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AWRO MOBILE ROBOT: AIDFOR WATER RESCUE OPERATIONS

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ABSTRACT
AWRO Mobile Robot: Aid for Water Rescue Operations, is a mobile robot that takes the appearance of a watercraft, which helps a lifeguard rescue a drowning person in deep swimming pools. AWRO is short for “Aid for Water Rescue Operations”. The mobile robot detects the drowning person by determining the splashing patterns of the person, which can be seen in the output image taken from an onboard camera. The system makes use of a PIC18F242 microcontroller to control the vehicle’s functions and movements. Also, communication between the PC and mobile robot is done through the use of serial communication. The control program of the mobile robot is implemented using several modules: the PIC microcontroller code, the main PC software running on top of the .NET framework, and the RoboRealm image processing software. With this, more lives can be saved, since it will be able to reach people who are drowning in areas where humans cannot normally reach. Test results show that the proposed robot can efficiently act as a rescue robot and can be further enhanced using some more advanced additive features.

Keywords: image processing, microcontroller, mobile robot, watercraft.

1. INTRODUCTION
Mobile robots play an important role in our society nowadays that help improves our way of living and even help us in our everyday lives such as automating some dangerous tasks or adding some security features in our daily routines.

Mobile robots have plenty of usage. They can do surveillance, rescue, delivery, and various tasks. They are also used for educational purposes and research studies. However, most of the applications are implemented to terrestrial-based mobile robots and water-based applications remain very few, despite the advancements of technology and the rapid developments in the field of robotics. Some robotic applications include home automation [1] and others are in agriculture or aquaculture applications [2]. Recently, underwater robots [3] became a focus of research primarily intended for surveillance and support systems.

Machine vision or computer vision [4,5] also became very popular in aiding robots to gather data and interact with their environment. Good signal processing techniques and algorithms [6,7] are used together with computer vision to improve the analysis of images such as image recognition, clustering, and identification [8,9], and lastly, an efficient wireless access link is a necessity in most remote applications[10,11].

This research intends to create an autonomous mobile robot in the form of watercraft so that it can aid a lifeguard in rescuing drowning people who are in deep swimming pools. The body of the mobile robot is created by using various raw materials, and power tools. Then, it uses various electronic components to control the functions of the mobile robot, especially its movement.

Lastly, a computer is used to store and run the control program, which enables the mobile robot to find a drowning person and distinguish it from the ones who are just swimming in deep areas, while conducting a surveillance operation.

2. STATEMENT OF THE PROBLEM
A micro-controller-based robot is designed to be able to act as a rescue or danger response system in a simulated swimming environment. The system uses an image processing module from Robo Realm that can detect a drowning person and discriminate against this person from other swimming persons. Obstacle detection and avoidance module are also used when the robot tends to go near the drowning person. And finally, rescue is done by the robot by deploying safety equipment such as a lifebuoy or vest to the drowning person to help him survive the accident.

3. ROBOT DESIGN AND SYSTEMS METHODOLOGY
AWRO is composed of 3 main components namely the Vehicle Components, Electronic Components, and Software Components. These main components work together to perform the main function of AWRO in adding safety features in a swimming pool and assist lifeguards in detecting possible danger and rescuing a drowning person.

3.1 Vehicle Components
The Vehicle Components constitute the body, propulsion system, camera stand, and lifebuoy mechanism of the robot. The body of the robot is the part that houses all of the components needed to provide the full functionality of the robot during rescue applications. The propulsion system consists of two 18-inch floor fans that control the travel direction of AWRO. The camera stand houses the onboard camera and all other electronic components used by AWRO.

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3.2 Electronic Components

The Electronic Components part consists of the personal computer, PIC18F242 Microcontroller, onboard camera, 2 Solid State Relay Circuits, MAX232 EIA-232 Driver/ Receiver, and WRT45G Wireless Router. The computer is used for storing and running the control program for the entire system. It acts as the main controller of the system that will determine the actions of AWRO in a rescue operation [12, 13, 14].

The PIC18F242 Microcontroller is the main controller of the system. This microcontroller is interfaced with the computer system's image processing program and serves as the actuator system that triggers important commands such as the activation of the propulsion system and the duration of operation of the said propulsion system [15, 16, 17].

The onboard camera serves as the vision system of the mobile robot. It takes snapshots of the visible area of interest (AOI) and transfers these images to the image processing algorithm that extracts the required data needed by the system to determine which actions are needed to be done by the robot.

The Solid State Relay Circuits part is the actuator system that receives the commands from the controller and is responsible for controlling the propulsion system of AWRO. These circuits control the direction of travel of the robot (turn left, turn right, move forward, stop) by adjusting the operation of the fan system of the watercraft. The MAX232 EIA-232 Driver is the link interface between the PC and the microcontroller.

A wireless router is also used to maintain a private network that serves as the bridge between the PC controller and the actuation system of the watercraft.

3.3 Software Components

The Software Components part consists of the microcontroller code, the main PC software graphical user interface, and the RoboRealm image processing software. The software controls the functions and performance of the whole system. Figure-1 shows the User Interface (UI) of the main PC software.

Figure-1. AWRO Main PC software user interface.

Figure-1 shows the main user interface of the AWRO. Microsoft Visual Studio is used to create the main software interface of the system and is responsible for integrating all of the system's software components. This program is also responsible for sending control commands to AWRO while receiving processed input from the image processing software. The program is also equipped with facilities for manually overriding the automated functions of AWRO. This program is designed and runs on top of Microsoft. NET framework for security and maintainability. It uses the latest in the framework's user interface technology in the form of the Windows Presentation Foundation (WPF) which exposes a unique event-driven system that enables centralized handling of input events, resulting in richer UI functionality and ease of use.

The Robo Realm software provides the image processing done on the system. If features a library of basic image processing modules that can be chained together to form a pipeline to perform more complex processing to implement AWRO's functionality such as object tracking, shape tracking, obstacle detection, and splash detection.

4. DISCUSSION OF RESULTS

4.1 Drowning Detection

The drowning detection module is programmed and tested in controlled environmental conditions. In these controlled conditions, the craft is isolated from the wavy environment of the pool by placing the craft along with its camera outside the pool area. A scenario of two swimmers and one drowning person in the pool is used. There are no other objects inside the pool area. The following tests are done only one drowning person is simulated in the pool area at one time. Swimmers are free to swim around the drowning person, but only one swimmer is allowed to approach the drowning person.

Figure-2 illustrates the simulation diagram in the pool area. The craft containing the camera is placed outside the pool area to verify the functionality of the drowning detection module. The craft is positioned near the sides of the pool. The craft and the camera are aligned in such a way that the front of the craft and the camera are facing the pool. Lighting conditions should be clear enough to perform drowning detection.

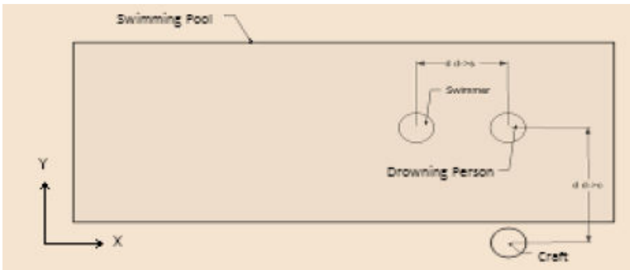

Figure-2. Drowning detection test setup.

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Figure-3. Drowning detection actual test setup.

Figure-3 shows the actual setup of the system installed on the side of the pool. Swimmers and the drowning person can be found anywhere within the area of the pool. Swimmers are free to do any swimming strokes. The drowning person simulates drowning actions for the duration of each trial and stays as stationary as possible in the designated area. The distance of the drowning person to the camera concerning the y-axis is adjusted with each trial. Besides, the distance of the swimmer to the drowning person concerning the x-axis varies for each trial. The drowning detection module classifies the detected target as a swimmer or a drowning person. Besides, the propulsion system of the craft is activated depending on the position of the drowning person within the horizontal x-axis. The drowning detection module only detects swimmers that swim in the horizontal x-axis.

The drowning detection is simulated and tested by adjusting the distances between the drowning person and the swimmers in the pool. Table-1 shows the results of the drowning detection.

Table-1. Drowning detection results.

Trials	Dds (m)	Ddc (m)	System response	Correct response	success
A	2	2	drowning	drowning	Yes
B	1.75	2.25	drowning	drowning	Yes
C	1.5	2	drowning	drowning	Yes
D	0.5	1.75	swimmer	drowning	Yes
E	1	1.75	swimmer	drowning	Yes
F	1.5	2	drowning	drowning	Yes
G	1.75	2	drowning	drowning	Yes
H	1.75	2	none	drowning	Yes
I	2	2.25	drowning	drowning	Yes
J	2.25	2.25	drowning	drowning	Yes

In Table-2, dds refer to the Distance of the Drowning Person to the Swimmer (in meters) concerning the x-axis and Ddc refers to the Distance of the Drowning Person to the Camera (in meters) concerning the x-axis. These factors affect the possible response of the craft in a real world situation. When an object is significantly near the craft, the craft avoids the detected object. When two or more objects are near the supposed target, the craft considers the group of objects as one object. The group ran 10 trials for the drowning detection test, and with each test, the distance variables mentioned in which serve as the uncontrollable factor in the succeeding trials. To minimize the errors generated during windy conditions, the group releases the craft right after the wind passes by.

The drowning detection module produced a 70% success rate. Trials A, B, C, F, G, I, and J produced successful results. Based on Trials D and Trials E, the swimmer was significantly near the drowning person, and the craft detected both persons as one swimmer. The "none" System Response on Trial H was the result of no motion in the test area for a short period, since the swimmer momentarily stopped, and the drowning person ceased to create splashing actions for a short duration. Given the results of the drowning detection tests in the controlled environment, the group concluded that a small value for Dds causes errors in the drowning detection module.

4.2 Obstacle Detection

Similar to the drowning detection module, the obstacle detection and avoidance module performs well when the tests are made in controlled conditions. The obstacles used are the Lifebuoy, the Styrofoam Ice Chest, and the Water Container. Obstacles that are placed in various places within the pool area are held by other swimmers to make the position of the obstacles as stationary as possible. The obstacles are also re-positioned between trials. The distance between the starting point and the nearest obstacle varied on every trial.

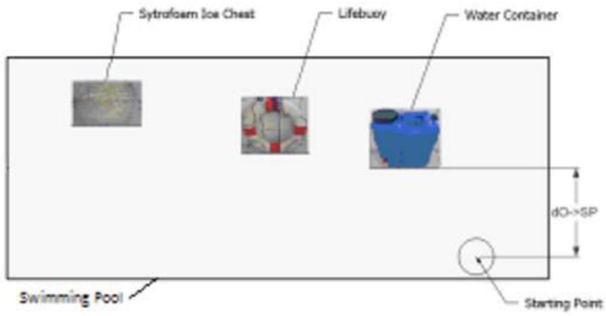

Figure-4. Obstacle detection and avoidance test setup.

Figure-4 shows the location of the obstacles within the swimming pool. For each trial, the locations of the obstacles are changed. After each trial, a different obstacle is placed near the starting point. The craft is then released. The obstacle detection and avoidance module responds accordingly to the obstacle being detected. When the obstacle detected is near, the obstacle detection and avoidance module instructs the craft to make evasive maneuvers before the craft hits the detected obstacle. A total of 15 trials are made, wherein the 3 obstacles are used simultaneously during each trial. Obstacles to be avoided in each trial are listed in Table-2. Dosp refers to the Distance of the Obstacle to the Starting Point (in meters). When the obstacle detection and avoidance module successfully detects and avoids the detected obstacle, the trial merits a success remark.

Table-2. Obstacle detection and avoidance results.

Obstacle to Avoid	Obstacle Detected?	Obstacle Avoided?	Dosp (m)	Remarks
Lifebuoy	YES	YES	2.5	Success
Styrofoam Ice Chest	YES	YES	3.0	Success
Water Container	YES	YES	2.5	Success
Lifebuoy	YES	YES	2.5	Success
Styrofoam Ice Chest	NO	NO	2.0	Windy
Water Container	YES	YES	2.0	Success
Lifebuoy	NO	YES	1.0	Windy
Styrofoam Ice Chest	YES	NO	1.5	Delayed Response
Water Container	NO	YES	2.5	Windy
Lifebuoy	YES	NO	2.0	Delayed Response
Styrofoam Ice Chest	YES	YES	1.5	Success
Water Container	YES	YES	1.5	Success
Lifebuoy	YES	NO	3.5	Windy
Styrofoam Ice Chest	YES	YES	3.0	Success
Water Container	YES	YES	3.0	Success

Based on the results in Table-2, the obstacle detection and avoidance module works 80% of the time. The inherent delay of the detection process, wherein the objects being detected cannot be recognized, contributes to the delay in obstacle avoidance. The sudden gusts of wind derail the craft away from the obstacle. In some cases, the wind overpowers the propulsion system of the craft. Wind tilts the craft in a position where the camera is not aligned with the obstacle, thus, creating errors in the obstacle detection and avoidance module.

The uncontrolled nature of the environment requires the system to compensate for any disturbance made to the vehicle, whether it will be originating from the environment or any miscalculations in the timing of the software. Since the disturbance compensations are done with the propulsion system, the said module must do so with accuracy and timing so that the vehicle can operate properly. Adjusting the Dosp improves the success chance for the obstacle detection and avoidance module.

4.3 Test Trials for a Rescue Operation

The craft can give immediate aid to the drowning person by throwing a lifebuoy near the drowning person within 2 to 3 minutes before drowning. To simulate a rescue operation, there are no other objects or swimmers in the pool area. Besides, the craft has been installed with a lifebuoy mechanism. The craft is required to transport the lifebuoy mechanism near the drowning person so the drowning person will have something to cling to for safety. The craft returns to the safety point with the drowning person clinging to the lifebuoy mechanism. The distance between the safety point and the drowning person is the full length of the pool. Each trial is composed of two parts: responding to the drowning person from the safety point and returning to the safety point once the drowning person has been secured on the life buoy. The initial setup for the test trials is shown in Figure 5. The safety point and the drowning person are placed on the two ends of the pool, as seen in Figure 5, in order to acquire consistent data. The craft is then deployed toward the drowning person.

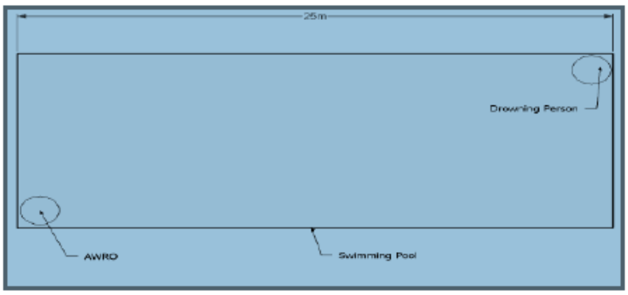

Figure-5. Simulated rescue setup.

The results in Table-3 show the rescue time from the safety point to the victim takes an average of about 2 minutes. Taking the victim from the point of distress to the safety area takes an average of about 3 minutes. The longer return time is the result of the added weight of the victim that the craft must haul. The group concludes that the craft is a feasible aid for maritime rescue operations if the distress area is 25 meters or less.

Table-3. Craft rescue and return time.

Trial	Rescue Time (s)	Return Time (s)
1	114	191
2	127	175
3	131	177
4	125	186
5	134	178
6	114	194
7	118	173
8	120	182
9	123	186
10	110	179

5. CONCLUSIONS

The study demonstrates that it is feasible to use the power of unmanned watercraft to aid in the rescue of people in distress in the water. Although for the moment, the practice of using humans to operate unmanned crafts and vehicles still proves to be the most practical. For such purposes, the study succeeded in providing a working prototype that serves as the proof-of-concept for more robust implementations to base upon. Image processing systems for maritime navigation and detection can be well-implemented. However, the exposure of such systems in real-world conditions has to be considered because the performance may vary when the testing conditions are uncontrolled. For the same reason, the group manages to test the functionalities of the craft while controlling some variables in the field.

During the obstacle detection and avoidance tests, the craft is able to detect and avoid the obstacles before the craft hits the stationary obstacle. The time that the craft takes to avoid the obstacle varies with what the obstacle detection and avoidance module detects and the distance between the obstacle and the craft. The craft reacts quicker if the obstacle has a more distinct shape and color.

6. RECOMMENDATIONS

Disturbances to the craft must be compensated for in order to maintain its travel directly toward the target. The automation software and hardware have to be concerned about these disturbances. One of these is the disturbance caused by waves coming either from wind or other sources, which can reduce the thrust of the propulsion or the two fans. Another source of disturbance is the direct exposure of the vehicle to blowing winds. It is a fact that the propulsion system relies on air to propel the vehicle, making it more susceptible to wind disturbance. So, when the wind speeds begin to approach and exceed the maximum thrust of the craft's propulsion system, it becomes impossible to compensate for the wind disturbance.

The limitations in terms of time and resources have prevented the study from exploring the vast possibilities open to this type of engineering undertaking. The following are recommendations for future studies. The use of additional instrumentation to perform tests on the stability and reliability of the craft, as well as associated software support that can help maintain the stability of the craft during field operations, the use of a design that will consider hydrodynamics for water-based operations, the development of primitive artificial intelligence that will suit the very dynamic nature of water-based operations and the development of an algorithm that detects swimming person along the y-axis of the craft.

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