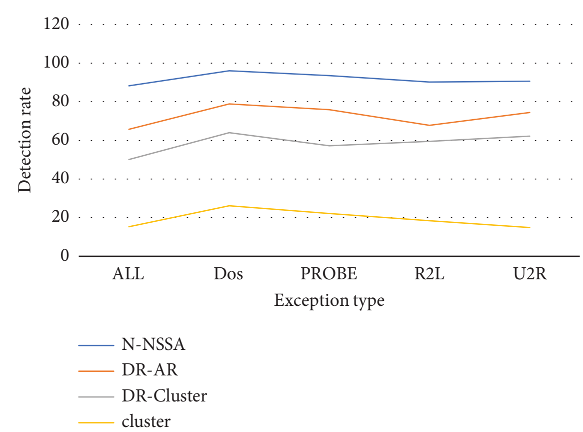

Figure 5: Comparison of detection rates of four methods.

dimensionality reduction operation to the data. In this way, the detection rate increased significantly. Dimensionality reduction of the data is very effective. Therefore, the third method uses a dataset with the same dimensionality reduction and analyses the dataset by association rules. The fourth method is a security situation recognition model by using neural networks. First, the data are cleaned and analyzed for situational awareness. The neural system is used to correct the results of the preliminary analysis and to obtain the final results.

In order to verify the acceleration of distributed parallelization model, 1–5 nodes were selected as the experimental cluster in this experiment. The largest data in the "parallel and serial time comparison" experiment were selected as the test data set.

Figure 6 shows the number of nodes continues to increase, and the speedup curve of the model also increases. However, when the number of nodes is 3 to 4, the growth rate of the curve becomes slower. This is because the increasing number of nodes increases the cost of communicating with each other. Communication between nodes will consume certain resources and time. It can be seen from experiments that the security situational awareness model based on neural performs well in terms of accuracy, false detection rate, time, and efficiency.

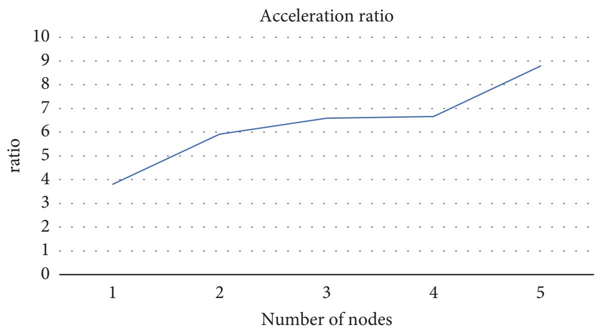

Figure 6: Acceleration ratio of different nodes.

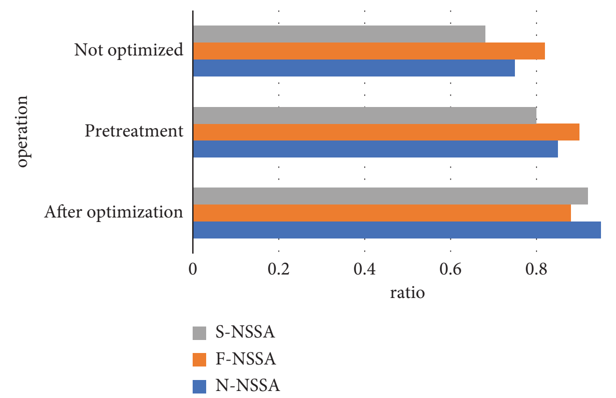

Figure 7: Comparison of detection rates of three models.

In Figure 7, three models proposed in security situational awareness have been greatly improved compared with experiments in the first part, and accuracy rates are all above 90%. However, different from the first two parts, in this part of the experiment, the detection rate of neural and star structure surpassed the detection rate of the forest model. This is because original data are effectively preprocessed after the first stage of situational awareness, so the neural model and star structure model overcome sensitivity to shortcomings of the data set, so the detection rate is higher.

In Figure 8, the second indicator is false detection rate (That is, abnormal data are incorrectly detected. The proportion of data judged to be normal.). From the data in the figure, it is not difficult to find that the detection rate of the three models is above 90%, and each abnormal type can be detected, and the false detection rate is below 10%. Therefore, the three models proposed are used for security situational awareness performance is better.

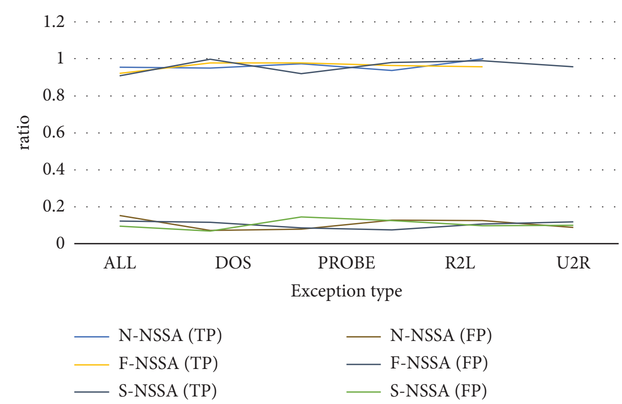

Figure 8: Comparison of detection rate and false detection rate of three models.

From Figure 9, we can obtain the conclusion that when dealing with datasets of the same size. This conclusion is justified in the third part of the first set of experiments. Due to model characteristics of the star structure, although peripheral modules are processed in parallel by many nodes at the same time, all data in the situation projection stage are processed by the central core module, which leads to performance in terms of time efficiency. Not as good as the forest model. Each node performs the tree-building operation of part of the data, thereby forming a forest model of the entire security situation. Finally, the final security situation is judged by the mode of the result of each tree, which not only avoids one-sidedness but also makes the processing of data very efficient due to such structural characteristics.

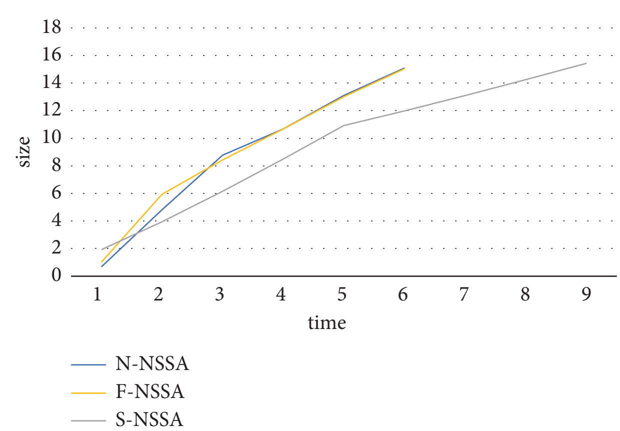

Figure 9: Comparison of different data scales.

As the number of nodes increases gradually, the processing time between models is compared. In Figure 10, the scale of the cluster continues to expand, and the number of nodes participating in parallel operations gradually increases, but time consumption for data communication and transmission between nodes will also increase. The node acceleration ratio of the neural model is relatively low because communication between each node is relatively large during the error adjustment learning process of the neural network. When the scale of the cluster expands, the number of nodes processing data in parallel also increases, which makes improvement of processing efficiency not obvious when the number of nodes increases. In this part of the experiments, node speedup ratios of the forest model and star structure are comparable. As mentioned in the previous part, due to the structural characteristics of the forest model itself, in the whole process of security situation awareness, each node is used for data processing, such as the construction of a decision tree independently and data transmission between each other is relatively small, so the acceleration ratio is very good. The star structure is the same

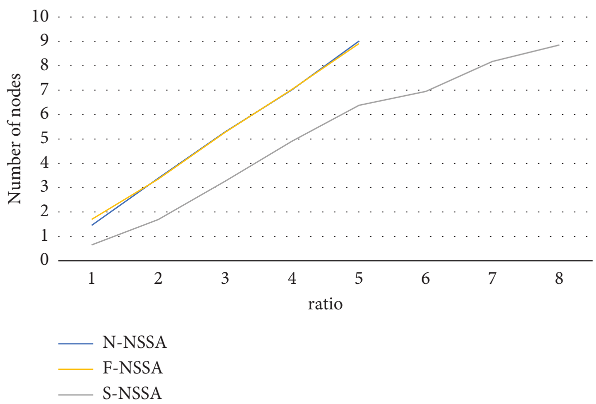

Figure 10: Acceleration ratio of different nodes.

as the forest model in the first two stages of security situational awareness. Each node processes data independently, and the parallel effect is good. Only in the third stage will there be data transmission between nodes.

Figure 11 shows the rising curve is the acceleration ratio curve, and the falling curve is the scale ratio curve. Both curves are approximately linear. The experimental results show that the model can achieve a good speedup ratio and scale ratio in a distributed cluster.

6. Countermeasures and Proposals to Strengthen Network Security Governance in the Era of Big Data

6.1. Improving Legislation, Systems, and Legal Awareness of Network Security. The law is a system of mandatory specifications; it is an institutional guarantee for network security management. In the absence of law, even the most advanced technologies and management tools are difficult to manage really well. Laws and regulations related to network security clearly warn all people in different ways about what behavior is unacceptable and what is allowed online. Although the law is a prevention tool and an enforcement tool, the reason for network security is to create the strongest and most reliable line of defense.

6.1.1. Effective Laws and Regulations Related to Network Security Improve Data Management. From the first "Regulations for the Protection of Computer Information System Security" adopted and enacted in 1994 to the first major network security law, the "Network Security Law of the People's Republic of China" adopted and enacted in 2017, the government has paid sufficient attention and firm support to network security management in terms of policies and regulations.

However, the development of the Internet is inexorable, and any technological breakthrough may lead to radical changes. Legislation, only steady and over time to master the dynamics and direction of the development of the Internet, insisting on the work of Internet security management at the level of legal support, timely and effective for the emerging things, to standardize the management system and gradually diversify the data—the scope of the network industry lifeline management system, so that only in this way can we carefully ensure the healthy, orderly, and safe development of Kit's network industry.

6.1.2. Raising Public Awareness and Promoting Network Security Laws and Regulations. Although the network provides people with many conveniences, it also brings some network security issues. In order to ensure the network security of every citizen, it is necessary to raise legal awareness, network security awareness, master basic protection skills to prevent Internet fraud and theft, improve the quality of civilized Internet access, and consciously regulate lawful Internet behavior. While each can work well on their own, they can come together in a strong united force for network security.

Since 2014, public safety agencies across the country have held annual on-site promotional events in September, "National Network Security Awareness Week—Rule of Law Day," to effectively raise everyone's awareness of safe Internet use. The Internet Security Department of Taiyuan Public Security Bureau also organized large-scale promotional activities during the annual Network Security Publicity Week and gradually developed from the May Day market in different areas of the city, various mass convergence of legal advertising, antifraud advertising, answering questions, and solving problems.

6.1.3. Establishing a Data Resource Security Protection Model Suitable for Taiyuan. At present, China's big data industry is mainly concentrated in developed regions such as North, Guangzhou, and Shenzhen, and many famous enterprises such as Sina, Baidu, 360 and Tencent have brought top scientific and technological talents to these regions, making these regions leaders in the big data industry. In addition, the southwestern circle of the big data industry, centered in Guizhou, has been studied and established as a regulatory policy system conducive to promoting big data innovation and development and actively introduced big data-related key enterprises and talents, which has led to significant development and gradually created a "Chinese big data center."

In the traditional region, Shanxi is disadvantaged due to regional constraints, transportation, climate, and other factors; since Shanxi is also in an important period of transformation and development, the demonstration zone of comprehensive reform is also located in Taiyuan. I believe that Taiyuan should increase economic investment in big data, actively introduce multisector talents, seek to seize development opportunities, continue to carry out research and development, achieve technical and economic development, and realize the development of the industry.

6.2. Strict Regulation of Internet-Related Crimes and Cleaning Up the Network Environment. General Secretary Xi Jinping attaches great importance to work on network security, stressing that "cyberspace is the common intellectual home

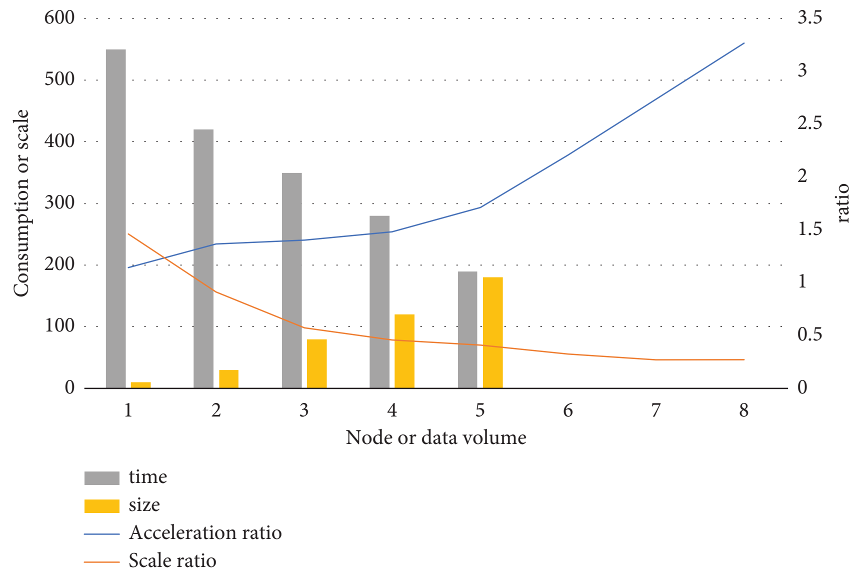

Figure 11: Acceleration ratio and scale ratio.

of hundreds of millions of people," which places specific requirements on public security organs at all levels to strictly manage network security and crack down on illegal and criminal activities using it. Public security institutions, especially network security departments, should keep in mind their purpose to serve citizens wholeheartedly and depart from their responsibilities and actions to implement a mechanism for the rapid resolution of Internet-related cases and incidents to create a safe and transparent network environment for citizens.

6.2.1. Speeding Up the Process and Efficiency of Security Management Work and Timely Follow-Up and Supplement Relevant Measures. Due to the regional mandate of public security authorities, many Internet cases are handled in different regions, requiring cooperation between public security authorities in different locations. In order to speed up the process of network security management and improve the effectiveness of network security management, it is necessary to strengthen interconnection mechanisms among regional public security authorities, especially in the field of network security. Regional public security agencies with an advantage in the "big data" field should share data resources to help fight and punish network attacks, while agencies in regions that are relatively behind should strengthen the capabilities of their personnel in the investigation, prevention and control, detection and surveillance, etc. Big Data" will only be available when talent and data are combined. Only a combination of talent and data can serve as "big data" in this domain.

National network security should have the idea of "one chess piece" and resolutely break the regional barriers that can set the Ministry of Public Security, the Provincial Public Security Bureau as the main battlefield for grabbing and the Municipal Public Security Bureau as the main battlefield for the network security situation, and perform more "cleaning the network," "fighting pornography and illegal," etc. More special operations for network security, such as "cleaning up the network," "fighting pornography and illegal activities," etc., should be implemented, training teams based on real-world operations, drawing vitality from experience and lessons learned, and leveraging the advantages of network security information resources to fight cybercrime and protect network security as protection as a powerful force in the fight against cybercrime and in the protection of network security.

6.2.2. Maximizing the Use of Big Data Resources to Develop and Implementing Proactive Network Security Management. "In order to fully leverage big data, we must first look at the weaknesses of network security management itself, starting with ourselves.

Given the difficulty of managing network security, managing network access rights, strengthening data encryption, and hardening terminals while not being lost as effective means of protecting data security, these are things that cannot be carried out once and for all or given the evolution of "big data." Therefore, by fully utilizing the resource of "big data," implementing and executing future-oriented network security management, improving the technical level of network security administrators, checking and filling time gaps, and updating firmware, etc., the network security management must be smoothly implemented to overcome attacks on the network.

6.2.3. Improving the Early Warning Function of Big Data and the Importance of Decision-Making. So-called "big data" is not big data but data analysis based on big data with strong predictive capabilities. The already mentioned "high school girl pregnancy prediction" is just one small application of "big data.

When Internet-related incidents and accidents occur frequently, it is necessary to use big data's early warning capabilities to prepare a response, not only to monitor and detect incidents and accidents after they occur but also to alert criminals, identify possible criminal activities in advance, and eliminate crime in its cradle.

6.3. Strengthening Software and Hardware in the Network Security Management Sector. "Without good 'weapons' in the age of big data, it is certainly impossible to win the 'battle' of network security management. I believe that the software and hardware of network security management departments should be strengthened on the following three fronts.

6.3.1. Use of High-Precision Hardware and Increased Investment in Technology. With "big data" in the total number of ZBs and an average annual growth rate of more than 25%, conventional electronic equipment is unlikely to perform the important tasks of security management and data analyses, so there is a need to invest vigorously in research and development. Big data is a strategic resource that concerns the rights and interests of individual citizens and national security and must be fully protected. Technologies and equipment in the research and development phase must be fully tested in both real-world and laboratory simulation trials.

6.3.2. Data Discovery, Removal of Data Barriers, and Data Sharing. Data are considered a resource and a wealth, but they should never be private property. If existing data regions and industry barriers are reasonable in terms of data security and protecting commercial interests, the future trend should be toward data sharing and collaborative development.

I think the priority should be to remove barriers in two directions. The first is the direction of national security, and people's lives should be coordinated, resources should be allocated rationally, all data should be analyzed together, and the Chinese system should be better in all aspects so that it contributes more to the direction of people. Second, the direction of combat and punishment should also be the aggregation of data, development and sharing, in the spirit of the "one defeat" idea, to achieve the maintenance of national security.

6.3.3. Intensifying Efforts to Train Big Data Professionals. In China, network security, big data pools, and other areas of talent are relatively scarce. In the face of the urgent demands of the big data era, we must put more effort into cultivating big data professionals. Talent is an important embodiment of national strength, and the lack of a talent pool is a weakness. The global state of big data is currently losing momentum, and we need to pick up the pace to avoid being left behind.

I think we can improve our big data talent pool in three ways. First, the state should add professional training programs in network security, big data, and other related fields to human resources education, especially at the undergraduate and graduate levels, based on sustainable, long-term training of professionals. Second, regardless of the model, we combine the reality of talent recruitment and improve the ability of the elite talent in society to develop, analyze, and use big data. Third, from the real work, we increase funding for talent training and encourage innovation. Third, from the real work, we increase investment for talent training and cultivate practical talent, with three aspects of joint efforts to strengthen China's network security management, big data, and other areas of common strength.

7. Conclusion

Information security education is an important part of quality education in China. Improving public information security education is very important for the development of society itself and the maintenance of national security. In recent years, the government has introduced a series of measures and policies to strengthen the research and development of information security technology and promote the development of information security protection levels; universities gradually pay attention to information security education and carry out related academic work, and the public awareness of information security education has been increasing, and information security education in China has been supported by a good environment and protection. Based on the current situation of information security education in China, this paper clarifies the concept and characteristics of information security education in the era of big data and then proposes an adaptive security situational awareness model to cope with the problems brought by streaming data in a complex environment based on the general theory of previous research. The model uses a self-learning strategy with error feedback for adaptive learning, which effectively reduces the probability of error detection and increases the detection rate to more than 98%, enabling it to be extended to large-scale processing of high-dimensional streaming data.

Data Availability

The experimental data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that there are no conflicts of interest.

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Research Article

WBS-Based Method in Teaching Management Information Project

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In modern times, with the development of industrialized society and the invention of clocks and watches, people have become more and more concerned about institutionalization, and higher education time and space have also shown the characteristics of institutionalization. In modern times, educational informatization has brought challenges and opportunities for educational reform and development. The vigorous development of education informatization has also produced changes in higher education spatiotemporally. For example, the rise of catechism and online learning, the importance of fragmented time, the development of space toward virtualization, and the expansion of interactive space for interpersonal interactions. In addition, the enrichment and sharing of educational materials, the informatization, and big data of educational management also contribute to the improvement of time efficiency and optimization of time structure in higher education. With the background of education under the new normal, this paper briefly analyzes the current situation of education informatization construction in colleges and universities from the perspective of education managers, and addresses the current situation and problems of teaching management informatization construction, such as organizational structure dominated by pyramidal functional departments, inefficiency, inability to connect work, difficulty in work gap, difficulty in horizontal coordination, and closed information. A work breakdown structure (WBS) based project management theory and work structure decomposition method are proposed. This paper finds that the improved association rule mining algorithm can improve the efficiency of teaching management practice in colleges and universities by more than 14.58%, which is an important reference value for college management informatization.

1. Introduction

Vocational education is an integral part of China's education system and is a special form of education [1]. In the field of development, vocational education crosses the three boundaries of industry, occupation, and education; and in the division of education levels, vocational education is divided into primary, secondary, as well as higher levels [2]. In 2005, the Ministry of Education issued the Decision of the State Council on Vigorously Developing Vocational Education, which pointed out that "the construction of education informatization should be strengthened and the application of modern educational technology in education teaching should be promoted," which initially put the development of informatization on the charter of vocational education development and vigorously promoted the development of vocational education informatization [3]. Since the release of the Ten-Year Development Plan for Education Informatization (2011–2020), China's education informatization has stepped into a new stage of development, and the strategic status of education informatization has reached an unprecedented new height [4]. Education informatization has become an important part of the process of education modernization, and it has become a strategic goal to promote the reform and development of education in China by accelerating the process of informatization and driving education modernization with education informatization [5]. From 2011 to 2015, China issued the Opinions of the Ministry of Education on Accelerating the Development of Vocational Education Informatization (2012), the Construction Plan of Modern Vocational Education System (2014–2020), the Decision of the State Council on

Accelerating the Development of Modern Vocational Education (2013), the Specifications for the Construction of Digital Campus in Vocational Colleges and Universities (2014), and the Plan on Deepening Several Opinions on Deepening Teaching Reform of Vocational Education and Comprehensively Improving Talent Cultivation Quality (2014), "Guidance on Comprehensively and Deeply Promoting Education Informatization during the 13th Five-Year Plan" (2015), "Action Plan for the New Development of Higher Vocational Education Plan (2015–2018)" and other policies [6, 7]. The development of vocational education informatization has gradually shifted from the primary development stage to the in-depth development stage, which is not only a major development opportunity but also a great challenge for higher vocational institutions [8].

At present, there are some achievements in the research related to education informatization in China, but it is still in the initial stage [9]. The research in vocational education informatization lags behind the research in basic education informatization and higher education informatization [10]. With the continuous development of China's economy and technology, the original system, structure, and talent training mode of vocational education can no longer adapt to the rapidly developing Chinese economy and the rapidly changing industrial structure, and the original vocational education must be reformed and developed, otherwise it will be difficult to adapt to the development needs of modern society [11]. Vocational education informatization is a huge push to promote the reform and development of vocational education. To make the work of vocational education informatization develop in a fast, appropriate and steady direction, it is necessary to continuously understand the current development level of vocational education informatization in each region to provide a reference basis for the promotion of vocational education informatization nationwide [12]. With the ultimate goal of better promoting the construction of educational informatization in higher vocational colleges in our region, this study takes the requirements put forward in the Opinions of the Ministry of Education on Accelerating the Development of Vocational Education Informatization as the purpose, combines the local characteristics of regional vocational education, analyzes the current situation and problems of educational informatization in higher vocational colleges, puts forward improvement measures and suggestions, and provides better educational informatization construction work for each higher vocational college reference [13].

2. Related Work

An important prerequisite for any concept to be of use is that it has a relatively clear connotation and extension. The concept of education informatization was first introduced in the United States in the 1990s [14]. In the 1990s, the U.S. government proposed the "information superhighway" plan in the "National Information Infrastructure" (N11 for short) [15]. The plan is to promote the development of an integrated information service system with the Internet as the core and to promote the extensive application of information technology in various fields of society, especially the application of information technology in education and the deep integration of information technology and subject teaching as an important way of education reform [16].

At present, the term education informatization has been widely used in China and is recognized by experts and scholars. However, the connotation of the concept of educational informatization is diverse, and domestic experts and scholars who have studied educational informatization have put forward their own understanding [17]. Throughout, various scholars have defined the concept of educational informatization from their own perspectives, and the central idea is the same, that is, the application of information technology to education [18]. Specifically, from the technical level, educational informatization can be the integration of digital, networked, intelligent, and multimedia education; from the educational level, educational informatization is a new educational concept with openness, sharing, interactivity, and collaboration, and we can regard educational informatization as a process of pursuing information-based education [19]. In summary, educational informatization aims at the development of students' abilities, the improvement of teachers' professional abilities and teaching standards, the sharing and use of global educational resources, and the overall development of schools [20]. The statistics of word frequencies revealed that infrastructure, informatization resources, teachers' informatization ability, management, and input, teaching, and talents were used more frequently, indicating that the research content of the existing studies was mostly investigated from these aspects.

Vocational education informatization is an important foundation and component of education informatization and national informatization, and [21] defined vocational education informatization as "the process in which teachers and students of vocational education use information technology to promote the teaching reform and development of vocational education on the basis of the network environment, so as to modernize vocational education and meet the needs of the times and society." [22] argued that vocational education informatization should be based on complete computer equipment and the Internet, and that vocational education informatization is oriented to vocational education, and its purpose is to improve the application of information technology among teachers and students in vocational institutions, so as to promote the development of vocational education teaching and reform. According to [23], the connotation of vocational education informatization mainly includes: vocational education informatization should be based on complete computer equipment and the Internet; vocational education informatization is oriented to vocational education, and its task is to improve the application of information technology so as to promote the development of vocational education teaching and reform; the quality of teachers in the information environment is the key to the success or failure of vocational education informatization; educational information resources. The development and construction of educational information resources is the basis and the main task to realize the continuous improvement of educational research level and educational teaching effect. [24] pointed out that "vocational education informatization refers to the use of multimedia and network information technology in the field of vocational education to promote the comprehensive reform of vocational education and adapt it to the new requirements for the development of vocational education in the informatized society." It is believed that the purpose of vocational education informatization is to promote educational reform; therefore, from regulations, policies, resources, talents, etc. related to vocational education informatization are all aspects of the development of education informatization. [25] interpreted informatization and education informatization from the perspective of information flow, analyzed the concept of informatization and the evolution of its connotation, and analyzed the differences between the concepts of education informatization and higher education informatization, and he believed that "higher education informatization refers to the use of contemporary information technology to transform the higher education system."

As shown above, it can be said that the informatization of vocational education is a process that is reflected in all aspects of vocational education and teaching. Specifically, it is a systematic project to modernize vocational education by using advanced educational concepts as guidance, applying modern information technology, and focusing on developing and utilizing information resources in order to cultivate innovative talents who can adapt to the requirements of the information society and accelerate the realization of vocational education.

3. Architecture

At present, there are six modules in the management information project of colleges and universities, including personnel management, teaching plan management, academic affairs management, grade management, financial management, and student registration management, and each module corresponds to different functions [17]. The management of student information and teacher information, teaching plan management, academic affairs plan management, grade management, financial management, and student registration management (as shown in Figure 1).

The organizational structure of the university MIS project (shown in Figure 2).

The WBS diagram of a college management information system project can be divided into four levels [18]. The second level is decomposed into six modules according to the stage of project implementation [19]; the third level of each module is decomposed according to the product composition of the project [20]. The specific WBS tree diagram (shown in Figure 3).

A digital campus is a virtual educational environment based on digital information and networking, which is established on the computer and network technology for the collection, processing, integration, storage, transmission, and application of campus information such as teaching, research, management, technical services, and living services, so that digital resources can be fully and optimally utilized. By realizing the digitalization of everything from the environment (including equipment, classrooms, etc.), resources (such as books, lecture notes, courseware), to applications (including teaching, learning, management, service, office, etc.), digital space is constructed on the basis of the traditional campus to expand the time and space dimensions of the real campus, enhance the operational efficiency of the traditional campus, expand the business functions of the traditional campus, and finally realize the comprehensive informatization of the educational process in order to achieve the purpose of improving the management level and efficiency. Therefore, the ultimate goal of digital campus construction is to realize education informatization, and digital campus construction is the means for higher education and vocational institutions to realize education informatization.

The platform has established 13 subsystems, including the multimedia information release subsystem, asset management subsystem, teaching task inquiry subsystem, classroom inquiry subsystem, online assessment subsystem, and life service system, which can meet different usage needs in the face of different users. Students, teachers, and evil managers of the college can use the platform to manage their own learning, teaching, and business matters. As shown in Figure 4 and Figure 5.

4. Improved Association Rule Mining Algorithm

To generate all frequent sets, the Apriori algorithm uses a recursive approach, as follows:

$K_1 =$ (llarge 1-itemsets).

For (l=2: K_{l-1} +μ: l ++)do begin.

$A_l =$ Apriori-gen (K_{l-1}) ‖Candidate set.

For all transactions $t\hat{J}B$ do begin.

$A_t =$ subset (A_l, t) ‖The set of candidates contained in transaction. t

For all candidates $c\hat{J}A$, do.

c.count++

End.

$K_l = \left\{c\hat{J}A_l|\text{c.count}^3 \text{ min sup}\right\}$

End.

Reply $= l \cup K_l$

The frequent first item set $K_1 \triangleleft$ and frequent second item set K_2 are generated one after another until some $u$value occurs to make K_u empty, and the algorithm terminates. In l the cycle, a set A_l of candidate l itemset is generated, and the role of each set in A_t is to generate candidate set of frequency sets, and the generation of each set is done by connecting $(l-2)$ frequency sets with only one different item by K_{l-1}, and the final generated frequency set K_l must be some subset of A_t. It is necessary to verify each element in A_t in database to determine whether each element can be added toK_l, and it is necessary to scan the database several times during verification. Therefore, the disadvantage of the Apriori algorithm is that generation of the candidate set is too large and

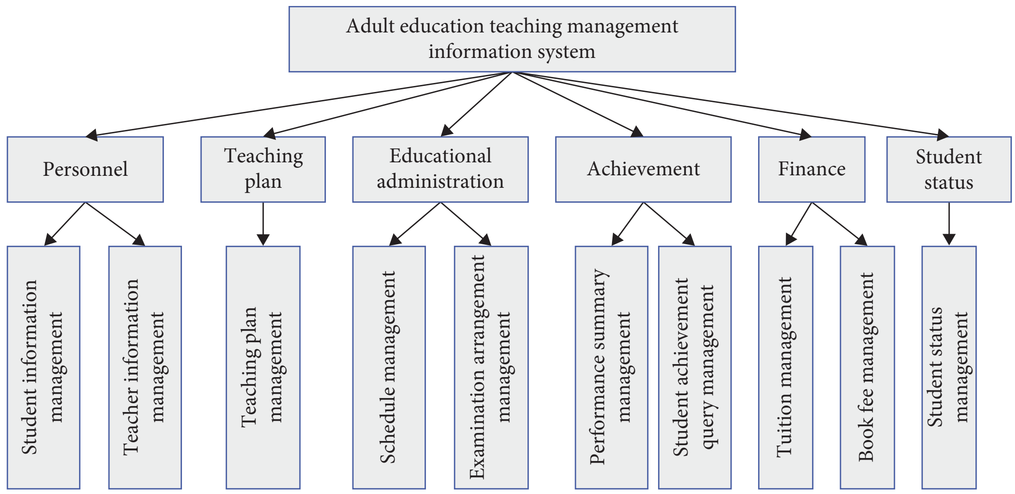

Figure 1: Student registration management.

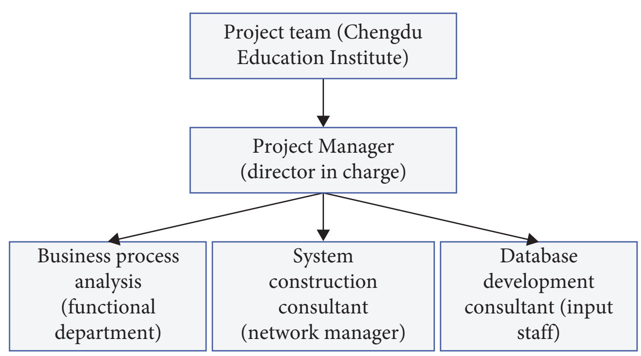

Figure 2: Organizational structure of teaching management informatization project.

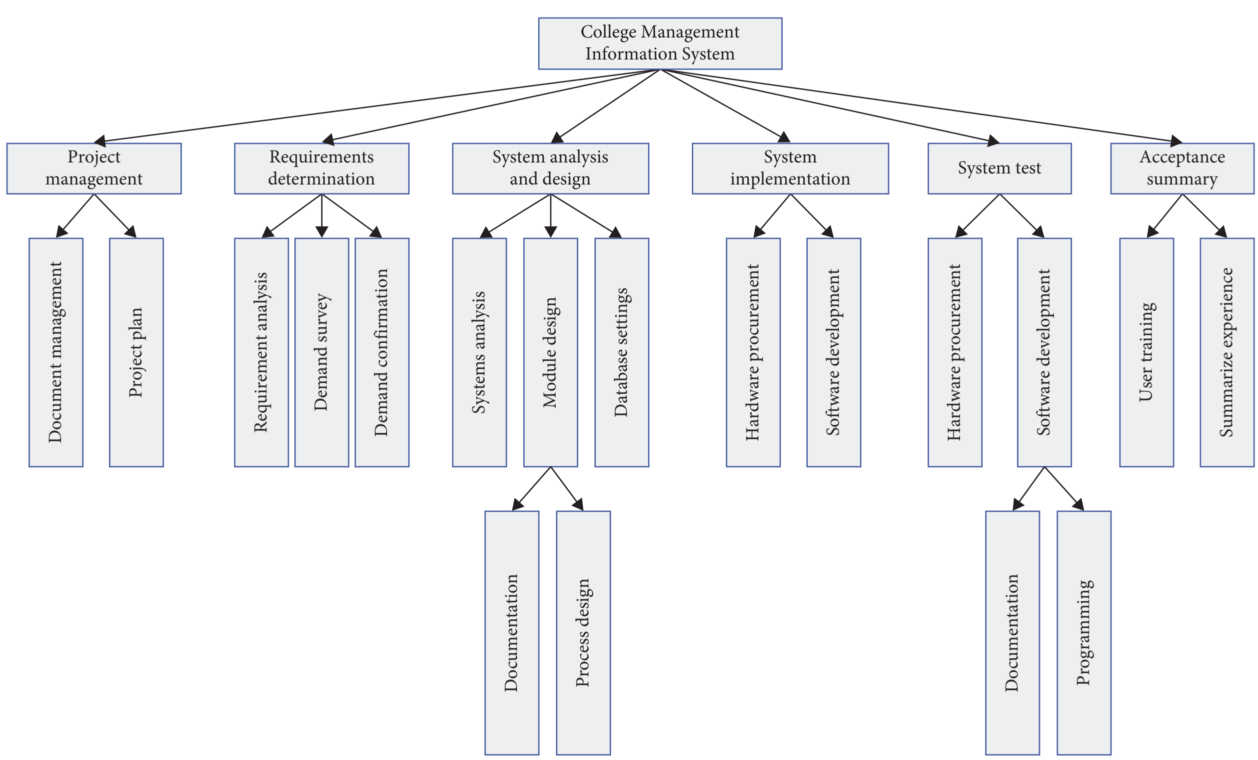

Figure 3: Structure decomposition of teaching management information system.

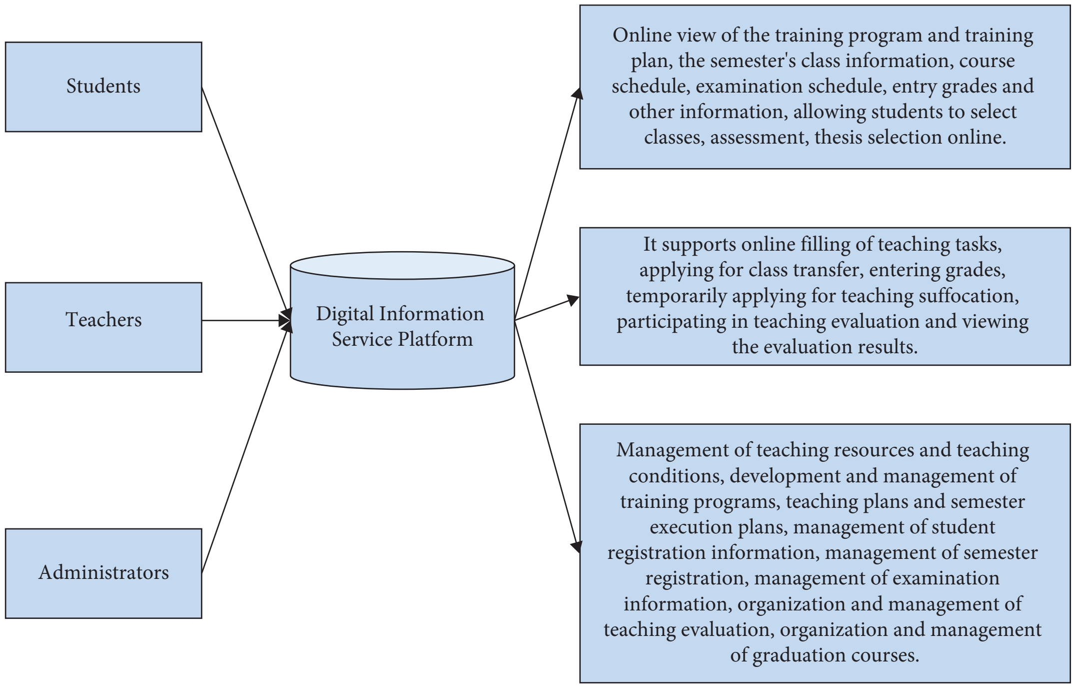

Figure 4: Functions and services of X College digital information service platform.

the scanning time is too long due to repeatedly scanning database, which is the bottleneck of the Apriori algorithm.

To improve the Apriori algorithm and enhance its efficiency, the pruning technique is added to the algorithm to reduce the size of candidate set A_l volume. The pruning technique is added to an algorithm based on the property that an item set belongs to a frequency set and all its subsets are frequency sets, and if there is a $(l-2)$ subset of a candidate item set in A_l that does not belong to a frequency set (K_{l-1}), this candidate set can be pruned out.

The association rules on basis of constraints are obtained based on the improved Apriori algorithm.

Definition 1. Let set of n different items be $J = \{j_1, j_2, \ldots, j_n,\}$, and set of management for J be B. Each management includes several items $j_1, j_2, \ldots, j_l$, and the association rule can be expressed as

$$E \cap Q_e \Rightarrow F \cap Q_f, \tag{1}$$

where Q_e and Q_f both denote constraints; E and F denote item sets, $E \subset J, F \subset J$, while $E \cap F = \mu, \mu$ denotes the existence of constraint associations for E and F when management includes both E item set that meets Q_e constraint and F item set that meets Q_f constraint.

Definition 2. Let management set B contains above constraint association rules, then the support of E item set under constraint $Q_e\text{Support}(E)$ is

$$\text{Support}(E) = \frac{\text{Support} - \text{count}(E)}{m}, \tag{2}$$

where M and $\text{Support} - \text{count}(E)$ denote the number of data (total number of matters) and E number of times item set appears in management, respectively. Within the management set B there are b% of management, including both E with Q_e constraints and F with Q_f constraints.

In terms of credibility, if $E \subset J, F \subset J$, while $E \cap F = \mu$, then the credibility of $(E \Rightarrow F)$ can be defined as

$$\text{confidence}(E \Rightarrow F) = \frac{\text{Support} - \text{count}(E \cup F)}{\text{Support} - \text{count}(E)}, \tag{3}$$

where $\text{Support} - \text{count}(E \cup F)$ denotes number of occurrences of E, F itemsets together in management. Within managed set B, there exists a% of F itemsets with both Q_f constraints within E itemsets with Q_e constraints.

In privacy protection of outsourced association rule mining, data owner requires cloud server to be able to compare support and confidence with read values. However, support and confidence must be kept confidential to cloud server and data owner, and comparison results must also be kept confidential to the cloud server.

In the Paillier encryption system, for all plaintexts m_1 and m_2 any random number used for encryption can be transformed into following equation, where modulo inverse $E(m_2)^{-1}$ is calculated by n^2.

$$(m_1 + m_2 \text{mod} n) = D\left(E(m_1) \cdot E(m_2) \text{mod} n^2\right). \tag{4}$$

And

$$(m_1 - m_2 \text{mod} n) = D\left(E(m_1) \cdot E(m_2)^{-1} \text{mod} n^2\right). \tag{5}$$

If (m_1, m_2) satisfies $0 \le m_2 \le m_1 \le n \le 2$, then

$$\begin{aligned} m_1 + m_2 &= D\left(E(m_1) \cdot E(m_2) \text{mod} n^2\right), \\ m_1 - m_2 &= D\left(E(m_1) \cdot E(m_2)^{-1} \text{mod} n^2\right). \end{aligned} \tag{6}$$

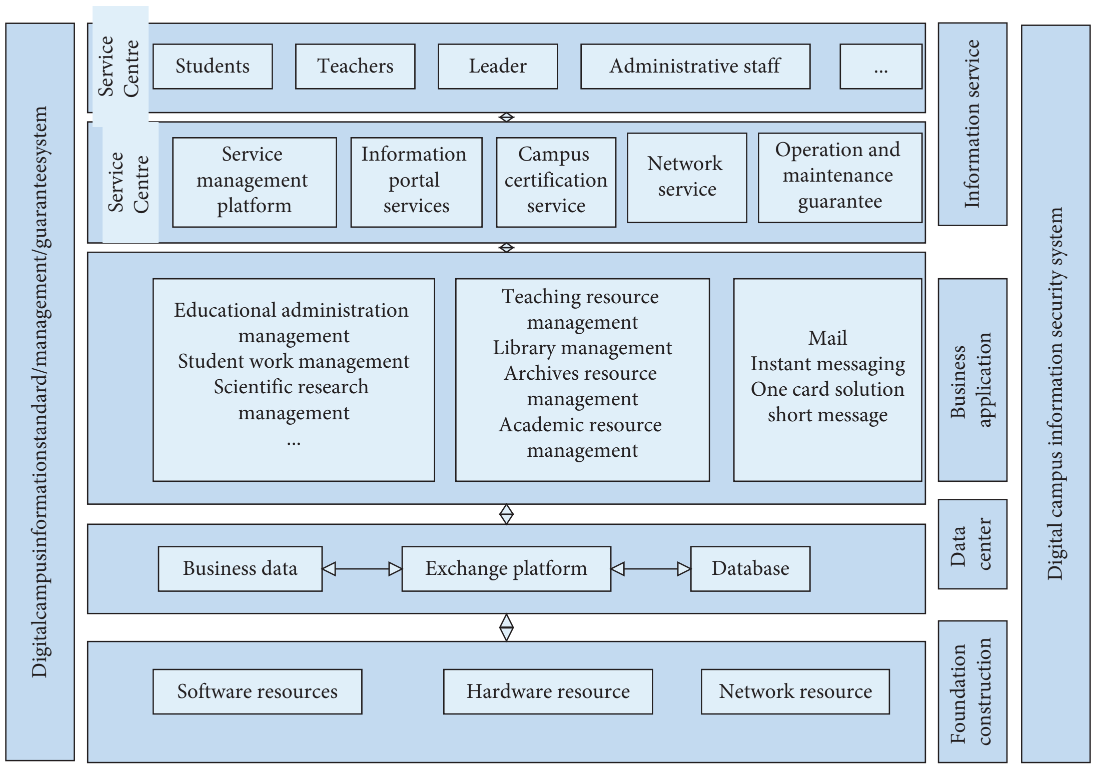

Figure 5: Framework system of the digital information service platform of X-college.

When sign of $m_1 - m_2$ is unknown, the Paillier cipher system can be improved. The encryption remains same, when m is negative, we can calculate $E(m)$ as $E(m \bmod n)$. decryption is modified to $D'(c) = [D(c)]_n$, defining $[x]_n = ((D(c) + \lfloor n/2 \rfloor) \bmod n) - \lfloor n/2 \rfloor$. if $-(n/2)m(n/2)$, then $D'(E(m)) = m$.

$$[m_1 + m_2]_n = D'\left(E(m_1) \cdot E(m_2) \bmod n^2\right). \tag{7}$$

And

$$[m_1 - m_2]_n = D'\left(E(m_1) \cdot E(m_2)^{-1} \bmod n^2\right). \tag{8}$$

If $-(n/4)m_1(n/4), -(n/4)m_2(n/4)$ is satisfied, then we can get:

$$m_1 + m_2 = D'\left(E(m_1) \cdot E(m_2) \bmod n^2\right). \tag{9}$$

And

$$m_1 - m_2 = D'\left(E(m_1) \cdot E(m_2)^{-1} \bmod n^2\right). \tag{10}$$

5. Results

A total of 569 student questionnaires were distributed and 569 were recovered, with a recovery rate of 100%. There were 569 valid questionnaires and 0 invalid questionnaires. It preliminarily meets the survey and design requirements.

Figure 6 shows the frequency of using devices in teaching of 73 teachers surveyed, from 1 indicating none to 5, indicating that the frequency of use is very often. From the above figure, it can be seen that teachers use information technology equipment very frequently, basically above 3.5 points. However, the frequency of using interactive whiteboards, digital cameras and video cameras, computer labs, and speech rooms is less than 3.5. This means that teachers are not very proficient in using the latest information technology teaching equipment, and the school's training in this area is not very effective. Moreover, the frequency of using computer labs and speech rooms is not high, which also indicates that in the process of implementing information technology teaching, many times it is only for competition, not really for teaching reform, and reform is just a formality.

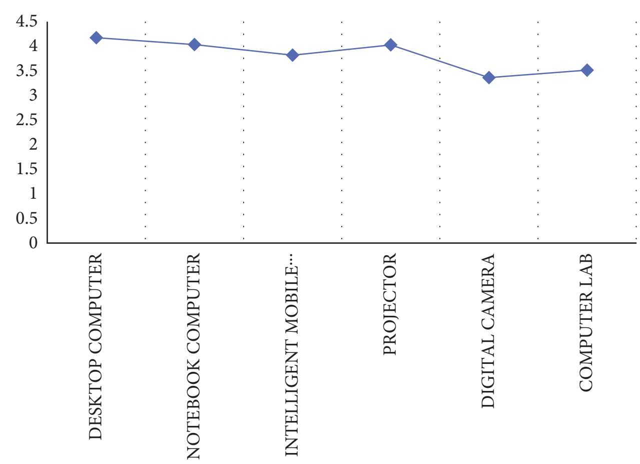

Figure 6: Survey on frequency of teachers' use of equipment in teaching.

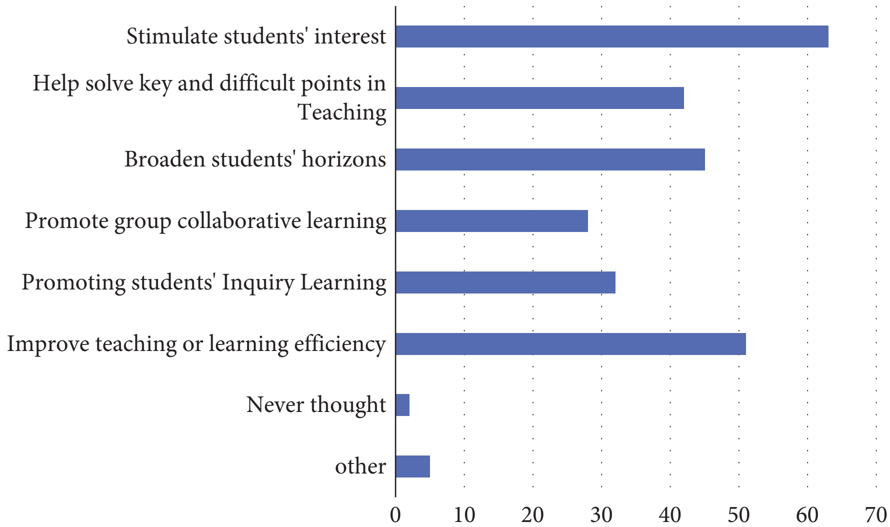

Figure 7: Survey of teachers' choice of using information technology for teaching purposes.

Figure 7 is a multiple-choice question that investigates the purpose of using information technology for teaching and learning among 73 teachers. The number of teachers was calculated according to the number of teachers. According to survey results, teachers' purpose of using information technology is mainly focused on "stimulating students' interests and improving students' attention." 63 people (86.3%) agreed with this view, and 50 people (68.49%) agreed with the view of "improving teaching or learning efficiency." Fifty people, or 68.49%, agreed with this view. However, in the process of implementing information technology teaching, the number of people who thought it could "promote students' inquiry learning" and "promote collaborative group learning" was less than 35 people, indicating that teachers did not consider "cooperative learning" and "collaborative learning" when implementing information technology teaching. This means that teachers do not take into account theories of "cooperative learning" and "inquiry learning" when implementing information technology teaching, so the effect of information technology teaching will be reduced and the quality of students' information technology learning will not be guaranteed.

Figure 8 shows a survey of 73 teachers' opinions on the use of information technology in classroom teaching and learning, which is a multiple-choice question. Among them, 65 (89.04%) were in favor of "effective motivation for students to learn." However, it can be seen from the survey that only 30 people (41.10%) agreed that "students have a greater sense of achievement in learning," only 24 people (32.88%) agreed that "students can remember what they have learned more easily," and only 24 people (32.88%) agreed that "students have a greater sense of achievement in learning." Only 22 people (30.14%) agreed with "developing students' horizontal skills (learning to learn, social skills, etc.)," and only 23 people (31.51%) agreed with "promoting cooperation among students". Only 25 people (34.25%) agreed with "changing students' learning styles."

Figure 9 shows a survey of 569 students who learned knowledge through the Internet. This shows that students are aware of information-based learning, but teachers and schools need to develop and encourage students to learn through information-based means, and to ensure that they do so.

Figure 10 shows a survey of 569 students on the use of school learning spaces and online platforms after school hours. The survey results show that 71% of students (404) said they had used learning spaces and online platforms, but 29% of students (165) said they had not used learning spaces and online platforms. This shows that nearly 1/3 of students did not consider using the school's learning space and online platform, which means that the usage rate is not high, indicating that students' learning habits and methods are not really computerized. Teachers do not emphasize or develop these platforms to use them for real teaching and learning. At a school management level, there is no reasonable information technology team and no information technology platform to motivate students to use learning spaces and network platforms for learning.

Figure 11 shows a survey of 569 students' perceptions of whether online information learning is helpful to them. The survey data shows that 90.69% of students, i.e., 516 students, think it is helpful, but 9.31% of students think it is not helpful, which means that teachers and school administration do not provide guidance and education on how online information can help students learn, and students are confused about how to do online learning.

Figure 12 shows a survey of 569 students about the installation of learning software on their cell phones. The survey shows that 83.66% of students, or 476 students, have installed learning software, but 16.34% of students still have not installed learning software. The installation of learning software facilitates teaching, learning, feedback, and answering questions in many ways. The fact that students do not install them means that teachers and school administrators do not have a policy or guidance for students to effectively use information technology for learning. Therefore, I believe that at the school management level and at the level of student education, measures should be taken to allow

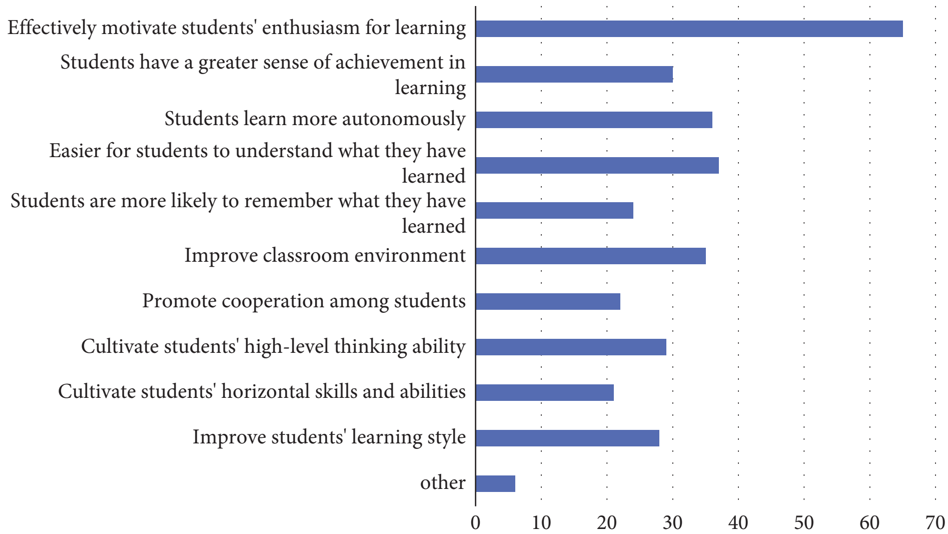

Figure 8: Survey of teachers' perceptions of positive impact of using information technology.

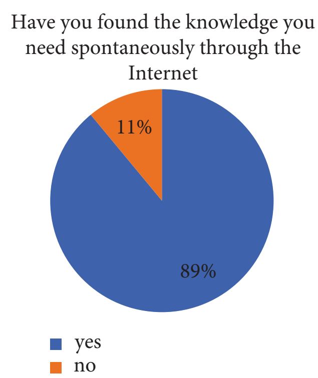

Figure 9: Survey on students' search for learning knowledge through online channels.

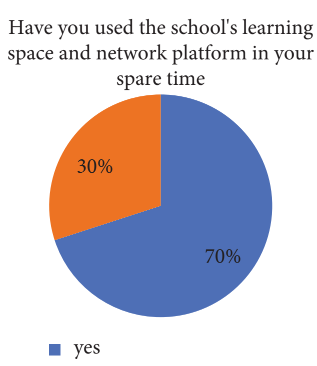

Figure 10: Survey on students' learning spaces and online platforms after school hours.

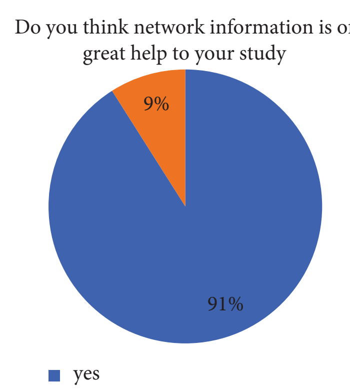

Figure 11: Survey of students' opinions on whether online information learning is helpful.

students to use all information technology tools to learn, rather than all information technology tools just for competition.

Figure 13 shows a survey of 569 students on online learning to get answers. The survey results show that 86.12%, or 490 students, will use online learning to get answers to classroom questions, but 13.88% of students will not use online learning to get answers. This means that students' ability to learn information technology has not improved with the development of time and requirements of information technology, so school management should induce students to use information technology to answer questions and find answers to questions rather than in studies without direction.

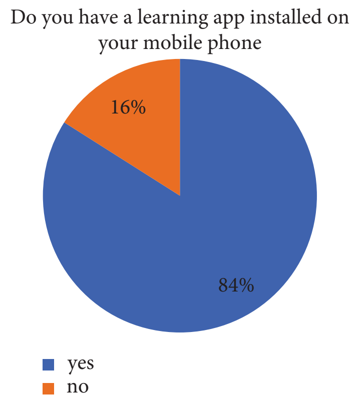

Figure 12: Survey on apps installed on students' cell phones for learning.

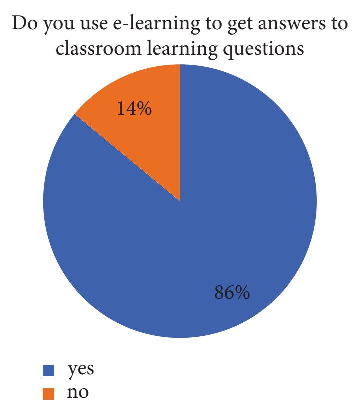

Figure 13: Survey of students' access to answers for online learning.

6. Conclusion

Management informatization, as an effective means to deepen management reform and improve the governance ability of universities, brings opportunities and challenges for the high-quality development of universities. However, we clearly realize that there are still many constraints that need to be solved. Management informatization in higher education is a long and complicated systematic construction project, which requires continuous research and exploration. Based on the theories of university management informatization, new public management, and digital governance, this paper starts from the current situation of universities, identifies the problems that restrict their development, then analyzes the cause-effect relationship of those problems, and finally proposes the solution countermeasures, which provides a case worthy of reference and discussion for the development of university management informatization.

This paper mainly forms the following conclusions for the promotion of the management informatization process in colleges and universities:

(1) Management informatization should strengthen the top-level design. Management informatization faces many serious challenges in colleges and universities, such as systemic, sustainability, and complexity, and must be planned for the overall situation and in the long term in order to continuously promote healthy and sustainable development.

(2) Management informatization needs users' participation in construction. Only by understanding the needs of teachers and students and strengthening multiparty public governance can we grasp the direction of system construction and development and realize the modernization of university governance capacity.

(3) Managers should establish the awareness of management informatization and service consciousness, break the thought of "emphasizing technology but not management," fine management, and active service, and realize the "one network for all" of university education management system by building a one-stop service hall.

(4) To establish a supervision and evaluation mechanism with the participation of many parties and common construction and governance, as well as an evaluation index system for the development of management informationization. Relying on the "Internet + Supervision" system, it can realize the transformation from manual supervision to intelligent real-time supervision; build a user-centered user evaluation and feedback mechanism; and explore the normalization, real-time, and data-based evaluation and feedback.

(5) Strengthen the construction of the management informatization team to create a composite professional team with strong innovation consciousness, a reasonable age and title structure, and a balance of business and technology. Attract more management informatization talents by establishing and improving a salary system that adapts to the characteristics of management informatization. Innovate the mode of using talents, implement a combined full-time and part-time model, and then attract more social participation in management by purchasing services and other forms. Establish a perfect evaluation and training system, target management informatization training work, and improve management informatization awareness.

Data Availability

The experimental data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declared that they have no conflicts of interest regarding this work.

Acknowledgments

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