EGT217

AI Engineering Project Report

**Development of Computer Vision-based AI Tools for Out-of-Bound Detection in Dementia Care Homes**

T4 Group 3

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**I) Introduction**

Founded in 1999, Apex Harmony Lodge (AHL) stands as a non-profit organization and the first purpose-built facility for individuals with dementia in Singapore. AHL's primary focus involves offering long-term residential and community care services, encompassing comprehensive care for senior residents at varying stages of dementia. The organization is dedicated to assisting residents facing cognitive challenges, such as difficulties in memory recall, formulating coherent thoughts, and making rational decisions.

Residents of Apex Harmony Lodge (AHL) may unintentionally venture beyond the predesignated safe boundary, which might potentially expose themselves to various risks. This encompasses wandering and elopement, safety concerns, and staffing challenges.

**1. Wandering and Elopement:** This behavior is often a result of cognitive impairments that expose them to dangerous situations and disorientation. Consequently, wandering significantly increases the likelihood of accidents and exposes the residents to unpredictable external environments.

**2. Safety Concerns:** Entering restricted areas within the care home can also lead to accidents, falls, and other safety hazards, raising the risk of injuries and legal responsibilities for the care home. This heightens the risks of injuries and exposes the care home to possible legal responsibilities, jeopardizing the safety of the residents.

**3. Staffing Challenges:** Dementia care homes may encounter shortages or employ inadequately trained staff, creating challenges in maintaining continuous supervision and responding promptly to wandering incidents. This situation places an additional workload on existing staff, increasing the risk of potential lapses in monitoring, and enhancing the likelihood of residents wandering unnoticed beyond the designated areas.

To address these concerns, this project seeks to enhance the overall well-being of residents at Apex Harmony Lodge (AHL) through a series of targeted objectives, with the employment of computer vision-based AI tools for out-of-bound detection in dementia care homes.

Firstly, it aims to enhance the residents’ safety by swiftly addressing the situations in which the residents may be exposed to potential hazards when venturing outside the designated areas.

Furthermore, by creating a safe and protected environment with AI tools, it aims to cultivate peace of mind and improve the living experience for both residents and their families, elevating satisfaction.

Subsequently, transparency and accountability are prioritized to build trust with stakeholders. This includes clear communication with residents, their families, and regulatory authorities regarding the purpose and benefits of technological advancements within the lodge.

Finally, the project focuses on enhancing care quality for Singapore's swiftly aging population, promoting a safe and supportive environment that stimulates independence and general well-being.

**II) Solution Approach**

**1. Human Detection Feature**

**Objective and Importance:** The human detection feature is critical in a dementia care home to ensure residents' safety by monitoring their presence. This feature helps to quickly identify if a resident is in an area where they should not be or if they need immediate assistance.

**Technical Approach:** The system utilizes OpenCV's Haar Cascade classifiers which are trained with numerous positive and negative images to identify human shapes and faces. These classifiers are robust against variations in human posture, clothing, and slight movements.

**Implementation Details:** In practice, the code activates the webcam, processes the video feed frame by frame, and applies the classifier to detect human presence. The system can switch between full body, upper body, and facial detection depending on the scenario, allowing for tailored monitoring in different care home environments.

**Benefits in Dementia Care:** This feature is particularly beneficial in dementia care, where patients may wander due to confusion. Early detection can prevent possible incidents and ensure that caregivers can provide immediate assistance.

**2. Loitering & Boundary Detection**

**Objective and Importance:** This feature aims to detect when residents linger near exits or restricted areas, which is a common concern for individuals with dementia who may wander and potentially leave the safety of the care home.

**Technical Approach:** By using coordinates (x,y) to define virtual boundaries within the camera's field of view and employing algorithms to track the time a resident spends in these zones, the system can identify loitering behavior.

**Implementation Details:** The system uses OpenCV to create virtual zones and checks if detected humans are within these boundaries over time. If a resident remains in a designated area for too long, the system triggers an alert.

**Benefits in Dementia Care:** The prompt alerts allow staff to intervene before a resident enters a potentially dangerous situation, such as wandering off the premises or entering an unsafe area.

**3. Alert System**

**Objective and Importance:** An efficient alert system is vital for immediate staff response to potential safety incidents in a dementia care home.

**Technical Approach:** The system employs an audio alert mechanism that is triggered when the software detects loitering or boundary crossing.

**Implementation Details:** Using Pygame's mixer module, the code plays a predefined sound to alert the staff. This is linked to the loitering and boundary detection features, ensuring alerts correspond to specific incidents.

**Benefits in Dementia Care:** The alert system ensures that staff can react swiftly to attend to residents who may be at risk, enhancing overall resident safety and security in the care home.

**4. Real-time Low Light Enhancement**

**Objective and Importance:** Proper visibility in low-light conditions is crucial for monitoring residents during all hours, especially at night when the risk of wandering is high.

**Technical Approach:** Image processing techniques are applied to the video feed in real-time to enhance visibility.

**Implementation Details:** The code adjusts gamma values and scales brightness dynamically based on the lighting conditions, using OpenCV functions designed for real-time image adjustments.

**Benefits in Dementia Care:** Enhanced visibility at night or in poorly lit areas of the care home ensures that the detection systems remain effective 24/7, which is essential for the safety of residents with dementia who may be more active or disoriented at night.

**5. Azure Blob Storage Service**

**Objective and Importance:** Secure and systematic storage of video footage is essential

for review and evidence in case of incidents within the care home.

**Technical Approach:** Cloud storage is utilized for its scalability, reliability, and security features, with Microsoft Azure's Blob Storage service as the backbone.

**Implementation Details:**  The code programmatically configures Azure Blob Storage with the necessary credentials and uploads the recorded video footage, tagging it with a timestamp for easy retrieval.

**Benefits in Dementia Care:** The ability to store and access historical footage provides care homes with the means to review incidents, improve safety protocols, and provide evidence if needed. This feature is critical for accountability and continuous improvement of resident care strategies.

**III) Data Analysis**

**Data Analysis in Dementia Care Houses:** Data analysis is the act of evaluating, cleansing, changing, and interpreting data with the goal of gaining usable insights and making educated decisions. In dementia care homes, where residents may have cognitive impairments that affect their behaviour and movement, data analysis is critical for understanding and managing their requirements effectively.

**Understanding Behavioral Patterns:** Behavioural patterns refer to the regular manner in which residents move, engage, and behave in the care home setting. Patterns can be detected by examining data from a variety of sources, including monitoring devices, and caregiver observations. These patterns may include residents' frequent travel routes, common activities, and any departures from their usual behaviour.

**Defining Boundaries for Out-of-Bound Detection:** To protect the safety and well-being of dementia care residents, boundaries must be established. Out-of-bound detection is the capacity to determine when a resident has passed a predefined boundary or departed from their regular patterns of behaviour.

**Analyzing Historical Data:** Historical data relates to previous records of resident activities, movements, and behaviours in the care home. By evaluating this historical data, caregivers can find repeating patterns, trends, and anomalies that may indicate possible hazards or changes in residents' statuses.

**Creating Effective Boundary Definitions and Detection Algorithms:** Caregivers can update and optimise border definitions and detection algorithms using the insights gathered from data analysis. This includes defining what defines typical behaviour and establishing thresholds for detecting deviations or unexpected actions. Caregivers can increase the accuracy and reliability of out-of-bound detection systems by continually refining these criteria and algorithms using real-world data.

**IV) AI Solution Development**

**Identification of Challenges**

**-** Analyzing the unique challenges faced by residents with dementia and nurses such as wandering and elopement, safety concerns, and staffing challenges

- Residents may leave AHL premises without the nurse’s knowledge which may be dangerous for the residents

**Objective and Scope**

Ensuring resident safety by minimizing the risk of residents wandering outside of AHL, and increasing operational efficiency as nurses can focus on more important tasks at hand.

**Model Architecture**

**Haar-like features:** Haar-like features are filters which perform calculations on a specific region to capture patterns from an image to distinguish objects, similar to a Convolutional Neural Network (CNN).

**Integral Images:** The next step is creating integral images. An integral image is derived from the original image which reduces the time taken to calculate the Haar features and does not slow down CCTV footage.

**Adaboost Training:** Most haar features have little impact in object detection. However, using Adaboost training can create a strong classifier using many weak classifiers for object detection.

**Cascade Classifier:** The cascade classifier consists of a few stages, many weak learners are trained to increase accuracy. When training, the classifier is exposed to positive and negative images to learn features of the image. Stages are designed to reject negative samples as quickly as possible since the majority of the windows do not contain anything important.

**Model Selection**

Haar Cascade was chosen for object detection due to AHL’s requirements. The classifier is very computationally efficient which makes it suitable for real-time detection in security camera footage. This leads to a high resource efficiency as it ignores regions which are unimportant for object detection. Resource intensive models like CNN and YOLO are more difficult to implement into real-time footage due to longer computational times and may cause lag in the system. Hence, the Haar Cascade model was chosen for its speed and efficiency compared to other object detection models.

**Implementation**

**1. Collecting Labelled Data:** High-quality labelled data is essential for training the AI model. This data should include examples of residents approaching or crossing predefined boundaries, as well as normal behaviour within the care home environment.

**2. Model Selection:** The appropriate model architecture must be selected based on the specific requirements of the project. In this case, the Haar Cascade model was selected due to its speed in human and boundary detection.

**3. Evaluation:** The trained model is evaluated using metrics such as accuracy, precision, recall, and F1 score to assess its performance. This step helps identify any weaknesses or areas for improvement in the model.

**4. Optimization:** To ensure optimal tracking of the patience, the Haar Cascade model undergoes optimization for real-time tracking while balancing accuracy and efficiency. The hyperparameters are adjusted to meet the requirements of AHL’s monitoring system.

**5. Deployment:** Once the model has been optimized, it can be deployed in the dementia care home environment. This involves integrating the AI security system with existing surveillance infrastructure and configuring it to generate real-time alerts when out-of-bound incidents are detected.

**V) Model Evaluation & Interpretation**

**Importance:**

Evaluating a pre-trained model is essential in identifying its suitability for the specific use case — Out-of-Bound Detection. Model evaluation ensures that the pre-trained model performs effectively and accurately in detecting out-of-bound incidents, also providing timely alerts to prevent potential safety hazards for residents. Furthermore, the model evaluation helps to make informed decisions by identifying potential limitations or areas for improvements in the pre-trained model’s performance.

**Evaluation Metrics:**

When using a pre-trained model, we generally do not need to train it from scratch. Evaluation metrics such as accuracy, precision, recall, and F1 score may not be directly applicable since we are not evaluating the model's predictive performance on a validation set. Instead, it focuses on metrics related to the model's performance which includes:

1. The overall duration took to train the pre-trained model, process, and detect real-time out-of-bound situations.
2. The computational resources such as CPU, GPU, or memory are required to run the pre-trained model efficiently in the deployment environment.
3. The ability of the pre-trained model to maintain accurate detection performance under various environmental conditions and scene dynamics such as low-lighting conditions, and different camera angles.

**Interpretation:**

Interpreting the evaluation involves analyzing the performance metrics and gaining insights into the pre-trained model's effectiveness in detecting out-of-bound incidents. It also involves identifying potential obstacles or constraints encountered during the evaluation process and considering possible solutions to address them. The goal of this interpretation is to provide a comprehensive understanding of the pre-trained model's performance and its suitability for Out-of-Bound Detection in the dementia care home environment.

**VI) System Development & Maintenance**

**Design**

**Requirements Analysis:** Gather specific needs for the object detection system from AHL stakeholders. Work with nurses and IT staff to gain insights such as the safety of residents and workflow integration to better integrate the system.

**System Architecture Design:** Develop an advanced architecture that describes components, data flows, and interactions. Choose Haar Cascade for object detection because of its performance and suitability for real-time applications.

**User Interface Design:** Design an intuitive user interface for AHL staff to interact with the system easily. The user design requires staff to operate the system without much technical knowledge of how the system works.

**Develop**

**Model Implementation:** Utilized the Haar Cascade model, incorporating Haar-like features and integral images. Adaboost training was used to enhance the model's ability to detect relevant objects with many weak classifiers.

**Optimization:** Optimized the model for real-time tracking, adjusting hyperparameters to balance accuracy and efficiency. The hyperparameters of the model were determined by the constraints of the monitoring system.

**Test**

**Simulated and real-world testing:** Test in simulated environments to see how the model performs under controlled conditions. Further development of real-world testing in AHL facilities to evaluate model performance in real-world care scenarios.

**Identifying Weaknesses:** Use test results to identify weaknesses or areas for improvement. Weaknesses can then be addressed after identifying them

**Deploy**

**Data Integration:** Implementing an object detection model and alarm system into AHL's current monitoring infrastructure. Make sure the security system has all its intended features and is working properly.

**Configure real-time alerts:** Configure the system to generate real-time alerts when out-of-boundary events are detected. Define alarm thresholds and escalation procedures so that AHL employees can react quickly.

**Employee Training:** Provide AHL employees with comprehensive training on interacting with the AI ​​system, interpreting alerts, and understanding the system's functions. Ensure staff are familiar with the interface and can use the technology effectively in their care role.

**Maintenance Considerations**

**Continuous monitoring:** The model’s performance will be monitored to detect any changes for any changes. Factors like system alerts, detection accuracy, and enhanced vision at night can be monitored to ensure that it remains operational. Regular system checks can help identify any issues that may occur before causing a problem.

**Model Retraining:** AHL can schedule regular retraining sessions to expose the model to new training data from the CCTV footage within the premises. This allows the model to adapt to new patterns which are more suited for AHL’s needs.

**Security Updates:** Frequent security updates are important to prevent breaches in the AI system from potential intruders. This includes applying patches, and ensuring that all packages and libraries are kept up to date to prevent any unsupported components within the code.

**Version Control:** Implement version control for the model and code to ensure that there is a history of all the changes and updates made to the system. This helps with tracking changes and system backup. In case of corruption in the system, version control can help to bring the system back online quickly.

**VII) Discussion & Conclusion**

The integration of advanced monitoring and alert systems in dementia care homes represents a significant step forward in ensuring the safety and well-being of residents. This project has successfully demonstrated the feasibility of deploying a multi-faceted detection and alert system that operates in real-time, providing robust surveillance and response mechanisms.

The key findings of the project are as follows:

**Human Detection:** The system accurately identifies the presence of individuals within the care home environment. This feature is essential for monitoring residents' activities and ensuring they are within safe zones.

**Loitering & Boundary Detection:** The implementation of loitering and boundary detection algorithms provide a critical layer of safety by alerting staff to potential risks, such as residents nearing exit points or entering unauthorised areas.

**Alert System:** The alert system serves as an immediate notification mechanism, prompting swift action from care home staff. This rapid response capability is vital in addressing potential emergencies or resident needs.

**Real-time Low Light Enhancement:** The capacity to enhance video quality in low-light conditions ensures that the monitoring system is effective around the clock, which is particularly important during nighttime hours when residents are unsupervised and the risk of wandering is heightened.

**Azure Blob Storage Service:** Utilizing Azure Blob Storage offers a secure and scalable solution for storing CCTV footage. The ability to connect to IoT Hub and other Azure services opens up possibilities for future integration, such as using advanced analytics and machine learning to study resident behaviour patterns, identify trends, and predict potential incidents before they occur. The use of Azure services, therefore, not only enhances the current security and monitoring capabilities but also lays the groundwork for a smarter, data-driven approach to resident care in dementia homes.

The implications of these findings are far-reaching. By addressing the unique challenges of dementia care, the project presents a model for how technology can be harnessed to improve the quality of care. The potential benefits include increased safety for residents, peace of mind for families, and enhanced operational efficiency for care home staff.

In conclusion, the project underscores the value of technological innovation in healthcare settings. The successful deployment of these features within a dementia care home could serve as a benchmark for similar facilities aiming to upgrade their care delivery and safety protocols. As we look to the future, the integration with Azure's ecosystem of services provides a promising avenue for expanding the system's capabilities, enabling more intelligent and predictive care solutions that can further revolutionize the management and care of dementia patients.

**VIII) Appendices (Detailed Project Implementation Guide)**

Access this link for the full project implementation guide:

[**https://docs.google.com/document/d/1A-X2UHXemn-\_rVfZ5xF1G4zrDa4X2DKJ1u1Re572i90/edit?usp=sharing**](https://docs.google.com/document/d/1A-X2UHXemn-_rVfZ5xF1G4zrDa4X2DKJ1u1Re572i90/edit?usp=sharing)

**IX) References / Data Source Links**

<https://github.com/SakshayMahna/Computer-Vision-on-Humans>

<https://medium.com/analytics-vidhya/haar-cascades-explained-38210e57970d> (model architecture)

**X) Contributions**

| **Tasks & Responsibilities** | | | |
| --- | --- | --- | --- |
| Leader:  Angel | Member:  Ying Jing | Member:  Derrek | Member: YouYan |
| 1. Research  2. Human Detection Feature  3. Loitering Detection Feature  3. Alarm System Feature  4. Azure Blob Storage Feature  4. Slides  5. Report  6. Director & photographer for demo video | 1. Research  2. Real-time Low Light Enhancement Feature  3. Azure Blob Storage Feature  4. Slides  5. Report  6. Editor & Scriptwriter for demo video | 1. Research  2. Human Detection Feature  3. Merged & Debugged codes  4. UI in Jupyter Notebook  5. Report  6. Actor for demo video | 1. Research  2. Loitering Detection Feature  3. Slides  4. Report  5. Voiceover for demo video  6. Provided mental support from overseas |