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SWIM LAP ADAPTIVE PROXIMITY SENSOR

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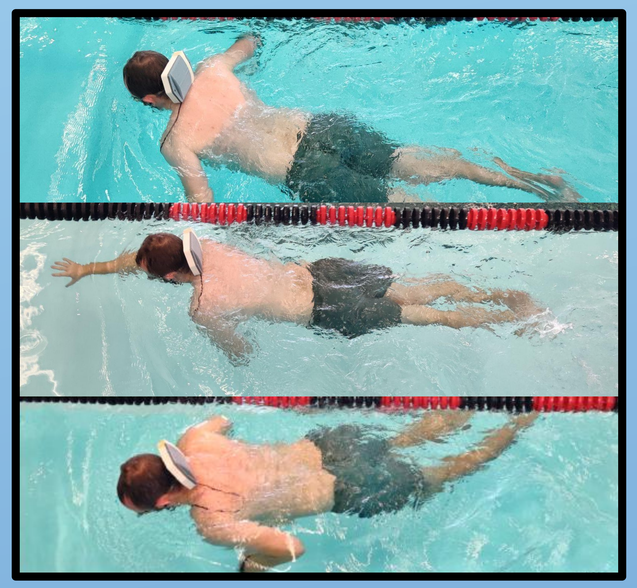
Abstract:

To swim safely, visually impaired swimmers require additional support from other people outside the pool to prevent them from colliding with the walls and lane lines of the pool. A standard method of supporting visually impaired swimmers is to use a padded stick to tap the swimmer and inform them that they are approaching a wall. While effective at preventing collisions with walls, this does not prevent the swimmer from colliding with the lane lines. To enable visually impaired swimmers to swim independently, we designed a device to help the swimmer stay centered in the swim lane (preventing the swimmer from colliding with the lane lines) and notify them of approaching walls (preventing the swimmer from colliding with the wall).

Design Specifications:

Based on testing and feedback from visually impaired people, we determined the following metrics to determine the effectiveness of the device's ability to guide the swimmer:

Metric #	Metric	Value	Units	Tested	Achieved
1	Dimensions (l x w x h)	3x5x2	cm	Yes	No
2	Volume	35	cm^3	Yes	No
3	Weight	0.1	kg	Yes	No
4	Operating Range	55	m	Yes	Yes
5	Positional Accuracy	0.5	m	Yes	Yes
6	Response Time	10	ms	No	-
7	Feedback Strength	70	dB (Audio)	Yes	Yes
8	Waterproofing	x8	Ingress Protection (IP)	Yes	Yes
9	Battery Life	3	Hours	Yes	Yes



A demonstration of the prototype in action. The swimmer veers close to the lane line, hears a prompt, then adjusts accordingly.

A rendering of the model of one of the anchors used for triangulation of the swimmer. The white parts show the waterproof casing. The black box is the battery. The red microcontroller is an ESP32 UWB Pro.

Design:

The design consists of two main parts: the triangulation, and the feedback.

Triangulation:

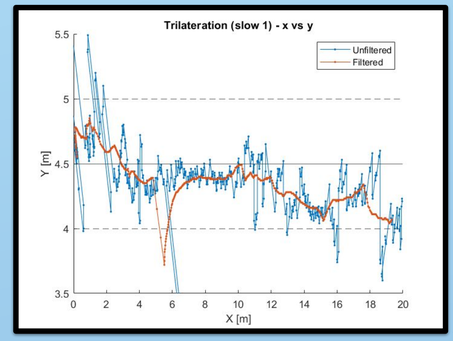
Four ESP32 UWB Pro devices are used for the triangulation of the device, which communicate using Ultra Wide Band communication. Three of the devices are placed around the pool as anchors, and one is attached to the goggles of the swimmer as a tag. The distance from each device is measured using two-way time-of-flight calculations between each of the anchors and the tag. The position of the swimmer is then calculated using a Least Squares Method [1].

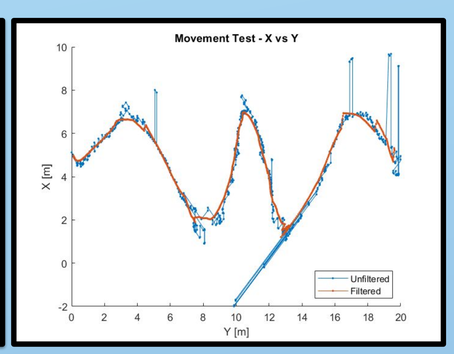
Feedback:

Feedback is provided to the swimmer via waterproof headphones. If the swimmer drifts too far in their lane either direction, feedback is provided by audio files which say "left" or "right". An audio file will play "flags" at 5 meters from the wall, and another audio file will play "wall" when 2.5 meters from the wall.

Results:

Tests were performed both on dry land and in water. Because of concerns for safety, the tests for accuracy were the main priority. To ensure that noisy results did not affect the sensor readings, an Infinite Impulse Response (IIR) filter was implemented on both the x and y positional readings of the swimmer.





Plots showing the accuracy of the device while moving in a straight line (left) and while moving in a zig-zag pattern (right). The readings from the device are shown in blue, and the filtered data is shown in orange.

To confirm that the device works with users, testing was performed with 22 volunteers on dry land, and 3 volunteers in the swimming pool. A survey was given to all of the volunteers with questions regarding the effectiveness, comfort, and ease of use of the device. The volunteers were also asked to provide feedback regarding how they think the device could be improved. The main takeaways from the survey are:

- The device was too large to be comfortable,
- infrequent disconnections make the device unreliable, and
- feedback was provided too often.

Conclusion:

This device can accurately tell where a swimmer is, but has issues that need address before commercial viability.

- The device can be used to direct someone who is swimming to go the correct directions.
- It can ensure that someone will not hit the lane lines or wall.
- More reliable connectivity should be investigated further.

Future Work:

While the testing performed proved that this design works as a proof of concept, there is remaining work necessary to make the device commercially available. To make the device more consistent, especially when underwater, the use of an antenna must be investigated. For a system that is more robust to disconnections, the use of more anchors should be considered. For user comfort and ease of use, a smaller battery and case should be used. Finally, a new user interface should be set up to make the device easier for visually impaired persons to set up.

Sources:
[1] Pelka, Mathias "Position Calculation with Least Squares based on Distance Measurements." ***Lübeck University of Applied Sciences: Technical Report*** **(2015): 1-3**