Heart "Drowning" Meets "Water" — An Intelligent Anti-Drowning Device

I. Research Background

A study by the World Health Organization estimates that there are 236,000 drowning deaths worldwide each year, making it the third leading cause of unintentional injury death globally. In 45 countries, drowning is one of the top five causes of death for children aged 1–14. Additionally, drowning incidents result in direct and indirect economic losses. For example, in countries like the United States and Australia, drowning causes an average annual loss of $85 million to nearly $300 million. This highlights that drowning is a serious social issue that cannot be ignored.

Current anti-drowning devices, such as life jackets, are often bulky and hinder the user's mobility and experience, leading many to discard them and rendering them ineffective. Manual anti-drowning devices, on the other hand, fail to account for the fact that people in distress often panic and forget to activate the device. Therefore, we aim to develop a comfortable, automated anti-drowning device that addresses these shortcomings, reducing the impact of drowning on lives and society.

II. Design Concept

1. **Plan**

(1) **Hardware Construction**: We plan to create a wristband with an attached box containing the device. Since adrenaline levels rise during drowning, leading to an increased heart rate, we have installed a heart rate sensor in the box to monitor heart rate as the trigger condition (activated when heart rate increases or decreases sharply). An LED light and a speaker are also included to emit an alarm, enabling quick detection and rescue.

(2) **Airbag Design**: We use a chemical reaction between baking soda (6.5g) and citric acid (10%, 50g) to generate gas for inflation. The baking soda is placed in the airbag, while the citric acid is stored in a bottle (with a motor controlling the bottle's opening). The gas and byproducts produced in this reaction are safe, non-toxic, and non-polluting. (Chemical formula: $3NaHCO_3 + C_6H_8O_7 \rightarrow C_6H_5Na_3O_7 + 3CO_2 + 3H_2O$)

(3) **Programming**: Considering the significant variations in heart rate among people of different ages and professions, we use the difference between the current heart rate and the heart rate after 2 seconds as the detection condition for airbag deployment. If the difference exceeds 15, indicating drowning, the motor will open the bottle to release the airbag, the light will turn on, and the alarm will sound.

III. Device Introduction

1. Hardware Design

We used Arduino components for construction. The hardware and their functions are as follows:

- **Heart Rate Monitor**: Monitors the user's heart rate in real time and triggers the device when abnormalities are detected, serving as the activation condition.
- **LED Light**: Illuminates after activation, making the drowning person more visible and achieving the goal of "detected within 10 seconds, rescued within 20 seconds."
- **Speaker**: Emits an alarm sound after activation, serving the same purpose as the LED light.

2. Airbag Design

Using a sports sleeve as a template, we encase the entire device in an airbag to address waterproofing issues. A mesh structure is also used to support the device and prevent water ingress.

IV. AI-Powered Drowning Detection System

1. Model Architecture

We developed a computer vision-based drowning detection system using YOLOv11 Object Detection (Fast) model. The system is trained on a comprehensive dataset containing over 2,000 images of swimming pool and beach environments with detailed annotations.

2. Dataset and Classes

The model is trained to recognize 8 distinct classes relevant to water safety monitoring:

- **Boat, Kayak, Sail boat, Speed boat, Surf board**: Watercraft detection
- **Person NOT in water**: Individuals safely on land or deck
- **Person in water**: Normal swimming or water activities
- **Person drowning**: Critical detection of drowning incidents

3. Model Performance

The trained model achieves excellent performance metrics on the validation set:

Table 1: Model Performance Metrics

Metric	Value	Description
mAP@50	78.6%	Mean Average Precision at 50% IoU
Precision	72.3%	Accuracy of positive predictions
Recall	80.9%	Ability to find all positive samples

4. Real-time Detection Capability

The system processes images with resolution 640×480 pixels and provides real-time detection results. A sample detection output demonstrates the system's capability:


```
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        "image": {"width": 640, "height": 480},
        "predictions": [
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                "class": "Person in water",
                "detection_id": "662b428d-e9c4-47d0-9b98-fb2d2ae496c6"
            },
            {
                "width": 162.0, "height": 113.0, "x": 372.0, "y": 262.5,
                "confidence": 0.5770531892776489, "class_id": 4,
                "class": "Person in water",
                "detection_id": "0528b590-b443-4c3d-99b0-b6db3db338a8"
            }
        ]
    }
}
```

5. Integration with Physical Device

The AI detection system works in conjunction with the physical anti-drowning device:

- **Primary Detection**: Heart rate sensors in the wristband
- **Secondary Verification**: Computer vision system for visual confirmation
- **Emergency Response**: Combined triggers activate rescue protocols

V. Innovations and Application Value

1. Innovations:

- Fully automated design: Real-time heart rate monitoring determines whether drowning is occurring and activates the device, preventing missed rescue opportunities due to human error and enabling quick and accurate rescue.
- Compared to existing anti-drowning devices, our product is compact, minimally intrusive, and uses a hygienic and reliable inflation method.
- Integrated AI-powered computer vision system for secondary verification and area monitoring.

2. Application Value:

As the COVID-19 pandemic gradually subsides, regions such as Hong Kong, Macau, and mainland China are reopening, leading to a recovery in tourism and finance. People are eager to travel abroad, and swimming and water activities are undoubtedly popular choices.

Recent news has frequently reported negligence by lifeguards leading to drowning deaths. At the same time, few swimmers wear life jackets, making it difficult for victims to seek help during emergencies in the water.

In contrast, this intelligent anti-drowning device not only provides protection without affecting the user's experience but also, with the combination of LED lights, speakers, and AI monitoring, enables quick detection of drowning persons, increasing survival chances. It has promising development prospects.

VI. Conclusion and Future Development

1. Use a relay to control the GPS switch, activating the GPS system only when the user is drowning to protect privacy.
2. Incorporate more reference data and multiple drowning detection conditions to enhance the device's stability.
3. Improve the method of adding chemical reagents, such as packaging them similarly to instant noodle seasoning packets, for user convenience.
4. Expand the AI training dataset to include more diverse water environments and lighting conditions.
5. Implement multi-camera synchronization for comprehensive area coverage in large swimming facilities.