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Smart Water Safety Robot

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ABSTRACT—

Smart Human Safety Assistant is an innovative floating robotic device designed to detect and assist drowning individuals in small water bodies like ponds. It uses a camera module with OpenCV on a Raspberry Pi for real-time human detection. Upon identifying a person in distress, it activates a buzzer and navigates toward them using IR and ultrasonic sensors, controlled by an Arduino Uno and motor driver IC. An air tube provides temporary support until help arrives. This system integrates computer vision and robotics, demonstrating strong potential for enhancing water safety through autonomous intervention.

Keywords- OpenCV, Raspberry Pi, Human Detection, Ultrasonic and IR Sensors

Introduction

Smart Water Safety Assistant is an autonomous floating robot designed to enhance safety in small, unattended water bodies like ponds and lakes. It uses a Raspberry Pi and camera module to process live video through the OpenCV library, enabling real-time human detection. Upon identifying a person in distress, the robot activates a buzzer to alert nearby individuals and begins autonomous navigation toward the victim to provide immediate aid.

The system integrates IR and ultrasonic sensors, an Arduino Uno, and motor driver ICs to guide the robot accurately. Controlled by Python-based software, the device effectively detects drowning situations, triggers alerts, and moves toward the person in need. This low-cost, scalable solution highlights the potential of combining robotics and computer vision for life-saving applications in environments lacking constant supervision.

Literature Review

Various systems have been developed to ensure water safety using technologies like IoT, computer vision, and robotics. Some research focused on drowning detection using surveillance cameras and AI-based human recognition. Others implemented floating robots equipped with sensors to monitor water conditions. However, most lacked real-time rescue capability or immediate alert systems. This project bridges that gap by combining a Raspberry Pi, OpenCV, camera module, and sensors to detect drowning individuals and provide timely alerts and support, making water rescue quicker and smarter.

Tabel 1 Literature Survey

No.	Title	Key Focus
1	Human Movement Detection (2021)	Face detection & email alert
2	Drowning Detection (2023)	CNN-based image recognition
3	Underwater Detection (2024)	Pressure sensors for water activity
4	Solar Charging System (2024)	Reverse current protection
5	Arduino Following Robot (2022)	IR & ultrasonic sensor navigation

METHODOLOGY

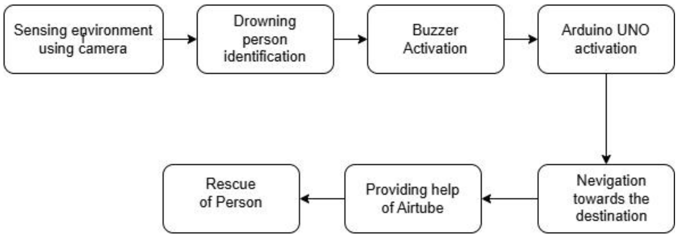

Figure 1: Process Flow of System

Sensing Environment Using Camera

The system continuously monitors the water body using a camera module attached to the floating robot.

The camera captures real-time video footage and sends it to the Raspberry Pi for analysis.

Drowning Person Identification

OpenCV and image processing techniques are used on the Raspberry Pi to detect human figures in distress.

If abnormal movements or signs of drowning are detected, the system triggers an alert.

Buzzer Activation

On detecting a potential drowning incident, a buzzer is activated to alert nearby people for immediate attention.

This serves as a local emergency alert system.

Arduino UNO Activation

After the alert, control is handed over to the Arduino UNO, which is responsible for hardware movement.

The Arduino receives commands from the Raspberry Pi and starts the navigation process.

Navigation Towards the Destination

The robot navigates toward the detected drowning person using ultrasonic and IR sensors to avoid obstacles.

The movement is controlled by motors interfaced with the Arduino and guided by sensor feedback.

Providing Help of Airtube

Once the robot reaches close to the person, it extends or provides an air tube (or floatation device).

This helps the person stay afloat until further help arrives.

Rescue of Person

With the air tube support and alert notification already generated, the person can hold on to the robot.

Nearby people or lifeguards can now safely perform the rescue operation.

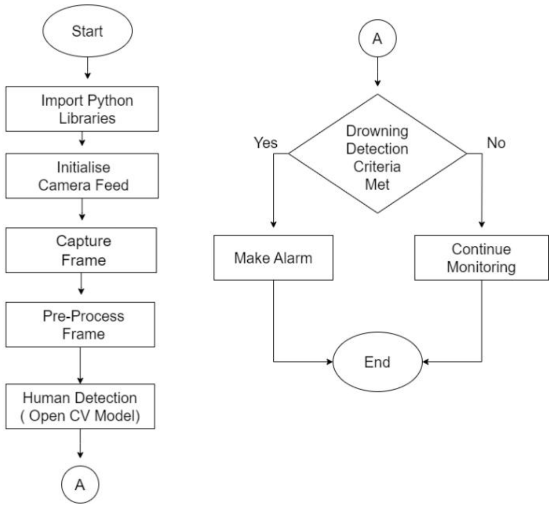

Figure 2. Flow Chart of System

Detailed Explanation of Each Step with Visuals:

1. Start - The system begins its operation.

2. Import Python Libraries - Necessary Python libraries are loaded to perform various tasks, like handling the camera and processing images.

3. Initialize Camera Feed - The camera is turned on and prepared to capture real-time video.

4. Capture Frame - A single image (frame) is taken from the video feed for analysis.

5. Pre-Process Frame - The captured image is processed (e.g., resized or filtered) to make it easier for the computer to analyze.

6. Human Detection (OpenCV Model) - Using OpenCV, the system checks if a human is present in the frame.

7. Drowning Detection Criteria Met? - The system assesses if the detected human meets the criteria for a drowning person.

If Yes - If the criteria are met, an alarm is triggered to alert nearby people of a possible drowning incident.

If No - If the criteria are not met, the system continues monitoring by returning to capture the next frame.

8. End - This represents the end of one cycle of detection. The process repeats to keep monitoring continuously.

IMPLEMENTATION

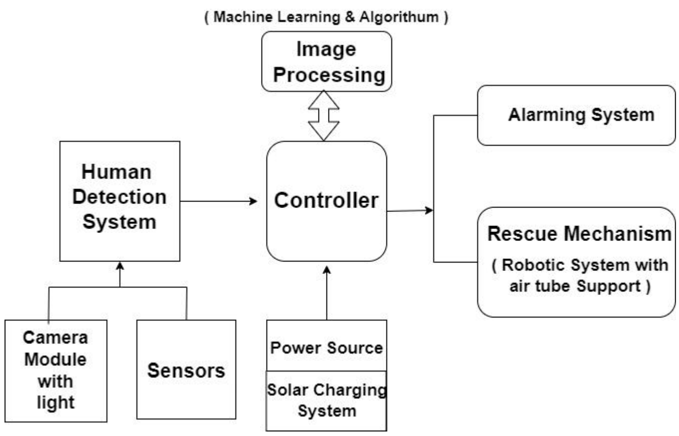

Figure 3. Block Diagram for Implementation

The Smart Water Safety Assistant integrates computer vision, sensor technology, and embedded systems to autonomously detect and assist drowning individuals in small water bodies.

Environment Sensing

A camera mounted on the floating robot continuously monitors the water surface. The camera is capable of 360° rotation for complete coverage and sends real-time video to a Raspberry Pi.

Drowning Detection

Using the OpenCV library, the Raspberry Pi processes the camera feed to detect human figures and evaluate distress behavior based on shape and motion patterns. This step involves edge detection and object recognition.

Alert System Activation

Upon detecting a possible drowning incident, the Raspberry Pi activates a buzzer to alert people nearby. This buzzer operates in the range of 95–110 dB to ensure it is audible from a distance.

Autonomous Navigation

The Raspberry Pi transfers control to the Arduino UNO, which uses inputs from IR and ultrasonic sensors to guide the robot toward the victim. These sensors measure distance and detect obstacles to allow safe navigation.

Rescue Mechanism Deployment

Once the robot reaches the drowning person, it deploys an air tube to provide immediate floatation support. This helps the victim stay afloat until human assistance arrives.

Power Management

A solar charging system powers the robot, making it energy-efficient and suitable for continuous operation in remote outdoor environments. The system can operate for several hours on a full solar charge.

This step-by-step methodology ensures real-time detection, quick response, and reliable assistance during drowning incidents, with minimal human intervention.

Result and Discussion

Parameter	Theoretical	Practical
Response time	30 sec	25-35 sec
Detection accuracy	95% (camera) 90% (sensors)	92% (clear), 85% (murky)
Movement precision	1-2 cm	2-4 cm
Power backup	6-8 hrs (solar)	4-6 hrs, 2-3 days (sun)
Rescue time	3-5 sec	3-5 sec

Key Observations

Response Time improved in some trials due to real-time optimized routing but varied with water clarity.

Detection Accuracy dropped slightly in murky water due to reduced camera visibility.

Movement precision was affected by turbulence and external water conditions.

Power backup proved strong under sunlight, supporting long-term autonomous operation.

Conclusions and Future scope

The Smart Water Safety Assistant is an innovative device designed to improve safety in water environments such as ponds and small lakes. Equipped with a camera and sensors, it continuously monitors the water, quickly detecting if a person or animal is in danger. Upon detecting someone in distress, the system immediately triggers an alarm to alert nearby people. It then navigates toward the individual, using precise sensors to guide its movement, ensuring prompt assistance.

Powered by solar energy, the assistant can operate for long periods, making it reliable and sustainable with minimal maintenance. Once it reaches the person, the rescue mechanism deploys an air tube for support, helping to keep them safe until help arrives. This project demonstrates how technology can be applied to save lives, offering a practical, automated solution for water safety that brings peace of mind to communities and families.

Overall, the Smart Water Safety Assistant is a valuable step toward using technology to prevent accidents and improve safety around water bodies.

Future Scope: Several areas can be explored to further enhance the utility, scalability, and performance of the proposed system:

1. Expanded Monitoring Capabilities: Future versions could include additional sensors, like thermal imaging or sonar, to improve detection accuracy in low-visibility conditions or at night. This would make the device more effective in varied environments and enhance its reliability in any weather or lighting.
2. Enhanced AI for Behavioral Analysis: By incorporating artificial intelligence (AI), the system could analyze movement patterns in the water to predict potential emergencies, such as detecting early signs of drowning. This predictive capability would allow for quicker response times and prevent accidents before they fully develop.
3. Integration with Emergency Services: The assistant could be upgraded to connect directly with emergency services via GSM or satellite communication, instantly notifying them of incidents. This would ensure rapid assistance, especially in remote or rural areas where on-site rescue support may be delayed.
4. Voice and Visual Alert Systems: Adding voice commands or flashing lights as part of the alarm system would increase its effectiveness in drawing attention to a potential emergency, especially in larger water areas or crowded places where a buzzer alone might not be heard.
5. Remote Operation and Control: Future models could allow users or lifeguards to remotely control and guide the device toward a detected person, enhancing flexibility and precision in rescue scenarios. A mobile app could be developed to display live camera footage and status updates.
6. Autonomous Path Planning: Implementing machine learning algorithms for path planning would enable the device to navigate around obstacles independently. This would make it more efficient in complex water environments, such as lakes with rocks, vegetation, or other objects.
7. Scalability for Different Water Environments: The Smart Water Safety Assistant could be adapted for use in larger bodies of water, such as rivers and coastal areas. By designing scalable versions, it could cater to varying water conditions and depths, expanding its application to a wider range of settings.
8. Advanced Power Management: Incorporating additional renewable power sources, like mini wind turbines, could further increase the device's sustainability. A more advanced energy storage system would allow longer operation times, making the device ideal for continuous monitoring.

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