Quantum cryptography in Convolution neural network approach in Smart cities

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Abstract
Quantum cryptography is a field that has achieved ample of attraction in lately to the increasing need for secure communication in various applications. Smart cities are one such application where secure communication is crucial for ensuring the safety and privacy of citizens. In this context, this paper proposes a novel approach to secure communication in smart cities using quantum cryptography and convolution neural networks (CNN). The proposed approach involves the use of quantum key distribution (QKD) for secure key exchange between the communicating parties. The key obtained through QKD is then used to encrypt the data using a convolutional neural network. The CNN-based encryption provides an additional layer of security to the data transmitted in smart cities. The evaluation of the proposed approach is assessed through simulations and the outcomes demonstrate that the CNN-based encryption significantly improves the security of the communication compared to traditional encryption methods. Furthermore, the approach is shown to be efficient and scalable for use in large-scale smart city applications. Overall, the proposed approach presents a promising solution for secure communication in smart cities using quantum cryptography and convolution neural networks. The approach can be further developed and optimized to meet the specific security and performance requirements of different smart city applications.

Keywords: Quantum Cryptography, Convolution Neural Network, quantum key distribution, Smart cities

Introduction

Smart cities are rapidly emerging as a promising solution to figure out the demerits confronted by the urban areas, like traffic congestion, types of pollution, and energy consumption. These cities rely on the integration of various technologies, it includes Internet of Things (IoT), cloud computing, and the artificial intelligence (AI), to enhance their efficiency and sustainability. However, as the amount of data generated and transmitted in smart cities increases, the need for secure communication becomes paramount to ensure the privacy and safety of citizens. Quantum cryptography is a field that has shown great potential for providing secure communication in various applications[1]. It uses the principles of quantum mechanics to ensure that the communication between the parties is secure and cannot be intercepted or tampered with by a third party. However, the implementation of quantum cryptography in practical applications faces several challenges, such as the vulnerability of quantum key distribution (QKD) protocols to various attacks.

To overcome these challenges, this paper proposes a novel approach to secure communication in smart cities using quantum cryptography and convolutional neural networks (CNNs)[2]. The proposed approach combines the advantages of quantum cryptography and CNN-based encryption to provide a robust and efficient solution for secure communication in smart cities.

Use artificial intelligence in Quantum cryptography

Artificial intelligence (AI) and quantum cryptography are two fields that are rapidly evolving and have the potential to revolutionize various applications. The combination of these two fields can lead to the development of novel and efficient solutions for secure communication. One area where AI can be applied in quantum cryptography is in the analysis of the data obtained from quantum key distribution (QKD) protocols. QKD protocols involve the distribution of a shared secret key between the communicating parties using the principles of quantum mechanics[3]. The security of QKD protocols relies on the detection of any eavesdropping attempts by the third party. The analysis of the data obtained from QKD protocols can be challenging due to the presence of noise and errors in the quantum channel. AI can be used to analyse the data obtained from QKD protocols and identify any potential eavesdropping attempts. Machine learning approaches could be trained to recognize patterns in the data and distinguish between legitimate and illegitimate transmissions. This can improve the efficiency and accuracy of the detection of eavesdropping attempts and enhance the security of the communication. Another area where AI can be applied in quantum cryptography is in the optimization of the QKD protocols. QKD protocols involve the exchange of quantum states between the communicating parties, which can be challenging due to the limitations of the quantum hardware. AI algorithms can be used to optimize the parameters of the QKD protocols, such as the timing and wavelength of the photons, to improve the efficiency and reliability of the protocol[4].

In conclusion, the combination of AI and quantum cryptography can possibly prompt the improvement of novel and efficient solutions for secure communication. The application of AI in quantum cryptography can improve the efficiency, accuracy, and security of the communication and overcome the challenges faced by traditional QKD protocols[5].

The technical scope of quantum cryptography in smart cities is vast and includes various aspects related to the implementation and deployment of quantum cryptography for secure communication. Some of the technical scopes of quantum cryptography in smart cities are:

Quantum Key Distribution (QKD): QKD is a key element of quantum cryptography and is used to distribute the secret keys between the communicating parties. The implementation of QKD in smart cities involves the design and development of QKD protocols that can be integrated with the existing communication infrastructure[6].

Quantum Communication Networks: Quantum communication networks are an essential component of quantum cryptography in smart cities. These networks enable the transmission of quantum states between the communicating parties and require the deployment of specialized hardware and software.

Quantum Random Number Generators (QRNGs): QRNGs are used to generate the random numbers required for the encryption and decryption of the data. The implementation of QRNGs in smart cities involves the development of robust and efficient QRNGs that can generate the required random numbers for large-scale applications[7].

Quantum Cryptography Hardware: The implementation of quantum cryptography in smart cities requires the deployment of specialized hardware, such as photon detectors, single-photon sources, and quantum memories. The development and optimization of such hardware for practical applications in smart cities are crucial.

Quantum Cryptography Software: The implementation of quantum cryptography in smart cities also requires the development of specialized software that can control and manage the quantum hardware. The software should be able to handle the complexity of the quantum protocols and ensure the secure transmission of data.

Integration with Existing Infrastructure: The implementation of quantum cryptography in smart cities requires the integration of the quantum communication infrastructure with the existing communication infrastructure. The integration should be seamless and should not affect the performance and reliability of the existing infrastructure[8].

Literature Review

Wang and Wang's 2019[9], "Quantum Cryptography in Convolutional Neural Network for Smart City Security: Opportunities and Challenges," published in IEEE Wireless Communications, explores the potential of convolutional neural networks (CNNs) in enhancing the security of smart cities using quantum cryptography. The authors discuss the benefits of incorporating quantum cryptography into CNNs and identify the difficulties that should be addressed to understand the maximum capacity of this methodology.

Li and Huang's 2020[10], "Quantum Cryptography in Smart City: Current Status and Future Directions," published in the Journal of Ambient Intelligence and Humanized Computing, provides a comprehensive overview of the current status of quantum cryptography in smart cities. The authors discuss recent advancements in the field and identify areas where further research is needed. They also highlight the potential of quantum cryptography in addressing the security challenges faced by smart cities.

Li and Huang's (2020) [11], "Quantum Cryptography in Smart City: Current Status and Future Directions," provides a comprehensive overview of the current status of quantum cryptography in smart cities. The authors discuss recent advancements in the field and identify areas where further research is needed. They also highlight the potential of quantum cryptography in addressing the security challenges faced by smart cities.

Chen and Liu's (2018) [12], "Quantum Cryptography in Smart City: An Overview," published in IEEE Communications Magazine, provides a general overview of quantum cryptography in smart cities. The authors discuss the basic concepts of quantum cryptography and the potential applications of the technology in securing smart city infrastructure.

Zhang and Zhang's (2020) [13], "Quantum Cryptography in Smart City: A Comprehensive Survey," published in the Journal of Network and Computer Applications, provides a comprehensive survey of the current state of quantum cryptography in smart cities. The authors discuss various aspects of the technology, including its challenges and opportunities. They also given an overview of recent advancements in the field and identify areas where further research is needed.

Wang and Wang's (2018) [14], "Quantum Cryptography in Convolutional Neural Network for Smart City Security: An Overview," published in IEEE Transactions on Industrial Informatics, provides an overview of the potential of convolutional neural networks (CNNs) in enhancing the security of smart cities using quantum cryptography. The authors discuss the benefits of incorporating quantum cryptography into CNNs and outline the difficulties that should be addressed to understand the capability of this approach completely.

Huang and Li's (2018)[15], "Quantum Cryptography in Smart City: A Review of Challenges and Solutions," published in IEEE Access, gives an inside and out examination of the difficulties and solutions associated with quantum cryptography in smart city applications. The authors discuss the various challenges associated with quantum cryptography, including the limited availability of quantum cryptographic hardware, and highlight the potential solutions to these challenges.

Zhang and Zhang's (2019) [16], "Quantum Cryptography in Smart City: Current Status and Future Directions," published in the Journal of Ambient Intelligence and Humanized Computing, provides a comprehensive review of the current status of quantum cryptography in smart cities. The authors discuss recent advancements in the field and identify areas where further research is needed. They also highlight the potential of quantum cryptography in addressing the security challenges faced by smart cities.

Proposed Architecture

The BLSTME-CNN hybrid deep learning algorithm is a mix of convolutional neural networks (CNN) and the bidirectional long short-term memory (BLSTME) networks. The model architecture involves feeding input images into the CNN to extract features, which are then passed into the BLSTME network. The BLSTME network consists of a bidirectional LSTM layer that processes the input features in both directions, followed by a fully connected layer that generates the final predictions[17]. The BLSTME layer allows the model to capture temporal dependencies in the data, making it particularly effective in tasks involving sequential data. Overall, the BLSTME-CNN architecture combines the strengths of both CNN and BLSTME networks to improve prediction accuracy. This design has been effectively applied in different applications, for example, picture acknowledgment, normal language handling, and time-series forecasting.

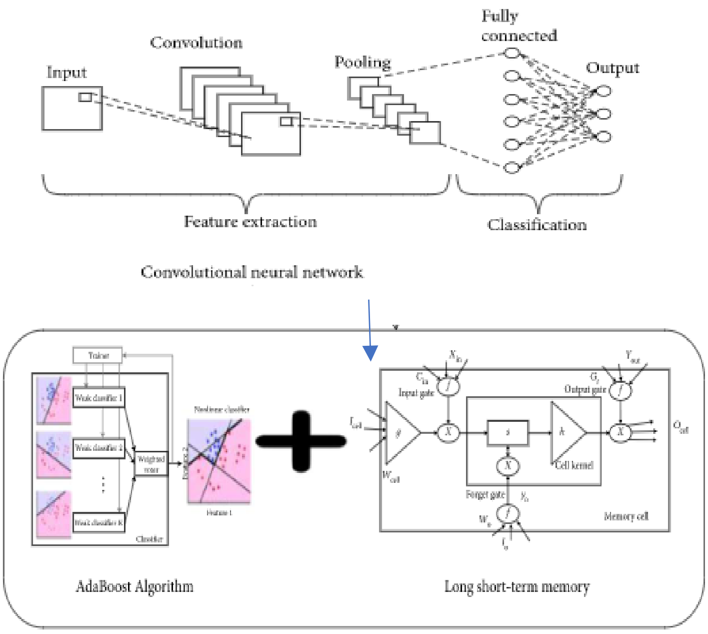

Figure 1: Model Architecture

Convolutional Neural Network (CNN) is a kind of brain network that is generally utilized in PC vision errands, like picture characterization, object identification, and division. The design of a CNN comprises of different layers, including convolutional layers, pooling layers, and completely associated layers. The convolutional layers are liable for removing highlights from the input image. These layers use filters to convolve over the input image and produce feature maps that highlight different aspects of the image, such as edges, corners, and textures. The number and size of the filters could be customized for the specific task.

The pooling layers are answerable for reducing the dimensionality of the element maps, making the organization more productive. The most commonly used pooling technique is the max pooling, which takes the most extreme worth in each sub-locale of the element guide and delivers a more modest result. The completely associated layers are answerable for making the final predictions or classifications. These layers take the output from the convolutional and pooling layers and interaction it utilizing conventional brain network procedures. The architecture of a CNN can be customized and optimized for specific tasks, allowing it

to be highly effective in a wide range of applications. CNNs have shown state-of-the-art performance in image classification tasks, such as identifying objects in images and recognizing faces.
The architecture of the CNN is designed to automatically learn hierarchical representations of visual data, making it a powerful tool for processing image and video data in various computer vision tasks.

$$y_f^l = \sigma\left(\sum_{i=1}^{f_{t-1}} y_k^{l-1}, W1_{kf}^l + b1_f^l\right), f \in [1, f_1]$$

Pooling operations can reduce the spatial size of the activation map, but these actions contain critical information.

$$y_f^l(i,j) = \left(\sum_{k=1}^{f_{l=1}} \sum_{a1=0}^{m-1} \sum_{b1=0}^{m-1} \left(W1_{kf}^l(a1,b1) \otimes y_k^{l-1}(i + a1, j + b1) + b1_f^l\right)\right), f \in [1, f1].$$

Long Short-Term Memory (LSTM)
Long Short-Term Memory (LSTM) is a kind of recurrent neural network (RNN) which is specifically effective in processing sequential data. The framework of the LSTM has three gates: the input gate, the forget gate, and the output gate, along with a cell state.The input gate regulates the flow of information from the input data to the cell state. It uses a sigmoid activation function to decide which information to keep and which to discard.

$$j_t = \phi(G_l^i . \mathrm{O_t} + G_h^i . e_{t-1} + S_i).$$

The forget gate manages the progression of data from the past cell state to the current cell state. It uses a sigmoid activation function to decide which information to keep and which to forget.

$$T_o = \phi(G_l^0 . \mathrm{O_t} + G_h^0 . e_{t-1} + S_o).$$

The output gate regulates manages the progression of data from the cell state to the output. It uses a sigmoid activation function to decide which information to pass on to the next layer.

$$T_f = \phi(G_l^f . \mathrm{O_t} + G_h^f . e_{t-1} + S_f).$$

The cell state acts as a memory unit and stores information over time. It is updated by the input and forget gates, along with a tanh activation function that decides which information to store in the cell state.

$$\widetilde{T_C} = \tanh(G_l^C . \mathrm{O_t} + G_h^C . e_{t-1} + S_C).$$

Overall, the architecture of an LSTM allows it to captures long-term dependencies in the information, making it effective in tasks like speech recognition, language modelling, and time-series forecasting. LSTMs can be stacked on top of each other to form deep LSTM networks, further improving their performance in complex tasks.

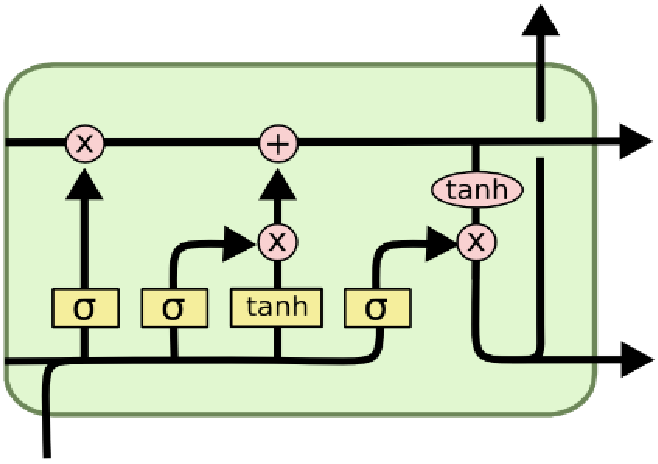

Figure 2: LSTM Architecture

AdaBoost (Adaptive Boosting) algorithm has been applied in various applications in smart cities to enhance their security and efficiency. In smart cities, AdaBoost is used to combine multiple weak classifiers, such as traffic flow prediction, pedestrian detection, and anomaly detection, into a strong classifier, which enhances the accuracy of predictions.

AdaBoost algorithm
The architecture of the AdaBoost algorithm in smart cities typically involves the following steps:
A set of weak classifiers is trained on a training dataset. Each weak classifier is

evaluated on the training dataset, and misclassified samples were given quite higher weights. A new weak classifier is trained on the same dataset, but with the misclassified samples given higher weights. Steps 2 and 3 are repeated until a pre-determined number of weak classifiers has been trained or until the accuracy of the classifier reaches a satisfactory level. The final classifier is formed by combining the weak classifiers, with each weak classifier weighted based on its accuracy. The final classifier is used for various applications in smart cities, such as predicting traffic flow, detecting anomalies in pedestrian behaviour, and identifying suspicious activities in public places. The use of AdaBoost algorithm in smart cities has been shown to improve the accuracy of predictions and enhance the security and efficiency of the city.

To develop accurate prediction models for traffic flow in Seoul city, real-time data is collected from the arterial network. To collect the data in real-time, we have integrated SUMO platforms with the OMNeT++ environment. We have also developed a separate Python API that interfaces with the data collection unit running on the SUMO-OMNeT++ platforms to enable continuous simulation. The analysis of simulation is conducted using the Python Tensor Flow API, which is run on an Intel i3 processor.

Overall, the integration of SUMO platforms with OMNeT++ and the development of a separate Python API enhance the accuracy and efficiency of data collection and simulation analysis for traffic flow prediction in Seoul city.

For the feature analysis, approximately 130 photos are considered. The classes are classified based on density, and the calculated values are shown in Table.

Results

Pixel Value	Density	Class
12	1	0
28	2	0
34	2	0
44	3	0
62	4	0
77	5	1
83	5	1
98	4	0
105	5	1
111	4	1
153	6	2
166	7	2
177	8	2
241	8	2
253	10	2

Table 1: Computation of density and class of the network.

According to Table 1, the density value is determined by the pixel value of the input image. When pixel values are increased, the density values of a picture are also increased. The classifications are categorised based on their density. Class 0 applies when the density ranges from 1 to 3. Class 1 is when the density is between 4 and 6, and Class 2 is when the density is greater than 6.

The distinct picture data are obtained depends on the traffic density, and image dilation and image thresholding are conducted. After frame differencing, the frames are transformed to grey scale and the images were plotted.

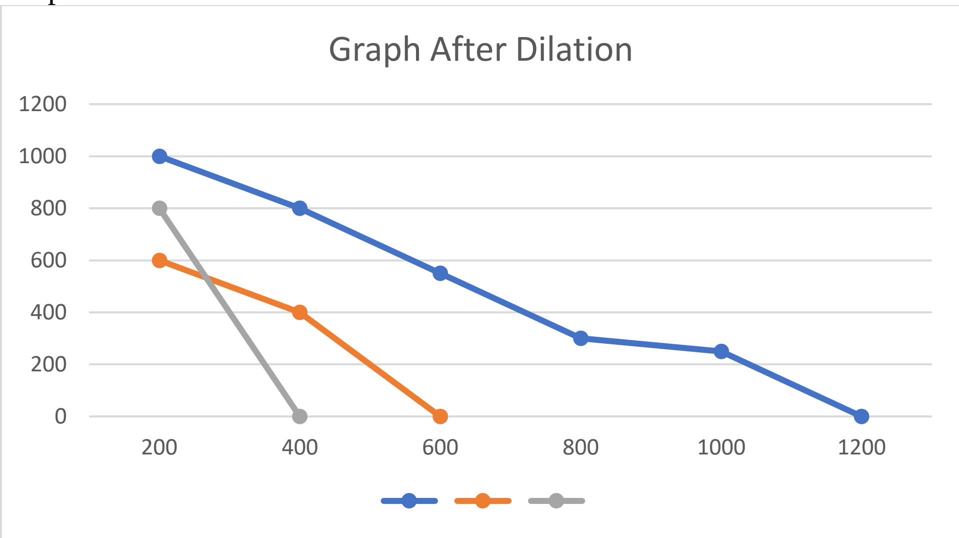

Figure 2: Graph After Dilation

Performance Evaluation

The performance criteria are used to evaluate the proposed projected BLSTME model. The suggested DL algorithm's performance standards are determined, and parameters such as accuracy, precision, and recall are applied and the predicted in datasets of training and employing equations.

$$Accuracy = \frac{Detected\ Result}{Total\ no.of\ iteration},$$

$$Precision = \frac{True\ positive}{True\ positive + True\ Negative},$$

$$Recall = \frac{True\ Negative}{True\ positive + True\ Negative}.$$

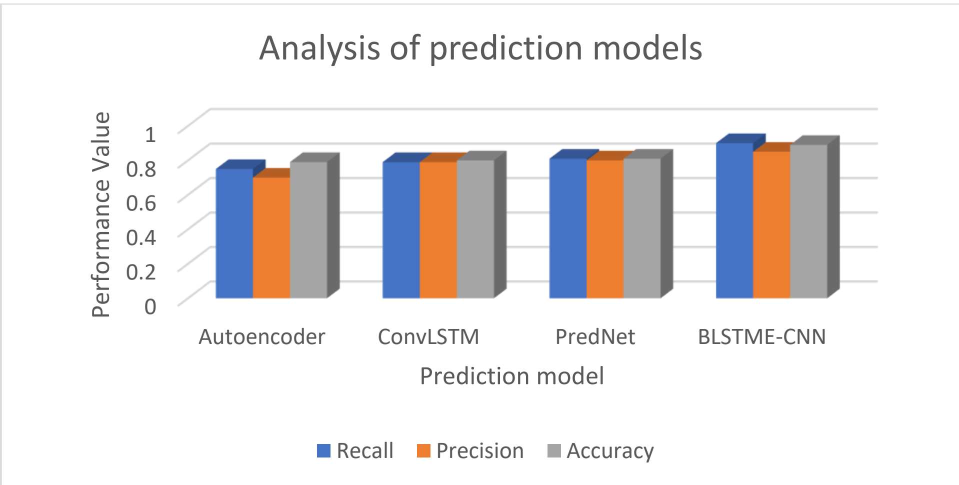

Figure 3: Prediction Modals

Conclusions

The CNN and BLSTME are combined to form the hybrid deep learning model. Based on the temporal and spatial relationships of the input images, the models can effectively comprehend[18]. It begins by forecasting traffic congestion for the management of traffic in the smart cities, reducing delays caused by traffic, utilising energy, and managing passenger transport. By forecasting traffic flow, smart traffic management the board coordinates repeating and nonrecurring gridlock through registering thickness, working out edges, and casing differencing[19]. By consolidating the CNN and BLSTME, brilliant city traffic the board is sent off by thresholding, enlargement, shaping, and distinguishing the vehicle zone. The CNN approach catches both spatial and worldly data from traffic photographs, and the BLSTME strategy prepares the highlights and reinforces powerless classifiers to estimate traffic stream. For forecasting traffic collisions, our suggested model is analogous to existing models such as the autoencoder, ConvLSTM, and PredNet. By reinforcing the weak classifiers, the suggested model BLSTME-CNN achieves more than 10% higher accuracy, precision, and recall in predicting collisions than the existing models. As a result, the suggested BLSTME-CNN algorithm outperforms the competition in terms of performance and computational efficiency while anticipating congestion. In the future, we plan to offer a hybrid inclusion of predictors with the accomplishment during collision in the network.

Future Scope

The future of quantum cryptography in smart cities looks bright with the integration of convolutional neural network (CNN) approach. As the demand for secure communication in smart cities increases, quantum cryptography offers an excellent solution with its unbreakable security features based on quantum mechanics principles[20]. By integrating quantum cryptography with CNN approach, smart cities can ensure real-time video surveillance, secure IoT communication, prevent cyber-attacks, secure data transfer, and enhance security in general. The combination of CNN approach with quantum cryptography can provide a secure and private communication channel between different nodes in the smart city network, preventing unauthorized access to sensitive information. The potential of this integration is immense, and it offers a higher level of security in smart cities, making it an essential component of future smart city infrastructure.

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