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AI Powered Drowning Detection and Alert System for Swimming Pool

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Abstract: The use of Artificial Intelligence in intelligent surveillance systems has improved the ability to detect emergency situations automatically and efficiently. This project presents an AI Powered Human Drowning Detection and Alert System designed for swimming pool safety using Computer Vision and Deep Learning techniques. The proposed system continuously monitors uploaded media files and live webcam streams to identify possible drowning situations in real time.

The system is implemented using a custom-trained YOLOv8 model integrated with OpenCV for image and video processing. Flask is used for backend processing, while HTML, JavaScript, and Tailwind CSS are used to develop the frontend monitoring interface. The system performs frame-by-frame analysis to detect swimmers, generate bounding boxes, and classify activities based on prediction confidence.

To improve detection reliability, the system applies confidence thresholding, frame buffering, and danger percentage analysis to reduce false alerts caused by temporary movements or water disturbances. Whenever dangerous activity is detected continuously, the system immediately generates warning notifications and audio alerts.

The developed solution provides a practical, affordable, and real-time safety monitoring system for swimming pools and other aquatic environments. By combining deep learning, intelligent surveillance, and automated alert generation, the system helps improve swimmer safety and reduces emergency response time.

Keywords: Artificial Intelligence, YOLOv8, Drowning Detection, Computer Vision, OpenCV, Deep Learning, Real-Time Monitoring, Surveillance System, Swimming Pool Safety, Alert System.

I. INTRODUCTION

Artificial Intelligence (AI) and Computer Vision are becoming important technologies in modern monitoring and surveillance systems. Recent improvements in deep learning algorithms have enabled computers to recognize objects, analyze human activities, and detect abnormal situations from images and videos with high accuracy. These technologies are widely applied in healthcare, transportation, industrial automation, and public safety systems to improve monitoring efficiency and reduce human effort.

Swimming pools are common recreational places where accidental drowning incidents may occur unexpectedly. In many situations, drowning happens silently and within a very short period, making it difficult for lifeguards or supervisors to react immediately. Continuous human monitoring may also become less effective because of fatigue, distractions, overcrowding, or poor visibility conditions. Delayed emergency response can increase the risk of serious injury or death. To address these problems, intelligent drowning detection systems can be developed using Artificial Intelligence and Computer Vision techniques. AI-based surveillance systems can continuously analyze video streams and identify unusual swimmer behavior automatically. Deep learning models are capable of detecting human movements and recognizing dangerous activity patterns in real time, which helps improve safety monitoring and emergency response.

The proposed project, AI Powered Human Drowning Detection and Alert System for Swimming Pools, is designed to detect drowning behavior automatically using deep learning and real-time video analysis. The system supports uploaded

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images, uploaded videos, and live webcam monitoring for continuous swimmer observation. A custom-trained YOLOv8 model is used to perform drowning detection and generate prediction results in real time.

Python and Flask are used to manage backend operations and real-time processing tasks, while OpenCV handles frame extraction, image enhancement, and continuous video stream analysis. The frontend interface is developed using HTML, JavaScript, and Tailwind CSS to provide an interactive and user-friendly monitoring dashboard. The system displays bounding boxes, confidence scores, warning notifications, and detection statistics during analysis.

The proposed system minimizes incorrect drowning alerts by storing recent prediction frames and analyzing detection confidence over multiple consecutive frames before generating warnings. Audio alerts and visual warning messages are generated whenever drowning behavior is detected continuously across multiple frames. The system also calculates danger percentage during video analysis to estimate the overall risk level.

The main objective of the proposed system is to provide a low-cost, efficient, and intelligent drowning prevention solution using Artificial Intelligence technologies. The project demonstrates how AI-powered monitoring systems can improve swimming pool safety and reduce emergency response time in real-world environments such as schools, hotels, sports complexes, and public swimming facilities.

II. RELATED WORK

Artificial Intelligence, Deep Learning, and Computer Vision technologies are widely used in modern surveillance and intelligent monitoring systems. Recent advancements in object detection, activity recognition, and Generative AI have improved the ability of machines to analyze visual information and identify abnormal situations automatically. These technologies are increasingly applied in healthcare monitoring, smart surveillance, transportation safety, and real-time emergency detection systems.

Prakash [1] proposed the NEPTUNE technique for early drowning prediction in swimming pools. The research focused on detecting dangerous swimmer behavior and identifying near-drowning situations at an early stage. The work demonstrated the importance of automated monitoring systems in reducing response time during emergency conditions. However, the proposed method mainly focused on prediction equations and did not include advanced real-time deep learning–based object detection techniques.

Redmon et al. [2] introduced YOLO (You Only Look Once), a real-time object detection algorithm capable of detecting objects from images and videos with high speed and accuracy. The YOLO framework significantly improved object detection performance by processing complete images using a single neural network architecture. Because of its real-time processing capability, YOLO became widely used in surveillance, monitoring, and safety-related applications. The proposed drowning detection system uses the YOLOv8 framework for real-time swimmer detection and activity analysis. Jocher et al. [3] developed the Ultralytics YOLO framework, which provides advanced implementations of modern YOLO models including YOLOv8. The framework supports real-time object detection, model training, image processing, and video analysis with improved accuracy and efficiency. The flexibility and lightweight nature of YOLOv8 make it suitable for real-time drowning detection systems using webcam and surveillance video streams.

Simonyan and Zisserman [4] proposed two-stream convolutional neural networks for action recognition in videos. Their model analyzed both spatial and temporal information from video sequences to improve human activity recognition performance. The research demonstrated how deep learning models can understand movement patterns and behavior from video frames. Concepts from activity recognition are useful in drowning detection systems where abnormal swimmer movements must be identified accurately.

Doshi and Yilmaz [5] proposed a continual learning approach for anomaly detection in surveillance videos. Their work focused on identifying unusual activities automatically from video streams using Artificial Intelligence techniques. The research highlighted the importance of anomaly detection in intelligent surveillance applications and demonstrated how AI systems can continuously improve detection performance over time.

Although several studies focused on object detection, action recognition, anomaly detection, and surveillance monitoring, many existing systems provide limited support for integrated drowning prevention applications. Some approaches depend on wearable sensors or underwater monitoring systems, which increase implementation complexity and cost. Other systems mainly focus on detection without providing real-time alerts, interactive monitoring dashboards, or false alarm reduction mechanisms.

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The proposed AI Powered Human Drowning Detection and Alert System combines deep learning, real-time video surveillance, OpenCV-based processing, and automated alert generation into a single integrated platform. Unlike many existing systems, the proposed solution supports uploaded image analysis, uploaded video processing, live webcam monitoring, confidence-based drowning detection, danger percentage calculation, and audio alert generation. By integrating YOLOv8 with real-time monitoring and intelligent alert mechanisms, the system provides a practical, scalable, and low-cost solution for improving swimming pool safety.

III. METHODOLOGY

The AI Powered Human Drowning Detection and Alert System is designed to monitor swimming pools using Artificial Intelligence and Computer Vision technologies. Instead of depending completely on human supervision, the system continuously analyzes live webcam streams, uploaded images, and uploaded videos to identify drowning behavior automatically. The system uses a custom-trained YOLOv8 model for real-time detection and OpenCV for image and video processing. Bounding boxes, confidence scores, and warning alerts are generated whenever drowning activity is detected. The project combines deep learning, real-time monitoring, and automated alert generation to improve swimmer safety and reduce emergency response time.

1. System Architecture

The architecture of the proposed system follows a modular client-server approach integrating frontend interfaces, backend processing, and AI-based drowning detection modules. The frontend is developed using HTML, JavaScript, and Tailwind CSS to provide a responsive user interface for uploading media files and monitoring live webcam feeds. The backend is implemented using Flask and Python for handling requests, video processing, and model inference. OpenCV processes incoming frames and sends them to the YOLOv8 model for real-time detection. The trained best.pt model identifies drowning behavior and generates bounding boxes with confidence scores. Whenever dangerous activity is detected, the alert module activates warning banners and audio alarms. The system also calculates danger percentage and displays real-time statistics through the monitoring dashboard.

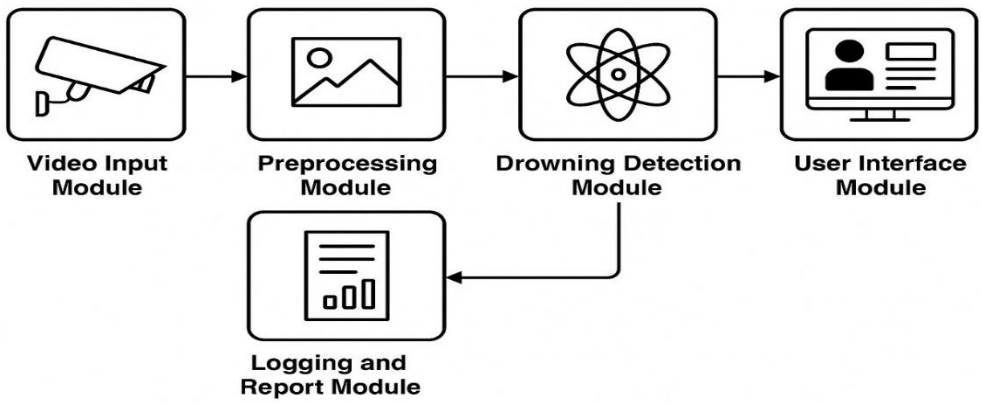

Fig. 1 Proposed System Architecture of Human Drowning Detection

2. Development Model

The proposed system follows the Agile Software Development Model because of its flexibility and iterative development approach. The project is divided into multiple modules such as frontend development, backend integration, AI model training, video processing, and alert generation. Each module is developed and tested independently before final integration. The Agile model enables continuous improvement of detection accuracy, user interface design, and system performance while reducing development risks and improving reliability.

3. System Workflow

The workflow of the proposed system begins when users upload images/videos or start live webcam monitoring through the frontend interface. The uploaded media or webcam frames are transferred to the Flask backend server for processing. OpenCV extracts frames and preprocesses them for analysis. The processed frames are passed to the YOLOv8 deep learning model, which detects swimmers and classifies their behavior as safe or drowning. Bounding boxes and confidence scores are generated for detected objects. If drowning behavior is continuously identified, the alert module triggers warning banners and alarm sounds. The processed outputs, danger percentage, safe frames, and drowning frames are displayed on the frontend dashboard in real time.

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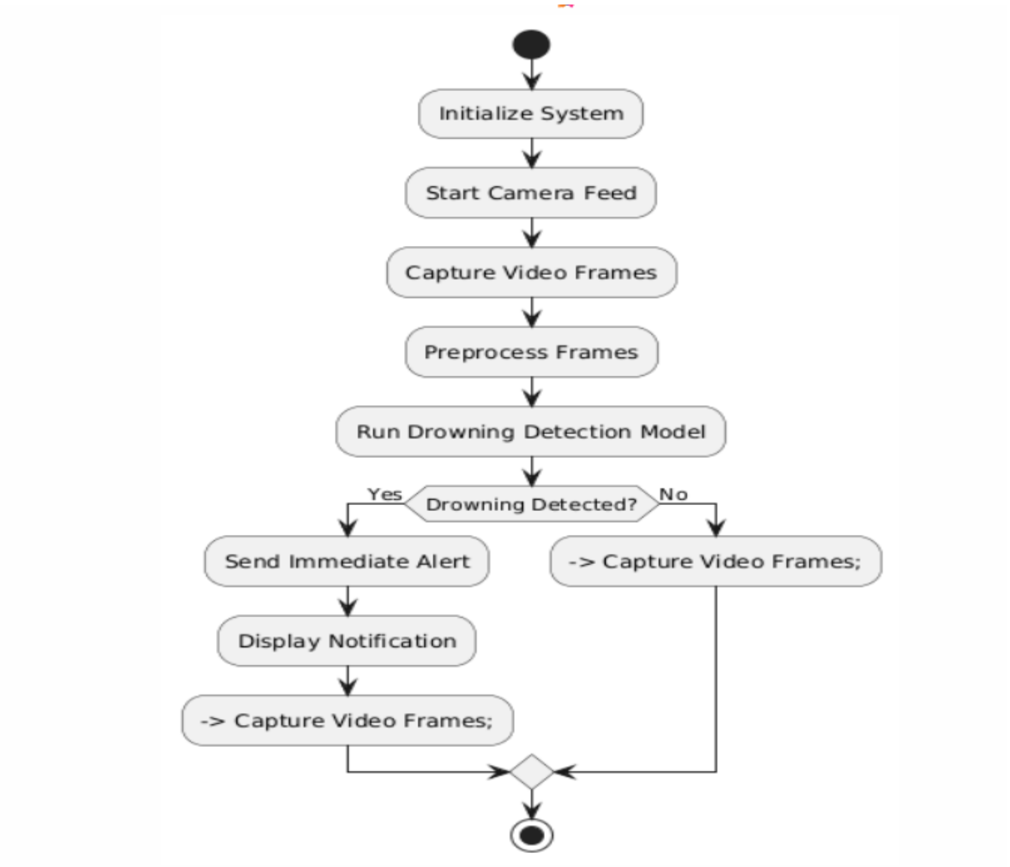

Fig. 2 Workflow of Human Drowning Detection and Alert System

4. Model Training

The drowning detection model used in the proposed system is trained using Google Colab and the Ultralytics YOLOv8 framework. A custom-trained dataset containing drowning and safe swimming images/videos is used for model training. Google Drive is mounted in Colab, and the YOLOv8 framework is installed for training execution. The training process uses parameters such as image size 640, batch size 16, and 100 epochs. The previously saved checkpoint model is loaded using last.pt, and training is resumed to improve model performance. After successful training, the final trained model is saved as best.pt and integrated into the Flask backend for real-time prediction and drowning detection.

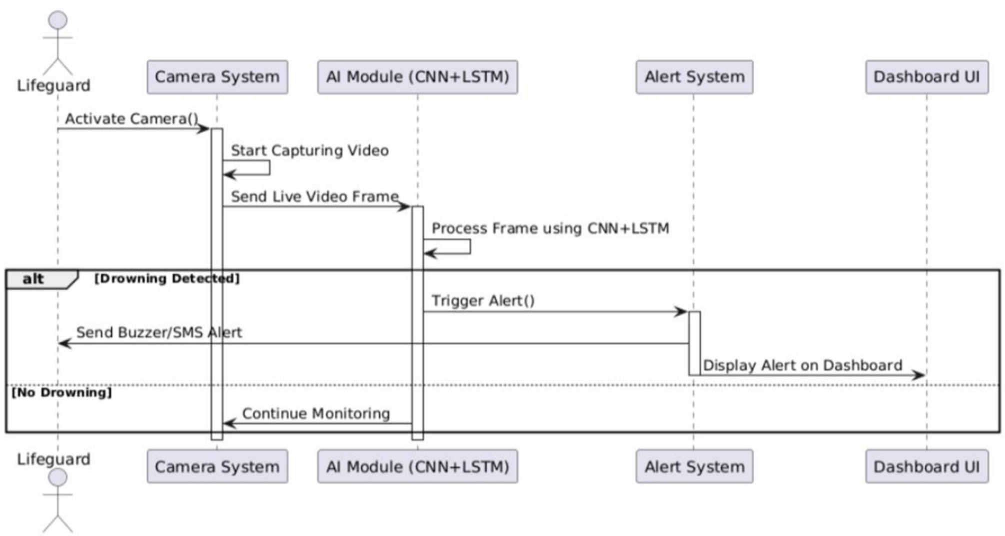

Fig. 3 Sequence Diagram for AI-Powered Drowning Detection and Alert System

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5. Real-Time Detection Logic

The proposed system performs frame-by-frame drowning detection using OpenCV and YOLOv8. To improve processing speed and reduce computational overhead, frame skipping optimization is implemented using skip_frame = 3. The system uses a confidence threshold value of 0.5 to filter low-confidence predictions. Bounding boxes are displayed in green for safe swimmers and red for drowning detection. During webcam monitoring, a frame buffering mechanism stores recent predictions to reduce false alarms. Alerts are generated only when multiple consecutive frames indicate dangerous activity. The system activates warning banners and audio alarms whenever drowning behavior is confirmed. During video analysis, danger percentage is calculated based on the number of drowning frames detected in the processed video.

6. Tools and Technologies

The proposed system is developed using Python for backend implementation and Flask for API handling and server-side processing. OpenCV is used for image preprocessing, frame extraction, and video analysis. YOLOv8 is used as the deep learning model for real-time drowning detection. The frontend interface is developed using HTML, JavaScript, and Tailwind CSS to provide responsive user interaction and monitoring dashboards. Google Colab is used for model training, while VS Code is used for development and implementation. GitHub is used for version control and project management.

IV. RESULTS AND DISCUSSION

The AI Powered Human Drowning Detection and Alert System was successfully developed and tested using real-time video surveillance inputs. The system was capable of detecting swimmers and monitoring their movements continuously using AI-based object detection techniques. The YOLOv8 model achieved accurate human detection and tracking performance under different swimming pool conditions. The system successfully identified abnormal movement patterns associated with drowning situations and generated alerts in real time.

The alert mechanism responded immediately by triggering warning notifications and alarms whenever a possible drowning event was detected. The real-time monitoring capability reduced response delay and improved emergency handling.

The proposed system demonstrated the effectiveness of Artificial Intelligence and Computer Vision technologies in improving swimming pool safety. The integration of deep learning, surveillance systems, and automated alerts created a reliable and efficient drowning prevention solution.

The project also showed that AI-based monitoring systems can reduce dependence on manual observation and improve overall public safety.

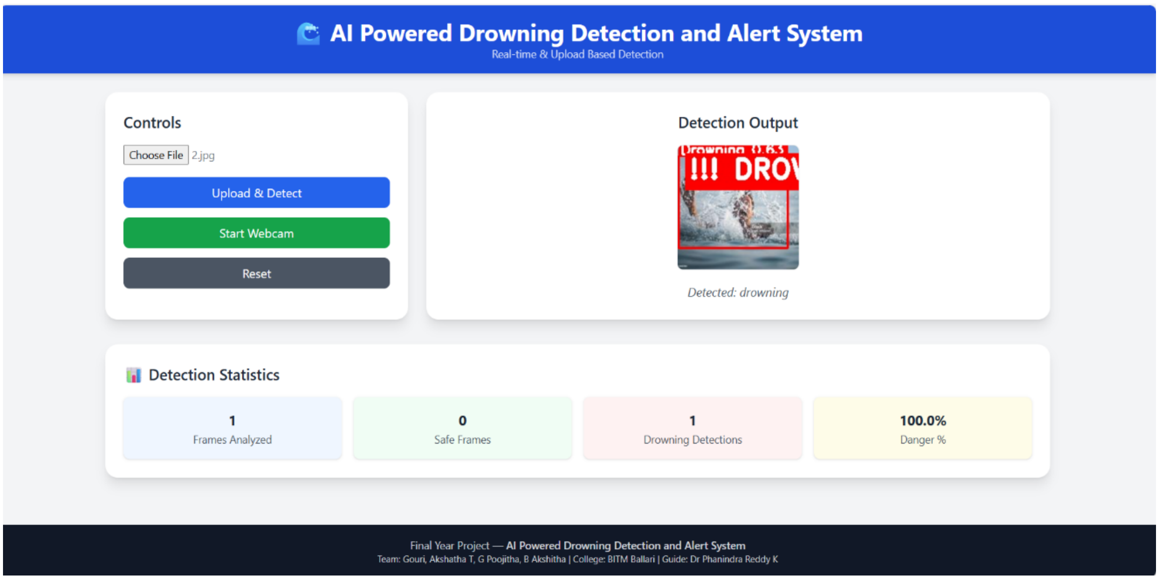

Fig. 4 Drowning detection from image

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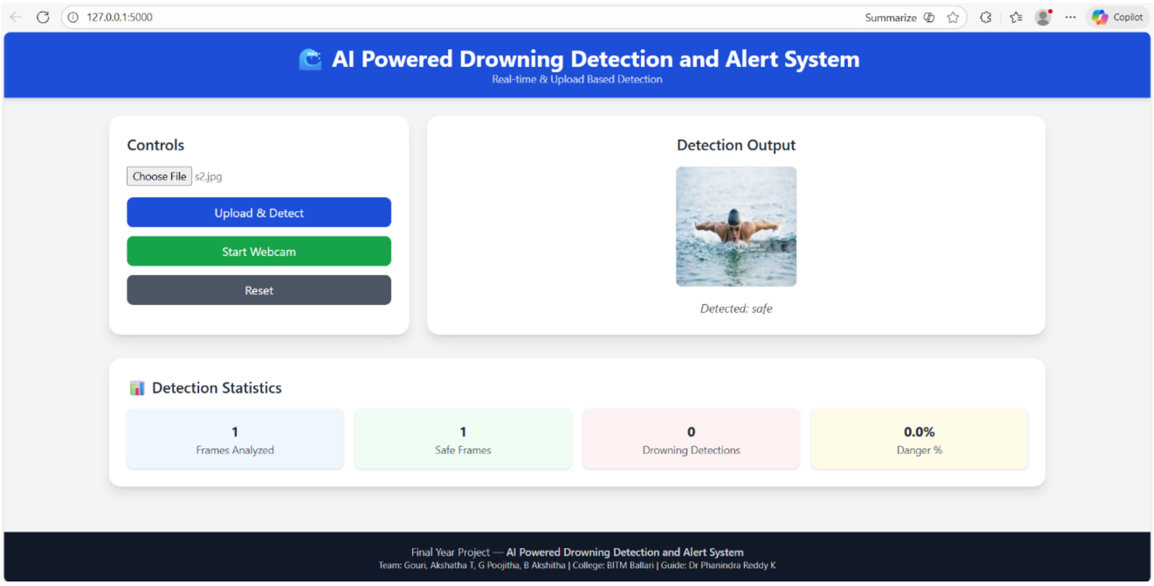

Fig. 5 Swimming detection from image

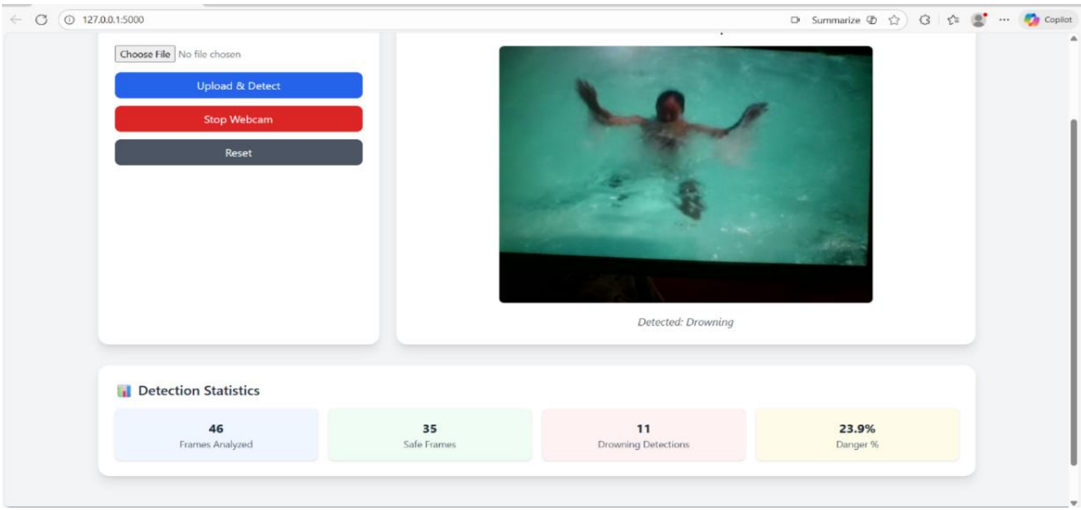

Fig. 6 Drowning detection from webcam

V. CONCLUSIONS AND FUTURE WORK

The AI Powered Human Drowning Detection and Alert System was developed to improve swimmer safety through automatic real-time monitoring and intelligent alert generation. The system successfully analyzes uploaded media files and live webcam streams to identify possible drowning situations using Computer Vision and deep learning techniques. By integrating YOLOv8, OpenCV, Flask, and a responsive frontend interface, the proposed solution performs continuous swimmer monitoring and generates warning alerts whenever dangerous activity is detected.

The implementation also includes confidence-based prediction, frame buffering, and danger percentage analysis to improve detection accuracy and minimize false alarms. Experimental testing showed that the system can effectively monitor swimmer activities and support faster emergency response in swimming pool environments. The developed solution provides a practical and affordable safety monitoring system suitable for schools, hotels, sports centers, and other public aquatic locations.

Future enhancements can further improve the performance and usability of the system. Additional features such as underwater camera support, multi-camera integration, and mobile-based emergency notifications can increase monitoring efficiency. Advanced activity recognition models and edge-device deployment using Raspberry Pi or NVIDIA Jetson may also improve portability and real-time performance. Cloud-based monitoring and smart rescue assistance systems can be integrated in future versions to provide more advanced drowning prevention capabilities.

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