Ejad: Facial Recognition for Lost People Identification

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Abstract— **Managing lost pilgrims during the Hajj season is a significant challenge due to the high density of crowds in Makkah and the holy sites. This paper proposes an innovative system for managing lost pilgrims based on a centralized database and facial recognition technologies. The system enables immediate identification of lost pilgrims by retrieving their personal information through field-compatible devices, facilitating swift reunification with their assigned groups or campaigns. The proposed solution focuses on providing critical support for vulnerable groups, such as the elderly and children, through integrated AI-driven solutions. Additionally, this system aligns with Saudi Arabia's Vision 2030 by leveraging advanced technologies to enhance the safety and overall experience of pilgrims. The study concludes with recommendations for refining the system to address evolving needs in crowd management.**

Keywords— C*rowd management, Hajj, Umrah, deep learning, Lost pilgrims, facial recognition*

I. Introduction

The issue of getting lost during Hajj is one of the significant challenges faced by pilgrims, especially with the high density of crowds and the diversity of languages and cultural backgrounds. With millions of pilgrims gathering in confined areas like Mina and Arafat, the similarity of tents and landmarks makes navigation difficult and complicates the process of distinguishing locations. Fatigue, extreme congestion, and the physical effort required for Hajj further increase the likelihood of losing directions, particularly among vulnerable groups such as the elderly, children, and individuals with disabilities. Additionally, language barriers often hinder effective communication between pilgrims and field staff, exacerbating the difficulty of providing assistance swiftly.

With advancements in technology, there are greater opportunities to provide innovative solutions to the problem of getting lost during Hajj. Mobile applications offering real-time navigation and guidance, as well as electronic wristbands containing personal information, can facilitate identifying and returning lost pilgrims quickly and efficiently. Moreover, incorporating facial recognition technology into these systems could further streamline the process of identifying lost individuals, even in cases where communication is impossible due to language or physical limitations. While some of these ideas have been implemented, there remains a need to develop more integrated and effective tools and solutions to address this issue, considering the unique circumstances of the Hajj season.

The success of such solutions also depends on their ability to operate efficiently in challenging conditions, such as extreme heat, network congestion, and the limited availability of technical resources in crowded areas. Therefore, it is essential to design systems that are robust, user-friendly, and capable of accommodating the diverse needs of millions of pilgrims. Integrating multilingual support, offline functionality, and seamless communication with field teams would further enhance the effectiveness of these tools. Addressing these challenges through technological innovation aligns with Saudi Arabia's Vision 2030, which emphasizes leveraging advanced technologies to improve the overall Hajj experience while ensuring the safety and well-being of all pilgrims.

Paper Organization

The structure of this paper is organized as follows:

Section **I** Introduction: Highlights the study's motivation, problem, and objectives. Section **II** Literature Review: Reviews prior studies and identifies research gaps. Section **III** Background: Covers foundational concepts and related technologies. Section **IV** Methodology: Explains the CNN architectures, training process, and evaluation metrics. Section **V** Results and Discussion: Analyzes model performance using metrics and graphical results. Section **VI** Conclusion and Future Work: Summarizes findings and suggests future improvements.

II. Literature Review: Human Face Detection and Crowd Management in Hajj and Umrah

The Hajj and Umrah pilgrimages attract millions of Muslims annually to Makkah and Madinah, presenting significant challenges in crowd management. Effective crowd management ensures safety and enhances the pilgrims' overall experience. This literature review focuses on recent advancements in face detection and recognition technologies for crowd management, with specific applications in Hajj and Umrah settings.

Face Detection and Tracking Techniques Improved YOLO Models: Alharbey et al. (2022) proposed a crowd management system based on an enhanced YOLOv4 framework, integrated with adaptive attention mechanisms to improve detection accuracy and reduce false positives. The system assigns unique IDs to detected faces, ensuring accurate tracking and counting, with a reported mAP of 91.2% on the WIDER FACE dataset. These advancements demonstrate the model's ability to process high-resolution images effectively and meet the demands of crowded environments.

Deep Learning and Attention Modules: Channel-wise and spatial attention mechanisms have been employed to refine detection accuracy in high-density environments. By focusing on critical features and suppressing noise, these mechanisms enhance the performance of models like CSPNet, a lightweight architecture designed for real-time applications.

Lost Person Identification: Gutub and Ahmed (2018) introduced a prototype face-recognition system tailored for identifying lost or missing individuals in pilgrimage contexts. The system leverages a custom HUFRD (Hajj & Umrah Face Recognition Database), capturing facial variations caused by lighting, pose, and physical stress. This system has significant implications for ensuring the safety of pilgrims, particularly those prone to disorientation.

Flow Rate Estimation: Another critical application discussed by Alharbey et al. (2024) involves using deep learning to estimate pilgrim flow rates. By integrating face detection and tracking into the crowd management framework, the system can identify congestion points, allowing authorities to take preemptive actions.

Humanitarian Challenges: A broader study analyzed the socio-humanitarian challenges faced during mass gatherings like Hajj and Umrah. It emphasized the importance of leveraging technology to address crowding issues, ensure safety, and provide assistance to vulnerable groups, including the elderly and individuals with disabilities. These findings underscore the potential for face recognition systems to play a pivotal role in minimizing risks and improving organizational efficiency during pilgrimage seasons.

III. Background

The management of lost pilgrims during Hajj represents a significant logistical and organizational challenge, exacerbated by the high density of attendees and the diverse linguistic and cultural backgrounds of participants. The Hajj pilgrimage annually brings millions of individuals together in confined and dynamic environments such as Mina, Muzdalifah, and Arafat. This convergence creates a highly complex setting where traditional methods of crowd management often prove insufficient. Furthermore, the physical demands of the pilgrimage, coupled with factors such as fatigue, extreme congestion, and the lack of familiarity with local landmarks, contribute to the likelihood of disorientation, particularly among vulnerable groups, including the elderly, children, and individuals with disabilities.

A comprehensive, technologically driven solution is required to effectively address the complexities of managing lost pilgrims during Hajj. One of the most promising proposals is the establishment of a centralized, unified database that securely stores detailed information about every pilgrim. This database would include essential personal data such as name, nationality, and age, as well as additional critical information, including group affiliations, the identity of supervising agents, and emergency contact details. By consolidating this information in a single platform, authorities can ensure its accessibility and usability in critical situations.

To further enhance its functionality, the proposed system could integrate advanced facial recognition technologies, such as Face ID, to enable real-time identification and location of lost pilgrims. Field teams equipped with compatible devices could instantly retrieve a pilgrim's profile by scanning their face, providing immediate access to pertinent details, including their group or campaign information and emergency contacts. This capability would significantly improve the efficiency of interventions and reduce delays in reuniting lost individuals with their groups, thus streamlining the overall management process.

The implementation of such a system offers numerous advantages beyond logistical efficiency. By prioritizing the needs of vulnerable populations—such as the elderly, children, and individuals who may not be familiar with Arabic—this solution fosters inclusivity and accessibility. The integration of user-friendly interfaces, multilingual support, and tailored features ensures that the system accommodates the diverse demographic composition of pilgrims, thereby enhancing the overall experience and safety of participants.

This approach also aligns with Saudi Arabia's Vision 2030, which underscores the importance of leveraging cutting-edge technologies to improve the safety, security, and experience of pilgrims. By adopting innovative solutions, Saudi Arabia not only demonstrates its commitment to meeting the unique needs of Hajj participants but also positions itself as a global leader in the management of large-scale religious gatherings.

Despite the transformative potential of this system, certain challenges and limitations must be acknowledged. Future iterations could incorporate additional features such as real-time tracking, predictive analytics for crowd behavior, and more robust multilingual interfaces to further enhance its effectiveness. Moreover, continuous refinement and adaptation will be essential to ensure the system remains responsive to evolving challenges and technological advancements.

By prioritizing the development and deployment of advanced crowd management systems, Saudi Arabia can set an international benchmark for managing mass religious gatherings. Such systems will ensure the safety, comfort, and well-being of millions of pilgrims while preserving the sanctity and spiritual significance of the Hajj experience.

IV. Methodology

This section describes the methodology employed to achieve the research objectives, including data collection, preprocessing, and model implementation.

A. Data Collection

The dataset utilized in this study was sourced from the Kaggle platform, comprising 4,000 facial images equally distributed between males (2,000) and females (2,000). The images represented diverse demographics, including variations in age and cultural backgrounds. To ensure uniformity and compatibility with the model, all images were resized to a fixed resolution of 128×128 pixels.

B. Synthetic Metadata Generation

To simulate real-world pilgrim scenarios and enrich the dataset, synthetic metadata was generated for each image using **ChatGPT**. The metadata included the following attributes:

- **Name:** Randomly generated names to simulate personal identifiers.
- **Country:** Diverse nationalities reflecting realistic global distributions.
- **Campaign:** Simulated campaign names to represent organizational groupings.
- **Supervisor:** Fictitious names assigned to campaign supervisors.
- **Supervisor Phone:** Randomly generated phone numbers assigned to each supervisor.

This approach utilized the natural language generation capabilities of ChatGPT to produce high-quality, realistic metadata. By incorporating these attributes, the dataset became more representative of real-world applications, facilitating deeper analysis and improved performance in machine learning tasks.

C. Preprocessing and Encoding

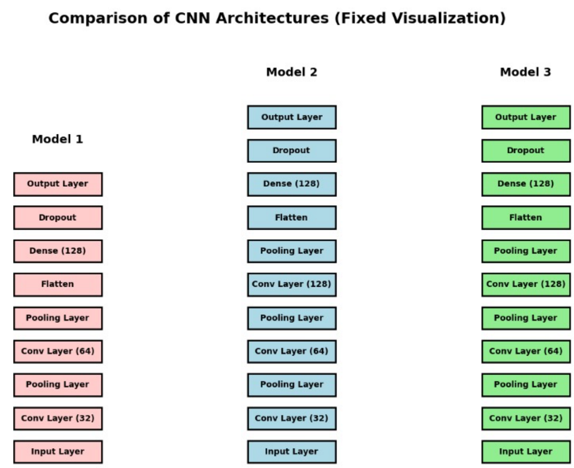
1. **Image Encoding:** All images were normalized and transformed into numerical matrices using **One-Hot Encoding**, representing pixel intensities on a normalized scale between **[0, 1]**. This transformation ensured that the model could efficiently process visual patterns.
2. **Metadata Encoding:** Categorical metadata attributes (e.g., Nationality, Campaign Name) were converted into numerical representations using **One-Hot Encoding**, enabling integration of structured information into the learning process.

D. Data Integration

The processed images were combined with their respective synthetic metadata to form a unified dataset. The final dataset included: 4,000 records with equal representation of males and females .Each record consisted of A resized, normalized image, Associated metadata attributes in an encoded format.

E. Model Architecture

In this study, three different Convolutional Neural Network (CNN) architectures were designed and tested to classify facial images paired with synthetic metadata. Each model varies in the number of convolutional and dense layers to evaluate the effect of network depth on performance. The general structure of the CNNs consists of:



F. Training Procedure

The training of all CNN models was conducted using the following the models were trained for **[20, 10, 5] epochs** to ensure convergence while monitoring performance on the validation set. A batch size of **[32]** was used for training to balance between computational efficiency and performance. The Adam optimizer with default parameters was employed to adjust model weights during training. The dataset was divided into training (80%) and testing (20%) subsets to evaluate model performance.

Implementation Tools All models were implemented using the following tools and framework TensorFlow/Keras: For building and training the CNN architectures. Adam Optimizer: To optimize the weights during training Categorical Crossentropy Loss Function: Used for multi-class classification tasks.

Evaluation Metrics The performance of the models was assessed using the following metrics Accuracy: The percentage of correct predictions across the test dataset. Loss: A measure of the error during training and validation. Precision, Recall, and F1-Score: For a detailed analysis of class-wise performance. Confusion Matrix: To visualize the classification results and analyze misclassifications.

V. RESULTS

This section presents the performance evaluation of the three CNN models. The results are analyzed based on training, validation, and testing metrics, including accuracy and loss. A detailed comparison of the models is provided to identify the optimal architecture.

MODEL	TRAINING ACCURACY	VALIDATION ACCURACY	LOSS
MODEL 1	57%	66%	1.92%
MODEL 2	73%	74%	1.9%
MODEL 3	88%	80%	1.6%

TABLE I. PERFORMANCE METRICS FOR THE CNN MODELS

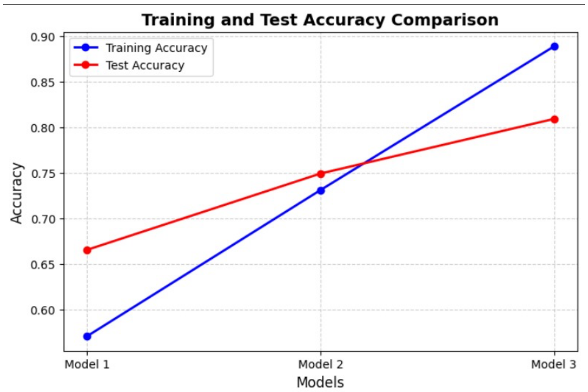


Fig. 1.

From **table I Model 1** demonstrates weak performance, with test accuracy exceeding training accuracy. This suggests that the model is too simple to capture complex patterns effectively. **Model 2** achieves a good balance between training and test accuracy, indicating strong generalization without overfitting, making it the most stable and reliable option. **Model 3** attains the highest training accuracy, but its lower test accuracy suggests overfitting **(Fig. 1)**, meaning it may not generalize well to unseen data. While Model 3 delivers the best accuracy, its overfitting risk makes Model 2 the most practical choice for real-world applications due to its stability and balance between performance and generalization.

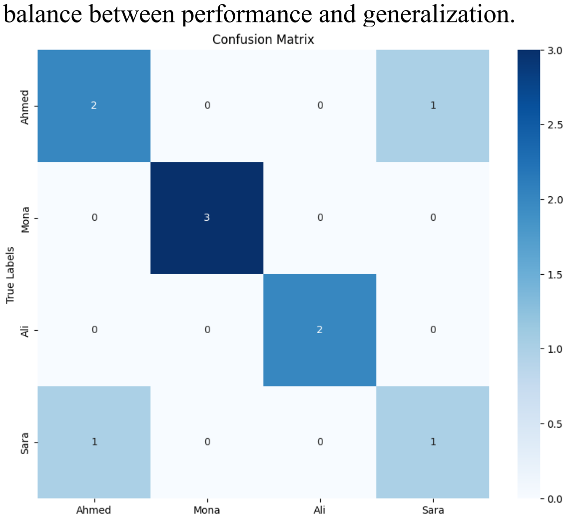


Fig. 2. Confusion Matrix

The confusion matrix **(Fig.2)** evaluates the model's classification accuracy by comparing actual vs. predicted labels. The model correctly classified Mona (3/3) and Ali (2/2) with no errors, showing strong reliability. However, Ahmed had one misclassification as Sara, and Sara was misclassified as Ahmed once, indicating potential feature similarities. To improve accuracy, enhancements like increasing training data, refining preprocessing, and optimizing deep learning models can be applied. Overall, the model performs well but requires refinements to minimize misclassification.

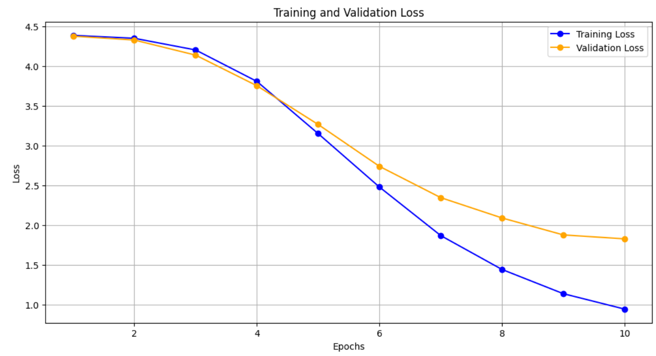


Fig. 3.

Fig. 4.

The training accuracy and loss show**(Fig. 3)** how well the model is learning from the training data, while the validation accuracy and loss reflect its ability to generalize to unseen data. In the accuracy graph**(Fig. 4)**, both training and validation curves increase consistently and stay close to each other, indicating that the model is generalizing well. However, in the loss graph**(Fig. 3),** although both training and validation loss decrease, a small gap starts to form in the later epochs, which suggests the model might be beginning to overfit. This means it is performing well on training data but could struggle with new data. To prevent this, techniques like regularization or early stopping could be applied to maintain a balance between learning and generalization.

Fig. 5. Main Result

The face recognition system accurately identified individuals by processing input images and retrieving relevant details. **(Fig. 5**) shows an example where the model correctly recognized **"Fahad Bin Ahmed" with 100% confidence** and displayed associated metadata, including country, campaign, and supervisor information. This demonstrates the system's reliability in identity verification and data retrieval, making it suitable for real-world applications.

Fig. 6.

We showcased the results of our trained classification model by selecting a set of images along with their associated details**(Fig. 6),** such as name, country, campaign, supervisor, and supervisor phone number. We then processed these images through the model to generate predictions and compared them with the actual labels. In the displayed images, the predicted names matched the true labels in most cases, indicating accurate classification. Finally, we presented the images with their details in a well-structured format, making it easy to assess the model's performance and verify prediction accuracy.

VI. Conclusion and Future Work

In this study, a facial recognition system was developed to assist in identifying lost pilgrims during the Hajj season. Three different Convolutional Neural Network (CNN) architectures were evaluated based on training, validation, and testing performance. The results demonstrated that Model 3 achieved the highest accuracy; however, it exhibited signs of overfitting, whereas Model 2 provided a more balanced performance, making it the most practical choice for real-world implementation.

The proposed approach integrates advanced deep learning techniques with a structured database system to improve the efficiency of lost person identification. The findings indicate that deep learning-based facial recognition can significantly enhance crowd management strategies, particularly in high-density environments such as Makkah during Hajj. However, challenges such as real-time deployment, processing limitations, and environmental conditions remain key areas for further research.

Future work will focus on optimizing model efficiency through techniques such as real-time inference, edge computing integration, and improved data augmentation strategies. Additionally, expanding the dataset to include more diverse facial variations and real-world conditions will enhance model robustness. This research aligns with Saudi Arabia's Vision 2030, which emphasizes leveraging AI and smart technologies to improve the safety and experience of pilgrims.

By refining the proposed system and addressing existing limitations, this study contributes to the advancement of AI-driven solutions in large-scale crowd management, ensuring a safer and more efficient pilgrimage experience.

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