2022 25th International Conference on Computer and Information Technology (ICCIT)
17-19 December 2022, Cox's Bazar, Bangladesh

Intelligent Door Controller Using Deep Learning-Based Network Pruned Face Recognition

Prangon Das*, Nurul Amin Asif*, Md. Mehedi Hasan*, Sarafat Hussain Abhi*,
Mehtar Jahin Tatha*, Swarnali Deb Bristi*
*Department of Mechatronics Engineering, Rajshahi University of Engineering & Technology, Bangladesh
Email: prangon.ruet.mte@gmail.com, asifamin.ruet@gmail.com, mmehedihasann@gmail.com, sarafat.rueteee@gmail.com,
tathamehtar245@gmail.com, bristidev030@gmail.com

***Abstract*—Nowadays, our home is designed with various technologies which have increased our living comfort and offering more flexibility. Installing various technology in our Home makes it a smart home and we also call this installation process Home Automation. The popularity of Home Automation systems is increasing rapidly and it develops the quality of living. Home automation offers automatic light, fan, temperature, etc. control and also an automatic alarming system to alert the people, etc. Already there are various techniques have been used for implementing Home Automation. Here, in this paper, an intelligent door controller, an application of home automation is presented by using deep learning techniques. An intelligent door basically opens automatically and closes after a predefined time based on the person coming in front of the door. If a person is known then the door will be opened and after his/her entrance the door will be closed automatically. And if the person is not known then the door will remain closed. Here to identify the person, the person's face is recognized by using deep learning. As well ass, Arduino and Servo motors are used to control the door opening or closing.**

***Index Terms*—Automatic door control, Face recognition, Arcface, Servo motor, Home automation**

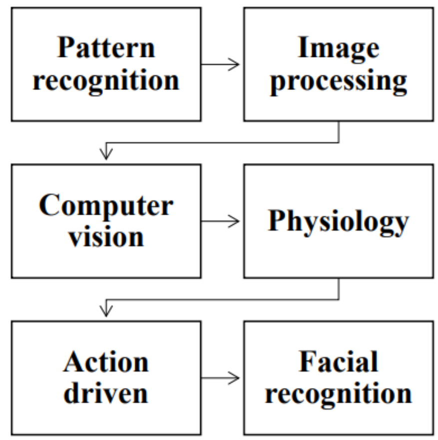

Fig. 1: Generic diagram of facial recognition system

I. Introduction

Current artificial intelligence-based technologies should not only suit people's incredibly diverse functional needs, but also their increasingly individualized experience and interactive wants. Artificial intelligence is a depiction of the iterative growth of computer information technology. As a result, in order to continuously enhance the user experience, contemporary artificial intelligence-based products need to include a particular feedback system [1]. There is a stronger emphasis on experience design in user experience design since it considers if individuals can have an emotional response to using the device. In terms of the major development path for human-computer interaction, the facial recognition-based feedback system that employs artificial intelligence and addresses the human emotion component as the design goal has progressively taken the lead from the standpoint of the user experience [2]. It is a critical stage in the creation of the facial recognition feedback system that uses artificial intelligence to improve social interaction [3]. Secondly, as a result of the iterative development of artificial intelligence technology, the continuous updating of the level of intelligent chip technology, and the noticeably improved level of artificial intelligence software and hardware development, human-computer interaction has developed into an essential component of intelligent design life.

Additionally, the demand for artificial computer intelligence is rising in different applications, like biomedical sectors [4], [5], autonomous vehicles [6], and so on. Different application scenarios and feedback mechanisms have been created and are currently in use. Beside that, face recognition [7] is progressing toward becoming more sophisticated and human.In the case of identity and information security, which has emerged as a major obstacle to be overcome, face recognition has developed into a substantial organic component of human-computer feedback systems. A friendly and useful way to gather data is through biometrics. Face recognition analyzes a face's feature data and identifies the provided face image using an existing face database. Figure 1 illustrates the variety of topics and characteristics it encompasses. It is widely utilized in various fields because combining the benefits of different fields can determine identity, capacity, and function. Studying the face recognition feedback system based on AI applied to intelligent chips is therefore very useful in real-world applications [8].

979-8-3503-4602-2/22/$31.00 ©2022 IEEE

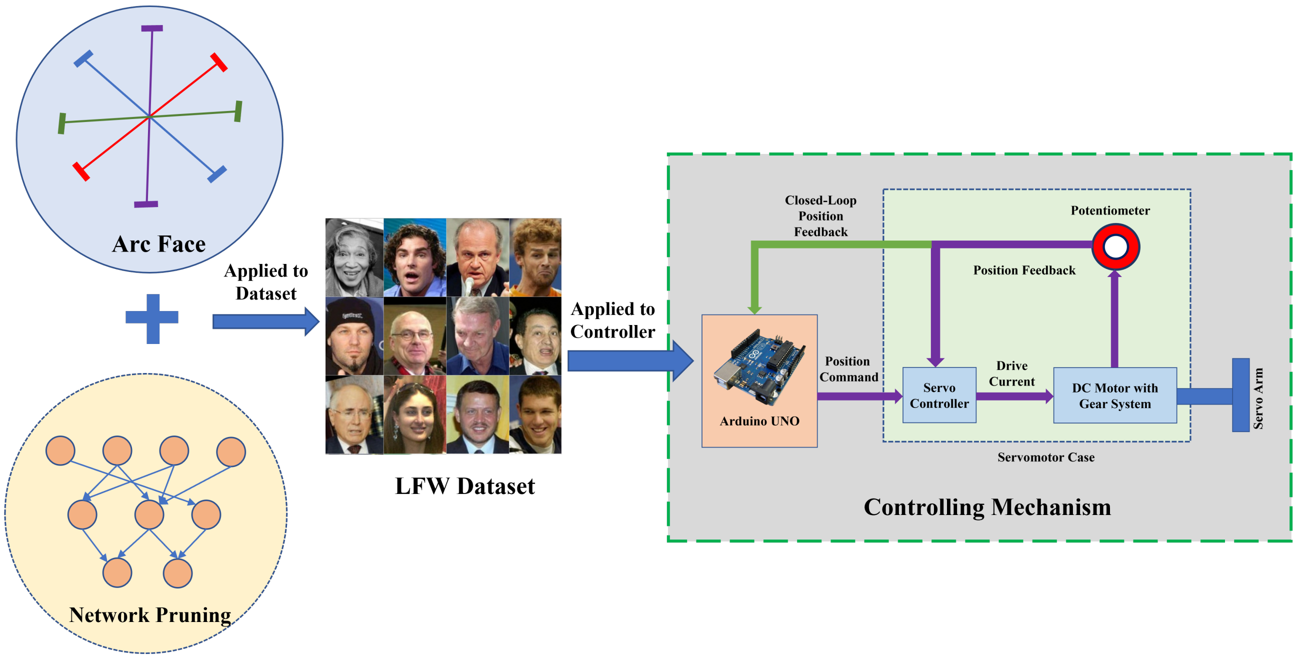

Fig. 2: Overall methodology of the system

II. Literature Review

This section's main emphasis is on the research initiatives that came before this research activity. However, this also entails researching how to create artificial intelligence-based door automation systems [9]. It is important to note that few studies have attempted to use the aforementioned artificial intelligence tools to solve the issues. Academics have nonetheless proposed a range of automatic door solutions. Despite this, academics have proposed a variety of automated door systems. In a different study, [10] proposed a fuzzy logic-based automatic door controller. Fuzzy logic was used to extend the opening distance and speed of the door. According to the article, 25 principles were used to construct a heuristic fuzzy logic controller for controlling the system controller. However, applying fuzzy logic in this circumstance does not make the system clever because it is designed in the "if A then B approach." The system is unable to think things through before acting. Facial detection and recognition-based automated door access system was recommended by the study [11], which is referenced below. Using the Principal Component (PCA) Analysis method, pertinent features from facial photographs were identified and passed to the microcontroller for authentication. The Matlab software's output, which served as a detection and recognition system, is sent to the microcontroller for further processing. Even if PCA successfully reduces the resulting feature dimensions. However, given that facial data must be transformed into grayscale images, convolutional neural networks (CNN) can do this task better. A person identification and intention analysis-based automatic door system were recommended by [12]. This project aims to eliminate the inappropriate behaviors of the door system through the implementation of a behavior analysis system that enhances task accuracy. Before using trajectory tracking and statistical analysis to identify an object's intent, the researchers first use contour detection to determine whether it is a human. After the intention was identified and confirmed, the system was able to respond in about 2 seconds with a low false activation rate and a high rate of accurate activation.

III. Methodology

This section illustrates how an end-to-end network pruned arcface face recognition model is used by an intelligent door controller. The overall overview of the system has been foreshadowed in fig. 2 where it can be seen that An Arcface + Network Pruned deep learning model has been trained with LFW dataset which is next applied to a controller for the controlling mechanism of the motor for intelligent door locking. There are two parts to the embedded system we propose: 1) An Arcface + network-pruned face recognition model, and (2) an Arduino and face recognition API connection mechanism which are discussed in the following subsections accordingly.

A. *ArcFace*

A loss function used in facial recognition applications is called ArcFace, or Additive Angular Margin Loss [14]. Traditionally, the softmax is employed for these jobs. Because the softmax loss function does not explicitly optimize the feature embedding to impose more similarity for intraclass samples and diversity for interclass samples, deep face recognition suffers from a performance gap under significant levels of intra-class variation. The Arcface loss for face recognition mechanism has been illustrated in fig. 6.

As the embedding features are scattered around each feature center on the hypersphere, we apply an additive angle margin

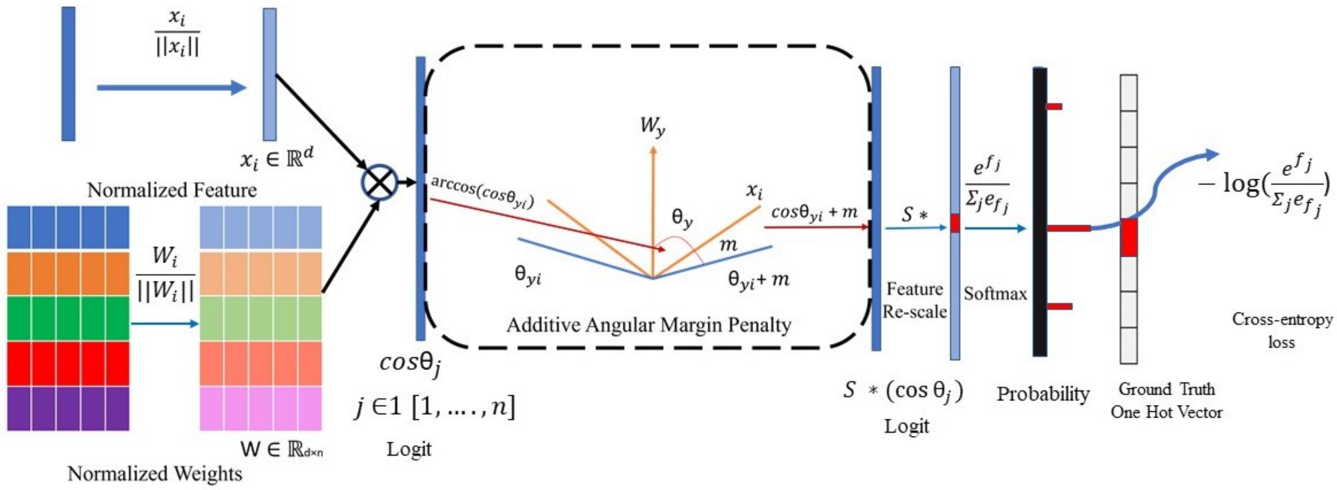

Fig. 3: Training a DCNN under the supervision of the ArcFace loss for face recognition [13].

Algorithm 1: The Pseudo Code of ArcFace

Input: Features Scale ss, Margin Parameter M, Class number n, Ground Truth ID gt

1. X = L2Normalization(X)
2. W = L2Normalization(W)
3. FC1 = FullyConnectedLayer(X, W, hidden_node=n)
4. OriginalTargetLogit = Pick(FC1, gt, axis=1)
5. Θ = COS^{-1}(OriginalTargetLogit)
6. MarginalTargetLogit = COS(Θ + M)
7. OneHotEncoding = Numpy.Utils.to Categorica (gt, num classes=n)
8. FC1 = FC1 + Numpy.Mul(OneHotEncoding, MarginalTargetLogit – OriginalTargetLogit)
9. FC1 = FC1 * ss

Output: Classwise affinity Score FC1

penalty m between x_i and W_{y_i} to simultaneously increase the intra-class compactness and inter-class discrepancy. Because the proposed additive angular margin penalty is the same as the geodesic distance margin penalty in the normalized hypersphere, we refer to our approach as ArcFace. The pseudo code has been illustraded in Algorthm 1 [13].

B. Network Pruning

Neural network pruning is a technique that is based on the logical notion of removing unnecessary components from a network that functions well but consumes a lot of resources. Large neural networks have in fact repeatedly demonstrated their ability to learn, but it turns out that not all of their components remain effective after training is complete. The goal is to get rid of these components while maintaining network performance [15].

The overall learning process of the iterative pruning algorithm has been summarized in Algorithm 2 [16].

C. API Connection Mechanism of Arduino with DC servo Motor

A DC servo motor that uses an open-loop system is one that cannot serve as a feedback reference while the motor is operating. As a result, there is no way for the system to detect faults or confirm that it is working effectively. By connecting a DC servo motor to an external controller, open-loop control of a servo system is made possible. The servo motor does not offer any feedback references of its own in this configuration. This is not an open-loop servo motor. The servo controller receives position feedback from the motor's "internal feedback" system. A potentiometer receives position feedback from the servo gear system. The reading from the potentiometer is then translated into values of a voltage, which correspond to the positions of the servo shaft [17]. The "internal feedback" qualities have the drawback of being limited to position feedback for the internal servo controller of the motor. These functionalities can only be used in this manner. The block design of an open-loop DC servo motor with "Internal" voltage feedback is shown in Fig. 4

Algorithm 2: The iterative pruning with uncertainty regularization learning procedure

Input: The sentiment classifier $\mathcal{M}_1$ for tasks 1; the released weights W_1^F; the preserved weights W_1^P.
Output: The sentiment classifier $\mathcal{M}_K$ for tasks 1 to K.

1: **for** each task $k = 2$ to K **do**
2: Pre-train a initial model for task k by updating released parameters W_{k-1}^F via cross-entropy loss $\mathcal{L}_{CE}$;
3: Update the preserved weights $W_{1:k-1}^P$ for tasks 1 to $k-1$ with uncertainty regularization via $\mathcal{L}_{CE} + \mathcal{L}_{REG}$;
4: Perform network pruning on released weights W_{k-1}^F and obtain released weights W_k^F for learning subsequent tasks;
5: Obtain temporal preserved weights W_k^P for task k as $W_k^P = W_{k-1}^F \setminus W_k^F$;
6: Re-train W_k^P for a smaller number of epochs, and get the overall preserved weights $W_{1:k}^P$ for tasks 1 to k as $W_{1:k}^P = W_{1:k-1}^P \cup W_k^P$.
7: **end for**

The preserved weights $W_{1:K}^P$ are used to build sentiment classifier $\mathcal{M}_K$.

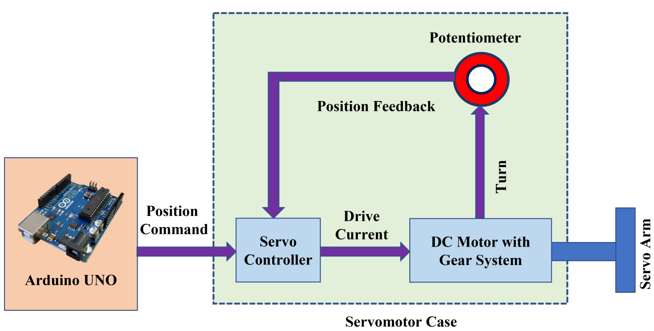

Fig. 4: The block design of an open-loop DC servo motor with "Internal" voltage feedback [17]

A closed-loop DC servo motor, on the other hand, has an operating system with a built-in feedback mechanism. As a result, the system can compare the output's anticipated and actual circumstances. The existence of closed-loop feedback acting as the primary controller for a DC servo motor is incredibly beneficial [17].

The motor's location at the moment may be determined, and any mistakes can be located and fixed. In some types of DC servo motors that are currently on the market, closed-loop feedback may take the form of voltage (potentiometer) or pulses (encoder).

These feedbacks operate in a manner that is quite similar to the "internal" feedback, which is proportional to the angular position of the motor shaft. The main subject of this essay is the use of a DC servo motor with voltage position feedback.

The voltage range of the closed-loop voltage feedback type's

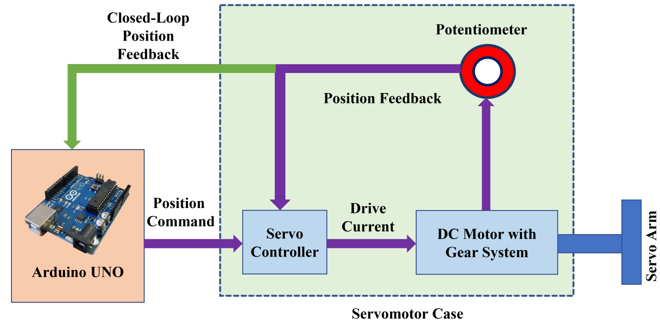

Fig. 5: DC servo motor block schematic with closed-loop voltage feedback [17]

potentiometer, which is located inside the servo motor casing, is almost probably the same as that of the "internal" voltage feedback. Figure 5 depicts the block diagram of a DC servo motor with closed-loop voltage feedback.

IV. Datasets & Results

In the next part, we explicate the experimental setup and quantitative findings, as well as the datasets that were utilized to train the arcface + network pruning face recognition model.

A. Experimental Settings & Datasets

For this experiment, we have utilized PyTorch to fine-tune a facial recognition model. The SGD optimizer is utilized across functions. Due to a computational limitation, the batch size is fixed to 64. Primarily, we have used LFW (Labelled Faces in the Wild) dataset [18]. Labeled Faces in the Wild (LFW) is an image dataset containing face photographs, collected especially for studying the problem of unconstrained face recognition. It has over 13 thousands images collected from the world wide web.

TABLE I: Comparison of testing accuracy between proposed model and other models based on our dataset

Face Recognition Model	Accuracy	Interface
CNN + Softmax [19]	80%	Slow
FaceNet [20]	85%	Fast
RetinaFace [21]	87%	Medium
ArcFace [13]	90%	Slow
ArcFace + Network Pruning	90%	Fast

B. Result

In the beginning, we just employed the arcface face recognition model in our dataset. The slow interface was a disadvantage of employing solely the arcface face recognition model.To address this problem, we employed Arcface and the Network pruning model concurrently to achieve 90% accuracy and a quick interface.

Table 1 shows the comparison based on testing accuracy and interface between our proposed model and other face

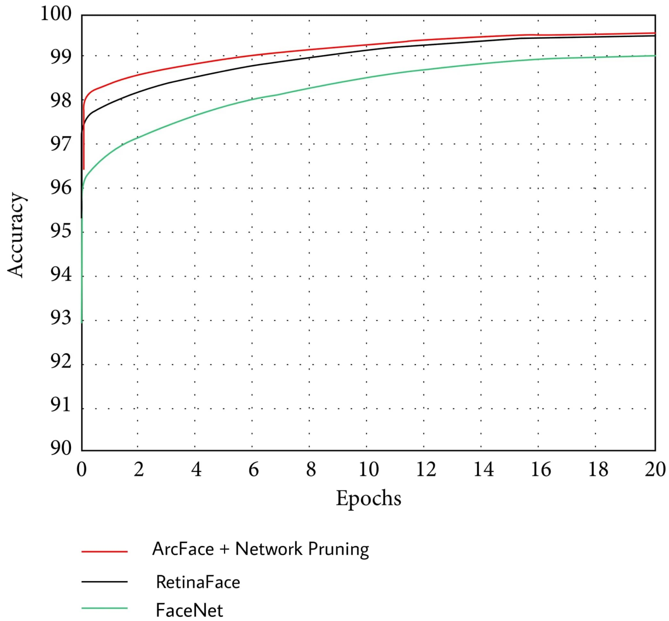

Fig. 6: A graphical representation of training result on different face recognition models

recognition models. Figure 6 depicts a graphical depiction of the training result our proposed approach and another face recognition model. Among them, our model exhibits exceptional accuracy.

C. Conclusion

Images are maintained in a database in this suggested door access system employing face recognition. This technique is employed for door lock access in both residential and business settings. This study offers an analysis of a real-time facial recognition system utilizing the arcface algorithm based on the current issues. We have also employed network pruning to achieve a real-time facial recognition-based door locking system and to speed up inference. As a result, this research implements a real-time face identification method based on arcface and network pruning that can ignore the impact of various expressions, angles, and sizes. In order to avoid the impacts of different expressions, angles, and sizes, this study implements a real-time face identification approach based on the arcface model and network pruning strategy. This system can detect human faces with a high degree of recognition speed and accuracy and a recognition efficiency of 90%. We demonstrate that our method frequently outperforms the state of the art using the most rigorous examination.

REFERENCES

[1] L. Feng, J. Wang, C. Ding, Y. Chen, and T. Xie, "Research on the feedback system of face recognition based on artificial intelligence applied to intelligent chip," in *Journal of Physics: Conference Series*, vol. 1744, no. 3. IOP Publishing, 2021, p. 032162.

[2] B. Zhu, D. Zhang, Y. Chu, X. Zhao, L. Zhang, and L. Zhao, "Face-computer interface (fci): Intent recognition based on facial electromyography (femg) and online human-computer interface with audiovisual feedback," *Frontiers in Neurorobotics*, vol. 15, 2021.

[3] C. Marechal, D. Mikolajewski, K. Tyburek, P. Prokopowicz, L. Bougueroua, C. Ancourt, and K. Wegrzyn-Wolska, "Survey on ai-based multimodal methods for emotion detection." *High-performance modelling and simulation for big data applications*, vol. 11400, pp. 307–324, 2019.

[4] M. Mashiata, T. Ali, P. Das, Z. Tasneem, F. R. Badal, S. K. Sarker, M. Hasan, S. H. Abhi, M. R. Islam, F. Ali *et al.*, "Towards assisting visually impaired individuals: A review on current status and future prospects," *Biosensors and Bioelectronics: X*, p. 100265, 2022.

[5] C. Das, A. A. Mumu, M. F. Ali, S. K. Sarker, S. M. Muyeen, S. K. Das, P. Das, M. M. Hasan, Z. Tasneem, M. M. Islam, M. R. Islam, M. F. R. Badal, M. H. Ahamed, and S. H. Abhi, "Towards iort collaborative digital twin technology enabled future surgical sector: Technical innovations, opportunities and challenges," *IEEE Access*, pp. 1–1, 2022.

[6] A. Biswas, M. O. Reon, P. Das, Z. Tasneem, S. Muyeen, S. K. Das, F. R. Badal, S. K. Sarker, M. M. Hassan, S. H. Abhi *et al.*, "State-of-the-art review on recent advancements on lateral control of autonomous vehicles," *IEEE Access*, 2022.

[7] T. Ahmed, P. Das, M. F. Ali, and M.-F. Mahmud, "A comparative study on convolutional neural network based face recognition," in *2020 11th International Conference on Computing, Communication and Networking Technologies (ICCCNT)*. IEEE, 2020, pp. 1–5.

[8] P. Das, T. Ahmed, and M. F. Ali, "Static hand gesture recognition for american sign language using deep convolutional neural network," in *2020 IEEE Region 10 Symposium (TENSYMP)*. IEEE, 2020, pp. 1762–1765.

[9] S. Sepasgozar, R. Karimi, L. Farahzadi, F. Moezzi, S. Shirowzhan, S. M. Ebrahimzadeh, F. Hui, and L. Aye, "A systematic content review of artificial intelligence and the internet of things applications in smart home," *Applied Sciences*, vol. 10, no. 9, p. 3074, 2020.

[10] H. Sümbül, A. Coşkun, and M. Taşdemir, "The control of an automatic door using fuzzy logic," in *2011 International Symposium on Innovations in Intelligent Systems and Applications*. IEEE, 2011, pp. 432–435.

[11] H. H. Lwin, A. S. Khaing, and H. M. Tun, "Automatic door access system using face recognition," *international Journal of scientific & technology research*, vol. 4, no. 6, pp. 294–299, 2015.

[12] J.-C. Yang, C.-L. Lai, H.-T. Sheu, and J.-J. Chen, "An intelligent automated door control system based on a smart camera," *Sensors*, vol. 13, no. 5, pp. 5923–5936, 2013.

[13] J. Deng, J. Guo, N. Xue, and S. Zafeiriou, "Arcface: Additive angular margin loss for deep face recognition," in *Proceedings of the IEEE/CVF conference on computer vision and pattern recognition*, 2019, pp. 4690–4699.

[14] "MS Windows NT kernel description," https://paperswithcode.com/method/arcface, accessed: 09-12-2022.

[15] H. Tessier, "Neural network pruning 101," https://towardsdatascience.com/neural-network-pruning-101-af816aaea61, 2021.

[16] B. Geng, M. Yang, F. Yuan, S. Wang, X. Ao, and R. Xu, "Iterative network pruning with uncertainty regularization for lifelong sentiment classification," in *Proceedings of the 44th International ACM SIGIR conference on Research and Development in Information Retrieval*, 2021, pp. 1229–1238.

[17] A. S. Sadun, J. Jalani, J. A. Sukor, and B. Pahat, "A comparative study on the position control method of dc servo motor with position feedback by using arduino," in *Proceedings of Engineering Technology International Conference (ETIC 2015)*, 2015, pp. 10–11.

[18] A. ANAND, "Lfw - people (face recognition)," https://www.kaggle.com/datasets/atulanandjha/lfwpeople, 2019.

[19] S. Sharma, K. Shanmugasundaram, and S. K. Ramasamy, "Farec—cnn based efficient face recognition technique using dlib," in *2016 international conference on advanced communication control and computing technologies (ICACCCT)*. IEEE, 2016, pp. 192–195.

[20] F. Schroff, D. Kalenichenko, and J. Philbin, "Facenet: A unified embedding for face recognition and clustering," in *Proceedings of the IEEE conference on computer vision and pattern recognition*, 2015, pp. 815–823.

[21] J. Deng, J. Guo, E. Ververas, I. Kotsia, and S. Zafeiriou, "Retinaface: Single-shot multi-level face localisation in the wild," in *Proceedings of the IEEE/CVF conference on computer vision and pattern recognition*, 2020, pp. 5203–5212.