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Optimal Compression of Remote Sensing Images Using Deep Learning during Transmission of Data

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Abstract

Industrial internet of things has grown quite popular in recent years and involves a large number of intelligent devices linked together to build a system that can investigate, communicate, gather and observe information. Due to this requirement, there is more demand for compression techniques which compresses data, leading to less usage of resources and low complexity. This is where Convolutional Neural Networks (CNN) play a large role in the field of computer vision, especially in places where high applications such as interpretation coupled with detection is required. Similarly, low-level applications such as image compression cannot be resolved using this methodology. In this paper, a compression technique for remote sensing images using CNN is proposed. This methodology incorporates CNN in a compact learning environment wherein the actual image that consists of structural data is coded using Lempel Ziv Markov chain algorithm. This process is followed by image reconstruction in order to obtain the actual image in high quality. Other methodologies such as optimized trunctiona, JPEG2000, JPEC and binary tree were compared using a large number of experiments in terms of space saving, reconstructed image quality and efficiency. The output obtained indicates that the proposed methodology shows effective improvement, attaining a 50 dB signal to noise ratio and space saving of 90%.

Keywords: Image Compression, Industrial Internet of Things, Convolutional Neural Network, Deep Learning, Space Saving, Remote Sensing

1. Introduction

Internet of Things is also called Industrial Internet of Things as it is commonly used in a number of industries such as aviation, mining and metals, energy/utilities, transportation, oil

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and gas, logistics and manufacturing sectors [1]. The advancement in sensor networks, smart cities, smart environment and home automation for military and civilian applications has resulted in the integration of IoT in every device and application. This is especially the case with development in the field of remote sensing technology where satellites capture high quality remote sensing images. However, the challenges [2] faced are the transmission and storage capacity due to the large amount of information involved while transferring remote sensing images [3]. In order to tackle this issue, a compression technique is involved while processing the images. However, the various features such as precise geographical matter, lucid data, complex spatial data [4] and some targets that are included in the remote sensing images. Based on the observations, it is identified that these methodologies are not apt for high frequency data and tend to concentrate on the low frequency data which is not that useful [5]. Hence, various features are considered for compressing remote sensing images.

Only a few remote sensing image compression methodologies [6] are present based on the survey and it is identified that compression takes place based on the space data systems (CCSDS). The CCSDS standard is enhanced and involved in the literature that involves various decoding methods. A CNN [7] is used to determine the best compression methodology and accordingly the quality of the image will be maintained sufficiently. In order to achieve high quality, 2 CNNs are joined together, resulting in image compression at an optimal scale. In this proposed work, the proposed CNN technique is designed with the ability to compress the image into readable information with the help of Lempel Ziv Markov chain Algorithm (LZMA) [8]. Thus the image is encoded on transmission. At the receiving end, this information is decoded and reconstructed to brain the original image which is of high quality. It was observed that the proposed methodology was compatible with a number of standards and is suitable for use in many applications. The output of this work was also compared with several other results like JPEG2000, JPEG, binary tree [9] and optimized truncation, taking into consideration the parameters such as space saving, reconstructed image quality and compression efficiency [10-12]. The output thus obtained proved that the proposed work is more effective when compared to the other methodologies.

2. Literature Review

In the beginning a number of control approaches were proposed incorporating predictive coding which resulted in image compression [13-14]. In [15] an image compression methodology that uses compressed sensing and universal scalar quantization for multispectral images was developed. Using the compression methodology, a hyperspectral image is developed holding information. One of the most popular compression technique is that of embedded coding which uses a stream of bits to denote a pixel [16] and is rebuilt at the receiving end to reconstruct the image. Another effective coding algorithm is that of Embedded Block Coding (EBC) as shown in [17] by the authors. This was further extended by the researchers in [18] who invented EBC with optimized truncation. Here each malforming subband is partitioned into many independent code-blocks such that every block can be used for truncation at a specific bit rate.

It has been observed that the non-significant coefficients are represented with the help of zero tree's root [19]. A number of binary tree-based coding techniques are designed to further compress the high resolution image. In [20] the authors also introduced a binary tree codec adaptively which compresses the image with high degree of accuracy and efficiency. A review of this algorithm lead to the development of good quality reconstructed images. Similarly, the authors in [21] compressed the images with the help of quad tree-based coding methodologies. In recent years, deep learning algorithms are used in both lossless as well as lossy image compression methodologies which proved to have high quality outcomes. The authors in [22] and [23] also proposed the use of Recurrent Neural Network (RNN) for compression or lossy images along with variable rate image compression technique.

Apart from these techniques, the authors in [24] presented the possibility of full resolution and reduction in distortion with the help of RNN methodology. However the drawback faced with this approach is that they cannot be employed using the evaluation parameters. In [25] the authors have introduced compressive auto encoders with the help of approximation. Non-linearity and standardized divisive normalization is combined by the authors in [26] using additive uniform noise to replace the quantization factor. Thus the reviewed methodologies indicate that optimal outcome in image compression is possible by incorporating deep learning techniques. The restriction of image usage with high resolution is thus eliminated and the methodology introduced indicates higher compression efficiency [27-28]. Moreover, CNN paves way to the detection of essential features automatically, without the need for human interference, which is the biggest advantage of the proposed work.

3. Materials and Methods

An image coded based on Lempel Ziv Markov chain algorithm (LZMA) and two CNNs are incorporated in the proposed model. In order to reconstruct images at a high quality in a precise manner, the structural data of the image is preserved by representing the input image in a compact manner at the encoding side. The quality of the reconstructed image is boosted by using another CNN at the decoder. High quality and image compression is achieved by integrating both the CNNs with one another. At the encoding and decoding side, the CNNs are represented by (E) and (D) respectively. LZMA is represented by (L). The input image related spatial information is retained by the encoding side CNN that aids in reconstruction of the image decoded by another CNN. At the CNN, convolution and ReLU integration is performed. Patches overlapping with the original image and illustrations, are extracted, and filtered out at the first layer. 64 feature maps are created using 3 × 3 × c sized 64 filters where the total image channels are represented by c. Further, the activation function used in this work is ReLU nonlinearity. Convolution operations are used for performing feature enhancement and downscaling by the addition of an extra layer. Convolution layer, batch normalization layer and ReLu layer are used in combination at the decoding side of the CNN. At the second layer, 3 × 3 × 64 sized 64 filters are used. Along with ReLU and convolution, batch normalization is integrated. Image reconstruction is performed with 3 × 3 × 64 sized c number of filters at the final layer. The training phase and results are enhanced by employing residual learning and batch normalization process. Bicubic interpolation process is used for reversing the process of down-sampling the input images to the compressed images. Figure 1 provides the architectural flow of the proposed system.

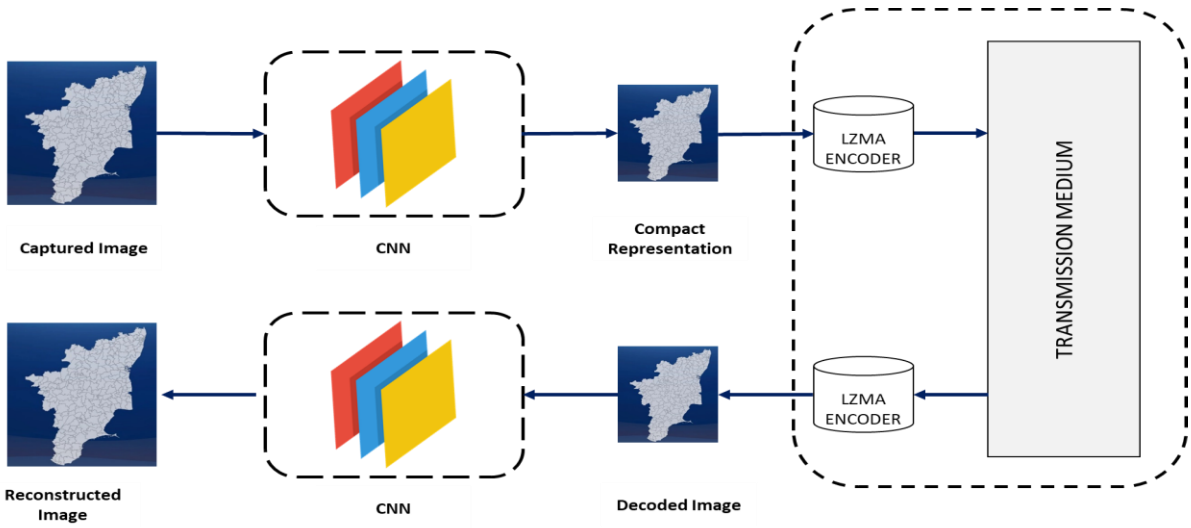

Figure 1. Structural design of the proposed architecture

The image size is minimized by using an image codec based on the LZMA algorithm after implementation of the CNN technique. Complex data structures are used with the concept of dictionary-based encoding technique by the lossless compression algorithm termed as

LZMA. In a real-time environment, the generated data is encoded at a speed of 10-20Mbps using the variable length dictionary. Similar to other schemes, decompression speed is required when large dictionaries are used. When compared to other compression techniques, similar decompression speed is achieved despite the use of a large-sized dictionary. Range encoder, sliding dictionary and delta filter are used to create the modified Lempel-Ziv algorithm. A sliding window is used for modification and compressing the input data effectively at the delta filter. Rather than the entire file, variations in the sequential data are considered for data compression. Among the previous and present bytes, the corresponding bytes are stored in several parts as the first-byte delta encoding result. When compared to the decoding technique, the level of difficulty with sliding dictionary encoding is high as the longest match has to be detected by this. An improved Compression Ratio (CR) is achieved by encoding all the symbols in the message with the help of a range encoder.

4. Results

A 1TB HDD 8, GB RAM, Intel Core i3 PC are used for execution of the proposed model. With respect to space saving, Peak Signal to Noise Ratio (PSNR), Root Mean Square Error (RMSE), MSE, bit rate, compression factor, and compression ratio, the optimal compression technique and its performance are validated. JPEG2000, JPEG, and BTOT imaging techniques are used for the purpose of comparison. For the purpose of experimentation, an aerial satellite based remote sensing image dataset is used. 20 images of size 1024x1024 are used for training the model. Testing is performed with 5 images. The testing images are not included in the training set. The size of the images are around 3000 kB. Bit rate, CF (Compression Factor) and CR (Compression Ratio) parameters are analyzed during image processing. The ratio of total bits in the original and compressed image is termed as CR and it ranges between 0 to 1. It is essential to maintain a low CR value. Negative compression is observed when the value of CR exceeds 1. However, the value of CF should be maintained at a higher range as it is the inverse of CR. In the compressed image, the total bits essential to represent a pixel is estimated with the bit rate or bits per pixel (bpp). Figure 2 provides the comparison of the existing and proposed models with respect to the compression efficiency.

PSNR, RMSE and MSE values are measured for analyzing the quality of the reconstructed image. The decompressed and actual images and their variations are computed extensively with the MSE value. To obtain better results, the MSE value should be close to zero and lies between 0 to 65. SS (Space Saving), packet size and bit rate are further analyzed.

The reduction of the file size to its uncompressed form is indicated and the compression technique is validated with SS. SS value must be approximately 100% to obtain optimal efficiency of compression. The compressed data is saved that leads to saving a large amount of storage space with higher SS value. The proposed model and existing schemes are compared in terms of SS, compressed packet size and compressed file size. Figure 3 provides the comparison of the proposed model and existing schemes with respect to PSNR value.

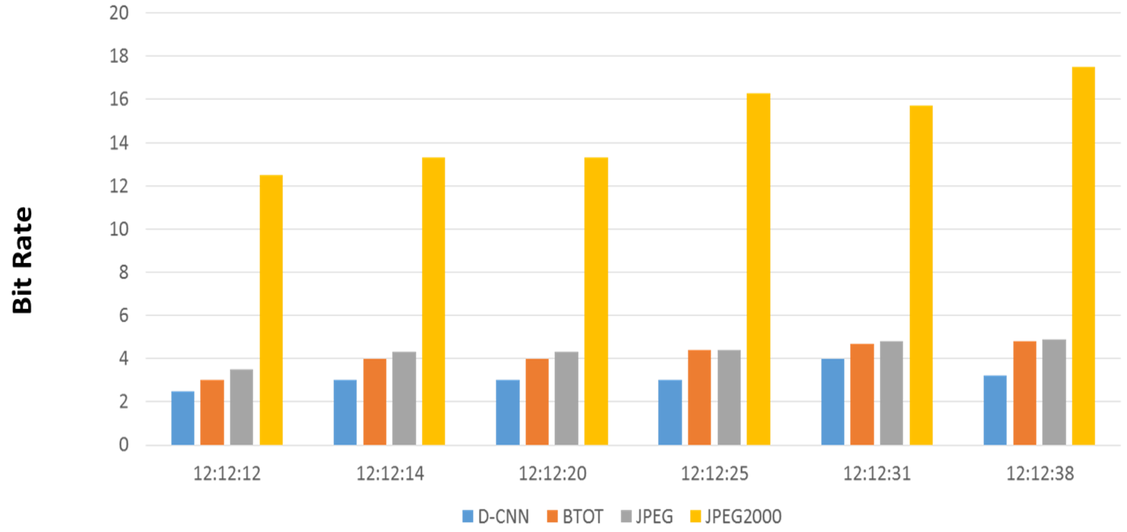

Figure 2. Comparison of various schemes with respect to compression efficiency

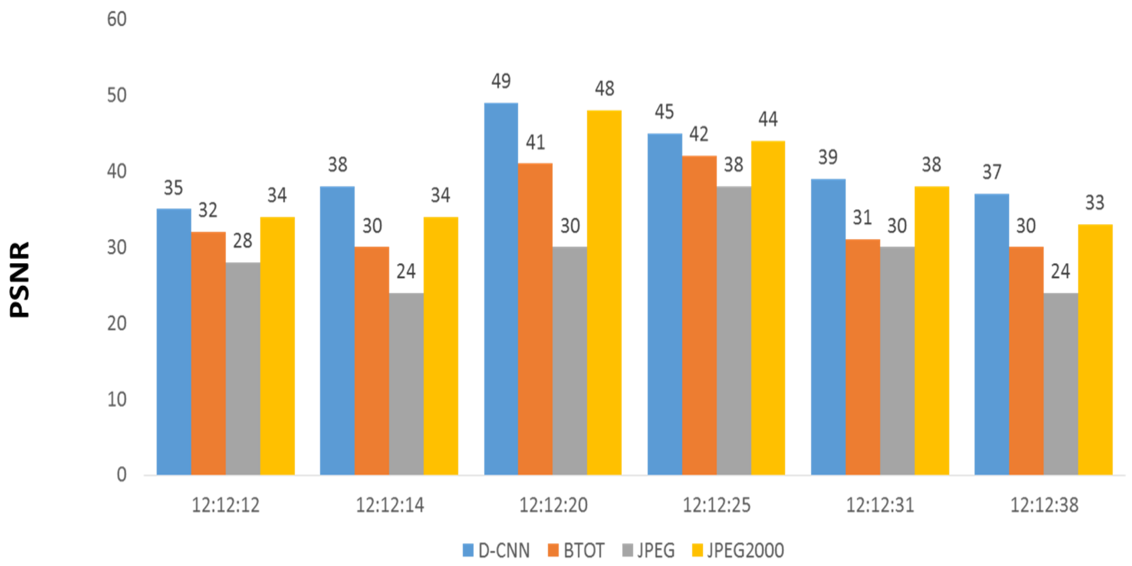

Figure 3. PSNR value comparison of proposed and existing schemes

From the comparison, it is evident that the proposed model is optimal for processing remote sensing images due to lesser resource requirements. Lesser packets are required for data transmission while achieving maximum CR, and a lossless transmission is achieved with the proposed algorithm. Quality of the image is maintained and better performance is achieved in terms of image compression with the proposed algorithm. Maximum PSNR and minimum MSE values are achieved with lossless compression performance while using JPEG2000. However, in terms of SS and CR, the values were considerably low due to the low efficiency of compression. In case of remote sensing image transfer, this technique is impractical due to the need for more resource utilization. Better bit rate, SS and CR values are offered with JPEG however, there is a tradeoff between the image quality and compression efficiency in this technique. Hence, it is not suitable for remote sensing applications. Image quality loss is not preferred due to the valuable data availability in each pixel in remote sensing images. Figure 4 presents the comparison of image quality and efficiency of the proposed and existing models.

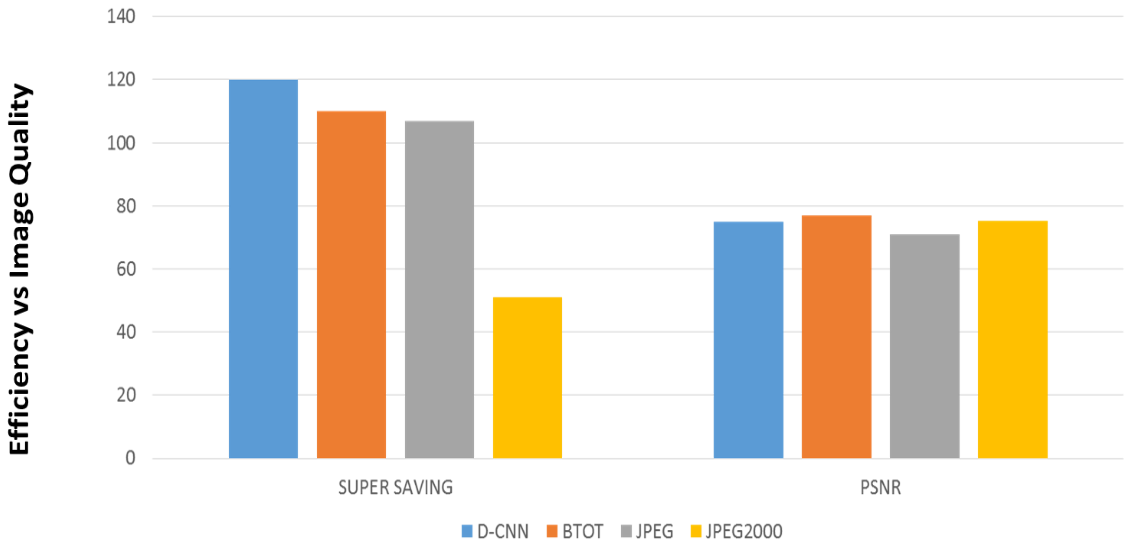

Figure 4. Image quality and efficiency comparison of proposed and existing models

5. Conclusion

Remote sensing images are processed using a novel CNN based image compression technique as presented in this paper. An optimal image compression model is developed by connecting two CNNs together in order to achieve an improved tradeoff between the efficiency of compression and the image quality. The actual image is learnt for the compact demonstration using the CNN model in the proposed technique. This consists of the structural information which is further coded with the help of LZMA. High quality reconstructed image is obtained by reconstruction of the encoded image for retrieving the original image. A space saving of 90% and an average PSNR of 50dB is achieved by the proposed model which is higher than the existing models. For processing remote sensing images, the proposed technique offers a simplified and easy to execute solution. Future work is directed towards implementing the simulated model on real-time hardware. Further, various applications can be executed with the proposed model to test the validity and performance. Total hidden layers, learning rate, epoch size and other such CNN model hyper parameters can also be enhanced to improve the performance of the proposed model.

References

[1] Indumathi, V., and S. Prabakeran. "A Comparative Analysis on Sensor-Based Human Activity Recognition Using Various Deep Learning Techniques." In Computer Networks, Big Data and IoT, pp. 919-938. Springer, Singapore, 2021.

[2] Haoxiang, W., & Smys, S. (2020). MC-SVM Based Workflow Preparation in Cloud with Named Entity Identification. Journal of Soft Computing Paradigm (JSCP), 2(02), 130-139.

[3] Sueiras, J., Ruiz, V., Sanchez, A., & Velez, J. F. (2018). Offline continuous handwriting recognition using sequence to sequence neural networks. Neurocomputing, 289, 119-128.

[4] Manoharan, J. S. (2021). Capsule Network Algorithm for Performance Optimization of Text Classification. Journal of Soft Computing Paradigm (JSCP), 3(01), 1-9.

[5] Maalej, R., & Kherallah, M. (2020). Improving the DBLSTM for on-line Arabic handwriting recognition. Multimedia Tools and Applications, 79(25), 17969-17990.

[6] Ruth Anita Shirley D., Ranjani K., Arunachalam G., Janeera D.A. (2021) Automatic Distributed Gardening System Using Object Recognition and Visual Servoing. In: Ranganathan G., Chen J., Rocha Á. (eds) Inventive Communication and Computational Technologies. Lecture Notes in Networks and Systems, vol 145. Springer, Singapore. https://doi.org/10.1007/978-981-15-7345-3_30

[7] Sathesh, A., & Adam, E. E. B. (2021). Hybrid Parallel Image Processing Algorithm for Binary Images with Image Thinning Technique. Journal of Artificial Intelligence, 3(03), 243-258.

[8] Koresh, H. James Deva, and Shanty Chacko. "Classification of noiseless corneal image using capsule networks." *Soft Computing* 24, no. 21 (2020): 16201-16211.

[9] Huang, K., Hussain, A., Wang, Q. F., & Zhang, R. (Eds.). (2019). Deep learning: fundamentals, theory and applications (Vol. 2). Springer.

[10] Amin, Sujit S., and Lata Ragha. "Alphanumeric Character Recognition on Tiny Dataset." In International conference on Computer Networks, Big data and IoT, pp. 657-667. Springer, Cham, 2019.

[11] Suma, V. (2019). Computer vision for human-machine interaction-review. Journal of trends in Computer Science and Smart technology (TCSST), 1(02), 131-139.

[12] Dhaya, R. "Light Weight CNN based Robust Image Watermarking Scheme for Security." Journal of Information Technology and Digital World 3, no. 2 (2021): 118-132.

[13] Carbune, V., Gonnet, P., Deselaers, T., Rowley, H. A., Daryin, A., Calvo, M., ... & Gervais, P. (2020). Fast multi-language LSTM-based online handwriting recognition. International Journal on Document Analysis and Recognition (IJDAR), 23(2), 89-102.

[14] Jacob, I. J. (2019). Capsule network based biometric recognition system. Journal of Artificial Intelligence, 1(02), 83-94.

[15] Boufenar, C., Kerboua, A., & Batouche, M. (2018). Investigation on deep learning for off-line handwritten Arabic character recognition. Cognitive Systems Research, 50, 180-195.

[16] Dhaya, R. "Efficient Two Stage Identification for Face mask detection using Multiclass Deep Learning Approach." Journal of Ubiquitous Computing and Communication Technologies 3, no. 2 (2021): 107-121.

[17] Hamdan, Y. B. (2021). Construction of Statistical SVM based Recognition Model for Handwritten Character Recognition. Journal of Information Technology, 3(02), 92-107.

[18] Shibly, Mir Moynuddin Ahmed, Tahmina Akter Tisha, and Shamim H. Ripon. "Stacked Generalization Ensemble Method to Classify Bangla Handwritten Character." In Proceedings of International Conference on Sustainable Expert Systems, pp. 621-638. Springer, Singapore, 2021.

[19] Baldominos, A., Saez, Y., & Isasi, P. (2019). Hybridizing evolutionary computation and deep neural networks: an approach to handwriting recognition using committees and transfer learning. Complexity, 2019.

[20] Dutta, K., Krishnan, P., Mathew, M., & Jawahar, C. V. (2018, August). Improving cnn-rnn hybrid networks for handwriting recognition. In 2018 16th international conference on frontiers in handwriting recognition (ICFHR) (pp. 80-85). IEEE.

[21] Sinha, Gita, and Shailja Sharma. "Offline Handwritten Devanagari Character Identification." In International conference on Computer Networks, Big data and IoT, pp. 457-464. Springer, Cham, 2019.

[22] Altwaijry, N., & Al-Turaiki, I. (2021). Arabic handwriting recognition system using convolutional neural network. Neural Computing and Applications, 33(7), 2249-2261.

[23] Shakya, Subarna. "Unmanned Aerial Vehicle with Thermal Imaging for Automating Water Status in Vineyard." Journal of Electrical Engineering and Automation 3, no. 2 (2021): 79-91.

[24] Lakkannavar, Banashankaramma F., M. M. Kodabagi, and Susen P. Naik. "Signature Recognition and Verification Using Zonewise Statistical Features." In International conference on Computer Networks, Big data and IoT, pp. 748-757. Springer, Cham, 2019.

[25] Baldominos, A., Saez, Y., & Isasi, P. (2018). Evolutionary convolutional neural networks: An application to handwriting recognition. Neurocomputing, 283, 38-52.

[26] Smys, S., Chen, J. I. Z., & Shakya, S. (2020). Survey on Neural Network Architectures with Deep Learning. Journal of Soft Computing Paradigm (JSCP), 2(03), 186-194.

[27] Ahlawat, S., Choudhary, A., Nayyar, A., Singh, S., & Yoon, B. (2020). Improved handwritten digit recognition using convolutional neural networks (CNN). Sensors, 20(12), 3344.

[28] Jacob, I. J., & Darney, P. E. (2021). Design of Deep Learning Algorithm for IoT Application by Image based Recognition. Journal of ISMAC, 3(03), 276-290.

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