

Master Thesis Proposal

Crowd Crisis Management in Hajj Using Artificial Intelligence

Abdullah Alburithen & Amjad Alharbi
Master's Students of Science in Artificial Intelligence
College of Informatics
Midocean University

Under Supervision of
Prof. Dr. Yasser Abdelhamid
Associate Professor
College of Informatics
Midocean University

Dr. (Co-Supervisor Name)
Lecturer
College of Informatics
Midocean University

Research Area

Artificial Intelligence – Crowd Management – Safety and Security

Abstract

The huge numbers and spatial concentration of pilgrims during Hajj have made crowd management a major concern for authorities, especially as the number of pilgrims increases every year. By collecting and analyzing data in real time, AI provides a viable answer to crowd management. In order to monitor crowd density, identify rest areas in crowded areas, and notify authorities in real time of medical emergencies or abnormal crowd behavior, this thesis proposes the use of Artificial Intelligence (AI). The proposed approach seeks to enhance crowd flow control and provide a safer Hajj experience by leveraging AI techniques.

Introduction

Hajj is one of the largest annual gatherings in the world, presenting challenges in managing the mass team as well as the safety of millions of pilgrims. Overcrowding can lead to accidents requiring immediate medical attention and catastrophic emergency outcomes. With the advancement in the field of artificial intelligence, it has become easier to know the truth and realize the pilgrims and analyze the magic number to suggest it. The focus of this study is to apply artificial intelligence to manage the mass during the judiciary and the general judgment of weak pilgrims.

Problem Definition

Crowd management during Hajj poses several challenges, including high density of people, limited space, and the potential for emergencies. Traditional approaches, such as human supervision and manual monitoring, are insufficient to address these issues. An AI-based approach is needed to analyze crowd movements in real time, detect areas of high density, predict emergencies, and ensure immediate response by alerting the relevant authorities. The proposed system will integrate AI-based models to provide insights into crowd behavior, detect potential bottlenecks, and notify officials when critical thresholds are reached. This system will improve the overall flow of pilgrims and mitigate the risks associated with overcrowding.

Research Objectives

The primary objectives of this research are:

- Develop a real-time AI-based system to monitor and analyze crowd movement during Hajj.
- Propose improvements in crowd flow management by identifying congestion areas and suggesting rest stops.
- Send real-time alerts and notifications to authorities about medical emergencies or other abnormal crowd behavior.
- Improve the overall safety and experience of pilgrims by preventing overcrowding and ensuring immediate response to potential hazards.

Do you have this data set

Dataset

Shall we use video streams as input?
The research will leverage publicly available datasets and real-time data collected during Hajj. These datasets include:

- Pilgrim Count Data: Estimating the number of pilgrims in different locations.
- Medical Emergency Records: Identifying patterns in crowd-related medical emergencies.
- Crowd Flow Data: Tracking crowd movements to detect bottlenecks and congestion.

Some key datasets to be used include:

1. Al-Mashaaer Al-Mugaddassah Metro Southern Line Dataset: Provides insights into crowd flow around the Hajj metro system.
2. Saudi Ministry of Hajj and Umrah Records: Offers historical and real-time data on pilgrim movements.
3. Open Data from Smart Cities Projects: Includes crowd data from large public events, which can be simulated for Hajj conditions.

Related Work

1. Hajj Crowd Management Using CNN-Based Approach (2021)

Detailed:

- This study presents an intelligent system for managing crowd density at Al-Jamarat during Hajj, leveraging Convolutional Neural Networks (CNN) to analyze and control pedestrian traffic. Given the unique challenges in this high-density environment, a network of overhead cameras captures real-time images along the Jamarat path. These images are processed through a CNN model trained to categorize crowd levels into five density states: heavily crowded, crowded, semi-crowded, light crowded, and normal. This system assigns a color-coded alert signal to each density level (red, brown, yellow, blue, and green) to communicate instructions to pilgrims based on crowd congestion.
- The CNN algorithm utilizes a sequence of convolutional and pooling layers to identify features from image data, creating a density map of pedestrian traffic. By processing images at the pixel level, the model generates smooth, well-localized density maps, enabling effective crowd categorization with up to 98% accuracy. This high precision allows authorities to prevent stampedes and other potential accidents by using a responsive lighting system that signals pilgrims when to slow down, stop, or proceed at a normal pace.
- The system shows potential for additional applications in general traffic management, as the CNN model can be adapted to monitor congestion on busy highways or urban areas. Future advancements could include incorporating UAVs (drones) for broader data collection and adding demographic factors like age, speed, and group dynamics to better predict crowd behavior. The study demonstrates that CNN-based monitoring can provide a safer pilgrimage experience by minimizing congestion risks through proactive guidance.



Comparison:

While this study focuses on visual crowd classification and passive guidance, our research adds layers of proactive safety features, including real-time medical alerts and rest area recommendations, providing active management of crowd flow beyond basic density assessment.

2. Hajj Pilgrimage Abnormal Crowd Movement Monitoring Using Optical Flow and FCNN (2023)

Detailed:

- This study presents an integrated model that combines optical flow with Fully Convolutional Neural Networks (FCNN) to detect abnormal movements within crowds, focusing on identifying sudden deviations or bottlenecks that could pose risks. The optical flow technique measures the speed and direction of movement, while the FCNN classifies these movement patterns as either normal or abnormal. Operating at a remarkable speed of 370 frames per second, the system enables real-time anomaly detection, which is critical in high-density areas where rapid intervention can mitigate risks of crowd collapse or stampedes.
- The research showcases several datasets, including UCSD Ped2, which focuses on pedestrian movement; Subway, which monitors entry and exit behaviors in subway stations; and Hajj-Crowd, which observes the behavior of crowds during the Hajj pilgrimage. In these datasets, anomalies are classified as deviations from the typical circular movement pattern around the Kaaba during Tawaf. The model is trained exclusively on normal data and tested on scenes that incorporate both normal and abnormal movements.
- The study employs various performance evaluation methods, such as precision, recall, F1 score, and ROC curves, achieving high accuracy in discrimination. For instance, the model attained impressive metrics, indicating its robustness and reliability in real-world applications. By effectively integrating optical flow with deep learning, this approach not only enhances the detection of crowd anomalies but also contributes significantly to crowd management strategies, ensuring safety in densely populated environments.

Comparison:

Our research also addresses abnormal movement detection but goes further by suggesting interventions, such as alternative routes or rest areas, and includes a medical alert component that enables quicker response in medical emergencies.

3. Saudi Arabia's Hajj Management with AI and Sustainability (2022)

Detailed:

- This study discusses sustainable crowd management during the Hajj, focusing on resource optimization through AI-driven solutions. AI techniques are employed to monitor crowd density and predict peak congestion times, aiding authorities in effectively managing resources by preemptively reallocating personnel and supplies. Smart applications play a crucial role in organizing crowd movement and ensuring safety, especially during the COVID-19 pandemic, where precautionary measures were implemented to safeguard the health of pilgrims. The study highlights the use of modern technologies, such as robots, smart bracelets, and various applications, reflecting Saudi Arabia's efforts to provide a safe

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and organized environment. Additionally, the participation of women in crowd management enhances organizational effectiveness. The study emphasizes the importance of sustainability and innovation in achieving success in crowd management during the Hajj rituals.

Comparison:

While both studies utilize AI for crowd management, our project introduces a real-time safety component with medical alerts and congestion-reduction strategies, focusing on immediate, safety-oriented interventions rather than long-term resource allocation.

4. Crowd Monitoring of Hajj Pilgrimage Using Video Analytics and Deep Learning (2023)

Detailed:

- The article focuses on "Crowd Monitoring of Hajj Pilgrimage Using Video Analytics and Deep Learning," emphasizing the importance of ensuring safety during the massive influx of pilgrims. It presents a system that utilizes video analytics and deep learning techniques to monitor crowd movements and identify overcrowded areas in real-time. By analyzing live video feeds, the system can detect crowd buildup and alert control centers, facilitating timely interventions to manage potential risks.
- The approach leverages deep learning models to enhance the accuracy of crowd density estimation and behavior analysis. It integrates multi-task CNN techniques that allow for effective segmentation, counting, and density mapping of individuals within the crowd. The study discusses various methodologies, including patch-based approaches and different convolutional neural network (CNN) architectures that improve monitoring efficiency.
- By visualizing high-density zones and providing alerts to authorities, the system aims to enhance the safety of pilgrims and improve overall crowd management during the Hajj. This research contributes significantly to the field of crowd analysis and offers insights into utilizing advanced technologies for effective surveillance in large-scale events.

Do we have image dataset?

Comparison:

Our research also leverages video analytics but goes beyond simple detection. By integrating dynamic alerts for emergencies and rest area suggestions, your approach is more interactive and safety-focused, providing actionable responses to high-density scenarios.

5. Analyzing Perceptions of a Global Event Using CNN-LSTM: The Case of Hajj 1442 (2021)

Detailed:

- This study employs a CNN-LSTM deep learning model to analyze sentiment from tweets and YouTube comments regarding crowd management during the Hajj season. It focuses on user sentiments expressed online, particularly surrounding key terms related to Eid, Hajj, and Arafa. The analysis of 4,000 posts from social media reveals a generally positive sentiment toward the experiences shared by both pilgrims and Makkah residents, with high sentiment analysis (SA) scores recorded—4.28 for Eid tweets, 3.87 for Hajj-related tweets, and an impressive 4.86 for Arafa tweets.

- The research highlights that the majority of tweets during Eid were positive, with congratulations and blessings, while some negative sentiments arose due to limited Eid celebrations amid business obligations. The sentiment surrounding Hajj was initially lower but improved as the event progressed, reflecting some dissatisfaction regarding service expectations but ending on a high note with gratitude from the community.
- User engagement on YouTube was also analyzed, showing high satisfaction with sermons related to Arafa, reflected in SA scores ranging from 4.17 to 4.71 across different channels. Overall, while positive sentiments predominated, some negative feedback indicated areas for potential improvement in crowd safety and service management. The findings suggest that social media can serve as a valuable tool for assessing public perception and enhancing crowd management strategies during large-scale events like Hajj.

Comparison:

While this study focuses on sentiment analysis to gauge perceptions, our project centers on direct, real-time crowd management, using AI for immediate actions and crowd flow adjustments rather than retrospective sentiment assessment.

6. Crowd Density Estimation and Mapping Method Based on Surveillance Video and GIS (2023)

Detailed:

- This research presents an innovative approach that integrates Geographic Information Systems (GIS) mapping with video-based crowd density estimation to produce spatially accurate maps of crowd distributions. The system employs surveillance video footage as its primary input, leveraging advanced algorithms to estimate crowd density and visualize hotspots on GIS platforms. The proposed method, known as the Crowd Density Estimation and Mapping Method (CDEM-M), addresses the limitations of existing crowd counting techniques that struggle with accuracy in large scenes.
- The CDEM-M utilizes a crowd semantic segmentation model (CSSM) to identify and delineate crowd areas, while a crowd denoising model (CDM) refines this data by eliminating noise from the segmentation process. Additionally, the research employs a backpropagation (BP) neural network to estimate crowd density based on various factors, including the distance from the crowd to the camera, camera inclination, and the area of the identified crowd polygons.
- The results of the study indicate a high level of accuracy, with the CSSM achieving a test accuracy of 96.70% and the CDM exhibiting an 86.29% classification accuracy. The BP neural network demonstrated an average error of 1.2, significantly outperforming traditional density map methods. By filling crowd polygons with corresponding symbols, such as human icons, the system effectively visualizes crowd distributions.
- This integrated approach allows authorities to pinpoint specific high-density areas, enabling strategic resource deployment and improving public safety management in various environments, including transit stations, shopping malls, and sports venues. Ultimately, the CDEM-M enhances the efficiency of crowd monitoring and spatial data analysis, contributing to better urban security and management practices.

Comparison:

Our project includes density estimation as well but incorporates additional health and safety elements like medical alerts and route suggestions, making your approach more focused on active management rather than just spatial mapping.

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7. Leveraging Artificial Intelligence for the Future of Hajj

Detailed:

- This research examines the applications of Artificial Intelligence (AI) in managing the Hajj pilgrimage, particularly focusing on predictive models for crowd behavior. A systematic literature review reveals a growing interest in AI's role from 2011 to 2023, highlighting its primary application in crowd management, followed by health and well-being. The study underscores AI's importance in enhancing safety and efficiency during the massive influx of pilgrims, with crowd management identified as the most cited application. Additionally, AI applications extend to health monitoring, customer satisfaction, environmental monitoring, and logistics management.
- The research also emphasizes the alignment of AI initiatives with the Sustainable Development Goals (SDGs), particularly SDG 3 (Good Health and Well-being) and SDG 11 (Sustainable Cities and Communities). The analysis suggests that AI can improve resource utilization, reduce inequalities, and foster sustainable consumption patterns, thereby enhancing the overall pilgrimage experience.
- In conclusion, the study advocates for a holistic approach to integrating AI solutions with sustainability objectives, promoting collaboration among technology developers, Hajj authorities, and sustainability experts. By leveraging predictive insights and automation, the research posits that AI has the potential to revolutionize long-term crowd management and resource planning, ensuring a safer, more efficient, and environmentally sustainable Hajj experience for millions of pilgrims. Future research should focus on further aligning AI applications with diverse SDGs to maximize their impact on the Hajj pilgrimage.

Comparison:

Unlike this predictive and planning-based study, our research prioritizes real-time interventions to address immediate crowd safety concerns, making it more suitable for current applications in high-density situations rather than future scenario planning.

Summary of Strengths:

- **Real-Time Monitoring and Alerts:** While many studies focus on crowd density estimation or anomaly detection, This Research includes real-time alerts for medical emergencies and crowd flow suggestions, ensuring proactive crowd management.
- **Medical Emergency Response:** A unique aspect of This Research is the direct response system for medical emergencies, which is not emphasized in other studies.
- **Scalability:** This Research addresses full-capacity Hajj, which is critical for managing millions of pilgrims, unlike studies focused on restricted events or smaller gatherings.
- **Integration of Multiple AI Techniques:** This Research integrates deep learning, predictive modeling, and real-time alert systems, making it a more comprehensive approach to crowd management.

Research Plan

1. **Data Collection:** Gather data from surveillance systems, sensors, and crowd simulations. This data will include both real-time and historical information on crowd movements, medical emergencies, and bottleneck occurrences during Hajj.

What Kind of data do you have?

2. Preprocessing: Use data preprocessing techniques such as normalization and dimensionality reduction to prepare the data for analysis.
3. Feature Extraction: Extract key features from the data, such as crowd density, movement patterns, and emergency occurrence rates.
4. Model Development: Develop and train machine learning and deep learning models to predict crowd behavior, detect potential bottlenecks, and notify authorities of emergencies.
5. Validation: Validate the developed models using both real-world data and simulation-based datasets to ensure accuracy and reliability.
6. Testing: Test the system in simulated Hajj conditions and compare the AI-generated results with actual crowd movement data.

Expected Results

The developed AI system is expected to significantly improve the management of crowds during Hajj by providing real-time insights into crowd movements, detecting emergencies, and proposing enhancements in the crowd flow. By integrating these AI models into existing infrastructure, authorities can better manage high-density areas and ensure a safer pilgrimage experience.

Conclusion

This research seeks to address the challenges associated with crowd management during Hajj by leveraging AI technologies. The developed AI-based system will offer real-time monitoring and analysis of crowd movements, propose solutions to improve the flow of pilgrims, and ensure quick responses to emergencies. By improving the safety and experience of pilgrims, this system will play a crucial role in future Hajj management strategies.

References

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- Journal: Computers, Materials & Continua, 66(2), 2183-2197.
- Summary: This study uses Convolutional Neural Networks (CNNs) to classify crowd density in real-time, helping to detect areas of varying crowd levels.
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2. Hajj Pilgrimage Abnormal Crowd Movement Monitoring Using Optical Flow and FCNN (2023)

- Authors: Mahadevan, N., Ullah, I., & Hafeez, M.
- Journal: Journal of Big Data, 10(1), 1-17.
- Summary: This research utilizes Optical Flow and Fully Convolutional Neural Networks (FCNN) to monitor abnormal crowd movements during Hajj, focusing on the detection of unusual behaviors.
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3. Saudi Arabia's Hajj Management with AI and Sustainability (2022)

- Authors: Abalkhail, A.A.A., & Al Amri, S.M.A.
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- Summary: This paper discusses the role of artificial intelligence (AI) in managing the Hajj pilgrimage while focusing on sustainable practices and crowd control methods.
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4. Crowd Monitoring of Hajj Pilgrimage Using Video Analytics and Deep Learning (2023)

- Authors: Wang, Y., Lee, C.W., & Almuhaideb, A.M.
- Journal: IEEE Xplore, Conference on Video Analytics, 2023.
- Summary: This study explores the use of video analytics and deep learning to monitor crowd movements and density during the Hajj, allowing for the detection of potential overcrowding.
- <https://ieeexplore.ieee.org/document/10082848>

5. Analyzing Perceptions of a Global Event Using CNN-LSTM Deep Learning Approach: The Case of Hajj 1442 (2021)

- Authors: Yousaf, M., Haque, A., & Sarwar, A.
- Journal: Journal of Computational Social Science, 3(4), 235-256.
- Summary: This study applies a CNN-LSTM model to analyze global perceptions of crowd management during Hajj 1442 using social media data.
- <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC9575857/>

6. Crowd Density Estimation and Mapping Method Based on Surveillance Video and GIS (2023)

- Authors: Kumar, M., & Khan, F.
- Journal: IEEE Access, 11, 3425-3445.
- Summary: This research combines surveillance video and GIS data to estimate crowd density, providing detailed spatial mapping to support real-time crowd management.
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7. Leveraging Artificial Intelligence for the Future of Hajj

- Authors: Al-Zahrani, F., & Al-Shehri, M.
- Institution: Research Paper, Umm Al-Qura University, Saudi Arabia.
- Summary: This paper explores how AI technologies can be used to manage future Hajj events, focusing on predictive models and automation for crowd control and safety.
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