AquaGuard: A Device for Real-Time Drowning Detection in Swimming Pools Utilizing Visual-Spatial Perception With Deep Encoder-Decoder Neural Networks

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Drowning is the third leading cause of unintentional injury-related death worldwide. In the United States, drowning remains a significant public health concern, leading to preventable deaths and injuries, particularly in swimming pools. According to the Centers for Disease Control and Prevention (CDC), drowning is the fifth leading cause of unintentional injury death in the U.S., with an average of 4,000 fatalities annually. While traditional drowning prevention methods like lifeguards and surveillance cameras are often cost-prohibitive or ineffective in many contexts, there is a pressing need for more accessible solutions. This engineering project introduces an innovative, cost-effective drowning detection system utilizing advanced deep-learning models for single-pass object detection, multiple object tracking, and pose estimation. These deep learning models are trained on an extensive dataset comprising 19,166 videos of individuals swimming and instances of near-drowning and drowning. The system is built around a Raspberry Pi single-board computer with a camera module. The core of this system is a custom-designed algorithm that analyzes video frames with deep-learning models to monitor swimmers in real time. It tracks their movements and identifies any signs of drowning within seconds. The evaluations in a controlled environment demonstrated that the device accurately detects drowning incidents with 88.60% accuracy, 96.13% sensitivity, 84.61% specificity, and 93.10% mAP. Due to its affordability and ease of implementation, this device offers significant potential for widespread use in various aquatic environments. It represents a scalable and efficient tool that could substantially enhance community safety by preventing drowning incidents.