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ENERGY EFFICIENT FACE RECOGNITION AUTHENTICATION

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Abstract: The objective of this project is to design an energy-efficient face authentication system from face recognition by capitalizing on advancements in deep learning and hardware optimization. With the use of model compression techniques like pruning and quantization, and specialized hardware like Google Coral Edge TPUs, our system achieves tremendous energy savings without affecting accuracy. Our system uses a multi-step procedure beginning with face detection using a light CNN. The detected face is then passed through an energy-conserving compressed face recognition model via methods like knowledge distillation and weight sharing. Our system is further optimized through the utilization of the Google Coral Edge TPU, which is just amazing with minimal energy consumption. We contrast the operation of our system on multiple datasets, such as LFW and IJB-A, and demonstrate that it computes at state-of-the-art accuracy on using less energy than other face recognition systems.

Keywords: Face Recognition, Energy Efficiency, Deep Learning, Model Compression, Hardware Optimization, Edge Computing, Authentication, Biometrics, Security, Google Coral Edge TPUI.

I. INTRODUCTION

Facial recognition is widely used for secure identity verification across fields like security, surveillance, and personal identification. Traditional systems, however, often consume high amounts of energy, making them unsuitable for environments with limited power, such as mobile devices or edge computing platforms. Recent advancements in deep learning and hardware optimization have paved the way for the development of more energy-efficient facial recognition systems.

This paper presents a solution that minimizes power usage while maintaining high accuracy in facial recognition. By incorporating model compression techniques and custom hardware, the system effectively reduces energy consumption without sacrificing performance. It is particularly well-suited for industries such as law enforcement, border control, and smart home security, as well as for deployment in remote or off-grid locations where energy resources are limited.

The paper outlines the system's architecture, including the use of specialized hardware and compression methods, and provides a comparative analysis using various datasets to demonstrate the system's ability to deliver both strong recognition accuracy and reduced power usage. The findings highlight the potential of this energy-efficient solution in a wide range of applications, offering a sustainable and effective approach to facial recognition technology.

II. LITERATURE SURVEY

1. This 2023 research introduces a novel face recognition framework that integrates Convolutional Neural Networks (CNNs) with a Nearest Mean Classifier (NMC) to optimize both performance and efficiency. The CNN component effectively extracts high-level facial features from input images, while the NMC handles classification by comparing these features to the average vectors of known classes. This lightweight classification method significantly lowers the computational overhead typically associated with deep learning models. Through extensive testing on various benchmark datasets, the proposed system showed improved accuracy and faster processing compared to conventional recognition techniques. One of its key advantages is reduced energy consumption, which makes it particularly suitable for low-power platforms such as smartphones and embedded devices. Unlike resource-intensive traditional systems, this hybrid model offers a balanced trade-off between accuracy and efficiency, supporting real-time face recognition without requiring high-end hardware.

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The study demonstrates how blending deep feature extraction with a simple yet effective classifier can result in a robust, scalable solution for modern applications. Overall, this approach contributes to the development of smarter, more sustainable facial recognition technologies.

2. A 2023 practical face recognition system was developed specifically for the Raspberry Pi, addressing the device's limited processing power and memory. The researchers designed a streamlined Convolutional Neural Network (CNN) tailored to work efficiently within the Raspberry Pi's hardware constraints. Their primary goal was to create a real-time facial identification system that balances performance and resource usage without sacrificing accuracy. By optimizing the CNN structure, they successfully reduced the system's computational demands, making it capable of operating smoothly in real-time even on such a low-power platform. The project focused heavily on minimizing energy consumption, which is critical for edge computing scenarios where power availability and processing capabilities are limited. This makes the solution highly suitable for use in portable or remote monitoring systems. The approach not only enhances the device's utility but also demonstrates how deep learning can be adapted for embedded environments without the need for high-end GPUs or cloud processing. The study shows that with thoughtful model design, it's possible to deliver reliable and responsive face recognition on affordable hardware, paving the way for more accessible and decentralized AI applications.

3. This 2022 study introduces a real-time face recognition system aimed at authenticating individuals using live video feeds. A key innovation in the system is its ability to detect and filter out blurry frames, ensuring only the clearest images are used for facial analysis. This selective frame processing boosts recognition accuracy by focusing on high-quality visual input. Additionally, to tackle poor lighting conditions—often a challenge in real-world scenarios—the system incorporates histogram equalization, a technique that enhances image contrast and visibility. By improving image quality before analysis, the model achieves more consistent performance across various lighting and environmental conditions. These enhancements make the system more reliable for real-time applications where consistent image quality cannot be guaranteed. The approach is particularly useful in security or surveillance systems, where live video is the primary source for facial identification. The combination of blur detection and image enhancement allows the model to adapt to imperfect input, resulting in a more robust and dependable authentication process. This research highlights the importance of pre-processing techniques in improving deep learning-based face recognition accuracy, especially in dynamic or uncontrolled environments.

4. The 2022 study outlines the creation of a user-friendly online learning platform tailored for mobile devices, aiming to support innovation and entrepreneurship education. Built using MyEclipse and employing Oracle databases alongside Ajax technology, the platform is structured on a browser/server (B/S) model, enabling efficient access and interaction through mobile web browsers. Core functionalities include secure user login, personalized access, and comprehensive course management tools, designed to offer a smooth and interactive learning experience. The platform was specifically tested for its applicability within Z Company, where researchers assessed its performance using statistical tools such as t-tests and reliability analysis. These evaluations focused on critical factors like system speed, ease of navigation, and overall user satisfaction. Results showed that the platform provided a responsive and engaging environment for learners, highlighting its potential as a scalable digital education solution. By leveraging modern web technologies and focusing on mobile optimization, the system bridges the gap between traditional education and flexible digital learning, offering a practical model for delivering coursework anytime, anywhere. This research emphasizes how thoughtful design and targeted evaluation can result in an effective educational tool suited to current mobile usage trends.

5. This study presents a face recognition system designed to verify student identities during online exams. The system utilizes live video streams to capture real-time images of the students and selects the clearest frames to ensure the most accurate identification. By focusing on the best-quality frames, the system improves its ability to accurately match faces, even in dynamic online settings. To overcome challenges posed by low-light environments, the system integrates histogram equalization, a technique that enhances image brightness and contrast, making the recognition process more reliable under various lighting conditions. The results from experiments demonstrate that this method performs effectively in real-world testing scenarios, offering a reliable solution for identity verification in online exams. The system's ability to work in real-time ensures that it can be deployed during live tests without causing delays. This approach provides a secure, efficient, and practical way to authenticate students remotely, reducing the risk of cheating or impersonation. By improving image quality and focusing on the most relevant frames, the system offers a seamless and trustworthy solution to meet the growing demand for secure online testing environments.

6. The 2020 research presents a face recognition solution tailored to the needs of online examination settings, aiming to ensure secure and reliable student authentication. The system uses live video feeds to verify the identity of examinees, selecting only the sharpest frames for facial analysis.

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This smart frame selection helps minimize errors caused by motion blur or poor camera focus, improving the overall accuracy of the recognition process. To handle environments with inadequate lighting—a common issue in home-based testing—the method incorporates histogram equalization. This technique enhances image contrast, making facial features clearer and more distinguishable even under suboptimal lighting conditions. Through experimental testing, the system proved to be both accurate and efficient in real-time conditions, making it highly practical for remote assessments. Its design ensures that identity verification is continuous and non-intrusive, helping maintain academic integrity without disrupting the test-taking experience. By addressing key challenges like lighting variability and motion blur, this approach delivers a dependable solution for modern e-learning environments. The research underlines the importance of adaptive and intelligent facial recognition in maintaining security in digital education systems, particularly during high-stakes assessments like online exams.

7. This 2022 survey provides a comprehensive examination of the diverse facial recognition technologies used in authentication systems. It organizes these approaches based on the type of input data, covering live video, standard 2D images, infrared imaging, and 3D facial scans. The survey highlights several widely used techniques such as Artificial Neural Networks (ANN), Principal Component Analysis (PCA) through Eigenfaces, Support Vector Machines (SVM), and Hidden Markov Models (HMM). Each method is analyzed in terms of its strengths, limitations, and applicability to real-world authentication scenarios. By comparing both traditional and modern approaches, the study offers valuable insights into how facial recognition has evolved over time. It also touches on the growing importance of hybrid models that combine multiple techniques for improved accuracy and resilience. Additionally, the paper outlines potential future trends, including the integration of deep learning and multi-modal systems. This survey serves as a useful resource for researchers and developers looking to understand the landscape of facial recognition technologies and their role in secure authentication systems. By providing both technical depth and a broad overview, it helps bridge the gap between theoretical research and practical implementation.

8. The 2024 study presents a facial recognition system powered by deep learning, with Convolutional Neural Networks (CNNs) forming the foundation of its architecture. The model is trained on an extensive dataset of facial images, enabling it to learn and distinguish the subtle features that make each face unique. A notable strength of the system is its high-speed recognition, processing inputs within a range of 360 to 390 milliseconds. This rapid response time makes it highly suitable for real-time scenarios such as security checks, access control, and digital identity verification. The term "hybrid" refers to the inclusion of additional techniques or enhancements that work alongside the CNN to improve the model's overall performance and efficiency. The system is designed to deliver both speed and accuracy without placing heavy demands on hardware, making it ideal for environments where real-time decision-making is crucial. This research highlights how a well-optimized deep learning approach can meet the dual demands of precision and responsiveness in biometric applications. It underlines the potential of combining different deep learning strategies to create effective, scalable face recognition solutions for real-world use.

.9. The 2020 study outlines a facial recognition system that divides the process into two key stages: face detection and individual identification. The system employs techniques like Eigenfaces and Fisherfaces to extract significant facial features for recognition. To enhance system performance and speed, Principal Component Analysis (PCA) is integrated to reduce the dimensionality of the data, preserving essential information while making computations more efficient. This approach helps the system process images faster without compromising the accuracy of face identification. The research emphasizes the importance of digital image processing in building robust biometric systems. By focusing on the enhancement of image quality and optimizing the selection of features, the system is able to deliver reliable results even under challenging conditions like low light or varying backgrounds. The use of PCA for data reduction further boosts system efficiency, enabling it to operate with lower computational resources. This method showcases how traditional image processing techniques, when combined with modern data reduction methods, can still offer high-performance facial recognition systems. The findings indicate that this combination of strategies ensures both accuracy and speed, making it suitable for real-time applications in security and identification fields.

10. This 2020 study tackles the challenge of minimizing energy consumption in IoT-based facial recognition systems. The proposed system activates the face recognition process only when human presence is detected, which reduces unnecessary processing and optimizes energy usage. By ensuring that the system only performs facial recognition when needed, it preserves both energy efficiency and security. This approach is particularly useful in smart environments, such as automated homes or offices, where conserving energy is essential. The system strikes a balance between sustainability and effective performance, offering an intelligent solution for real-time authentication while minimizing the environmental impact. It ensures that facial recognition remains robust, but without continuously drawing power. The research highlights the potential for integrating energy-saving strategies into biometric systems, making them more eco-friendly while maintaining high standards of security.

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11. This method not only improves the system's energy efficiency but also ensures that facial recognition remains quick and reliable, making it an ideal choice for smart, energy-conscious settings.

11. This study looks at how facial recognition can be used in IoT-based access control systems while focusing on reducing energy use. The system is designed to only activate the facial recognition process when it detects a person's presence, which helps save energy by avoiding unnecessary processing. This approach makes the system more efficient, ensuring that it only works when needed while still delivering accurate identification. The research emphasizes the need to balance strong security with low energy consumption, offering a practical solution for places where both are important. This method is particularly helpful in smart environments, such as homes or offices, where managing energy is crucial. By ensuring the system is only active when required, it reduces power use without compromising the ability to secure the space. The study shows how combining energy-efficient strategies with reliable facial recognition can create a more sustainable way to control access. This approach is ideal for environments that demand both security and energy savings, making it a smart and practical solution for modern access control systems.

III. PROBLEM IDENTIFICATION

Energy consumption and accuracy: High energy consumption due to continuous operation of authentication systems, need for solutions that conserve energy while maintaining accuracy.

IV. CONCLUSION

Overall, developing an energy-efficient face recognition system via CNN and NMC algorithm combination is a more complicated machine learning algorithm combination and is significantly enhanced by hardware equipment with high processing capacity. Implementation of the hybrid of the CNN and NMC methods best maintains computation complexity and classification ratios in balance and conserves a lot of energy without lowering the system performance whatsoever. The hybrid method gives real-time face recognition with increased strength and accuracy and can solve good performance in different situations. Other than this, a dedicated display module to show energy consumption is allowing transparency and system power consumption knowledge, which will result in more optimization and customer confidence.

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