An IOT Device for Checking Bathing Activity for Seniors Aging in Place

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Abstract

This document gives an overview of the IOT device created to tackle the issue of bathing disability when aging in place. Seniors may choose to live in their paid-off home as it may provide the most comfortable environment at the most affordable cost. Bathing disability is a predictor of other disabilities that may be simultaneously occurring with seniors. Being able to track bathing activity of seniors for worried children or care providers in a respectful manner may be helpful to identify potential condition changes in the aging individual.

Keywords

Bathing disability; IOT; bath timer

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Nomenclature

IOT = Internet of Things

MQTT = Message Queue Telemetry Transport

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1. Introduction

Seniors may have multiple options when deciding where to live during their post-retirement years. Some factors like finances, health, mobility, location and proximity to social networks, may also contribute to which option is best for the individual(s).

Assuming the individual(s) have a paid-off home, the most comfortable and affordable option may be to stay in place. This decision is the topic of ‘aging-in-place’, where the individual has the ability to live safely, comfortably, and independently in their home as they age.

The aspect of living independently as one ages is what may cause issues, especially if there are degradations in mobility or cognitive abilities. This could bring on a bathing disability where the individual will bathe less often. Bathing disability incident rates may be as high as 23 per 1000 for person months aged 70-79 and 43 per 1000 person months for those aged 80 and older [1]. Bathing disability can also increase the risk for needing more care, either through home aide services or admission to a long-term nursing home; as well as be an predictor for other disabilities [1].

This may be a point of concern for those in the senior’s social or health circles, like children or family doctors. How might someone in these groups be able to check how often the senior is bathing whilst respecting the senior’s independence?

This is the main problem being solved with a Raspberry Pi 4 B+, an RCWL-0516 Doppler microwave sensor and a simple LED light packaged in a small container. This container is intended to be installed in inconspicuous locations in the bathroom, ideally in the showering alcove or on the bathtub, to be able to accurately track and report out bathing activity.

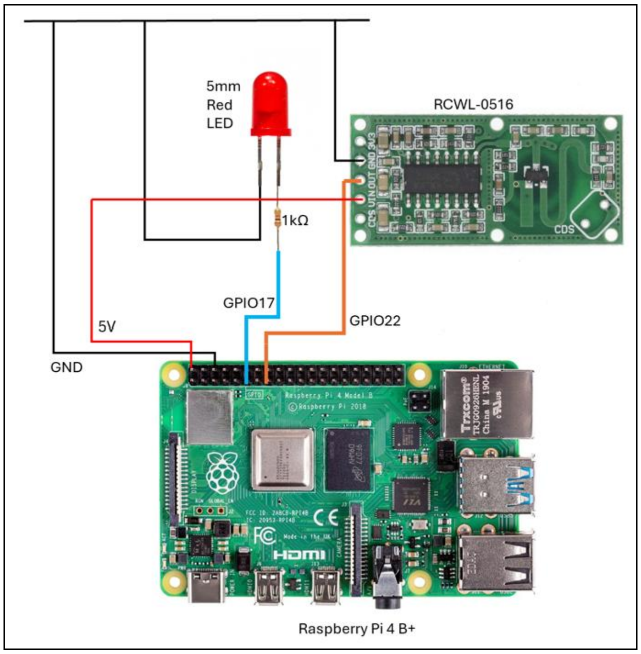
2. Methodology

A. Constraints

Since this device would be used in a bathroom, some constraints were considered to respect privacy and consider the environment. To protect privacy, no sensors that can sense personal information like microphones or cameras would be used. The sensor would also need to operate in an environment that regular has increased humidity and elevated ambient temperature, as well as needing to be waterproof to protect against potential condensation.

B. System Architecture

The chosen system was to use the Raspberry Pi 4 as an edge device to collect and summarize data, and then act as a client-publisher by publishing data in JSON format. The client-subscriber would listen for published data, parse it and insert the data into a database.



C. Sensor Selection

An RCWL-0516 Doppler Microwave sensor was ultimately chosen to sense when a person is bathing. The Doppler microwave sensor is an excellent choice since it is able to sense through most materials, has a sensing range of 7 metres, and can operate in a wide range of ambient temperatures.

The Doppler microwave is a high frequency device that senses changes in frequency (3.2 GHz) which signify motion being detected. The device outputs a LOW (0) or HIGH (1) signal that stays HIGH for at least 2 seconds. Due to this, the sampling rate was chosen to be 1 Hz, or a measurement taken every second.

D. Actuator Selection

This device technically does not need an actuator as it is intended to work as a timer, however to meet the project requirements a 5mm red LED was used. This LED turns on whenever the sensor reads HIGH. More useful actuators could be to send the shower controls ON/OFF signals for when a person enters the bathroom or leaves to automatically turn on or shut off water.

E. Messaging Protocol

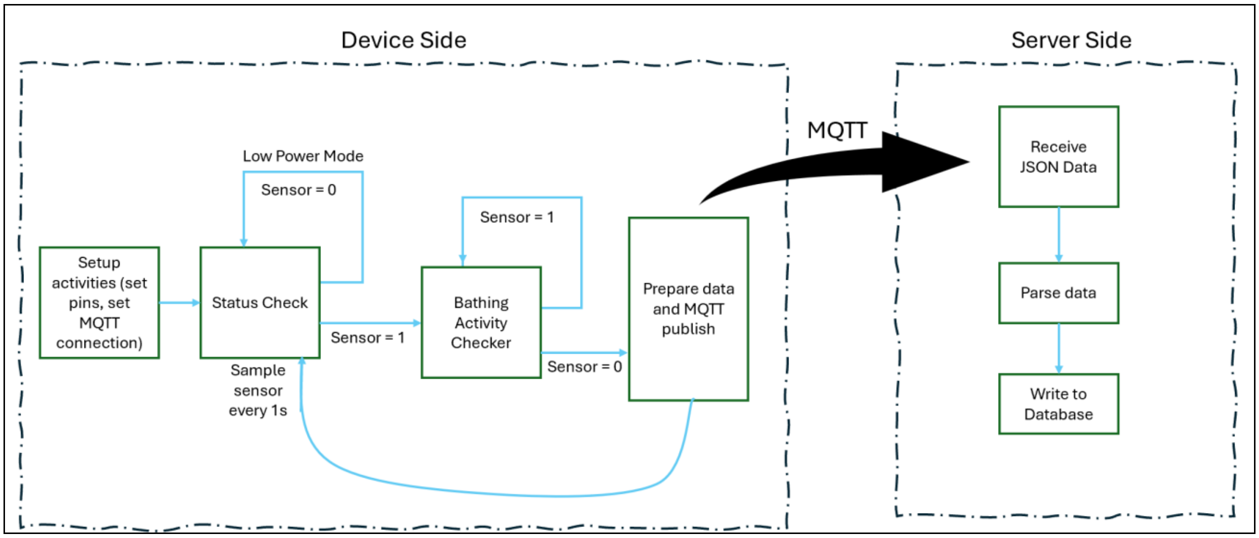
MQTT was used as the messaging protocol. HiveMQ was used as the broker with transport layer security to help protect the privacy of the data being transmitted.

F. Software Architecture

The Raspberry Pi runs a Python script that defines the pins being used and sets up a secure connection with the MQTT broker. The software is always deciding which mode to be in, either a low power mode that puts the device to sleep for short periods of time, and the active bathing tracker that the device will switch to once the sensor is triggered. Active bathing will time the start and end time of the bath.

Due to the sensor’s activity, a short algorithm was implemented to try to reduce the effects of false positives or false negatives. This algorithm runs for X amount of time and counts the number of times the sensor went HIGH in that period. There is then a comparison to a threshold value. If that HIGH count is larger than the threshold, the device assumes a person is still there. This will control a global variable which is used to decide which mode to be in.

Once the bath is complete (i.e. the HIGH count will be less than the threshold), the data will be prepared into JSON format and published via MQTT.

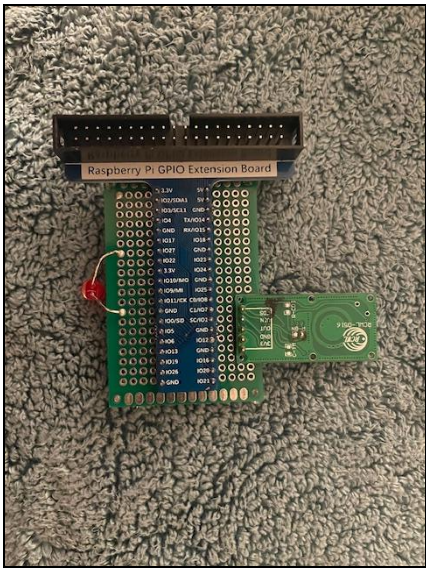


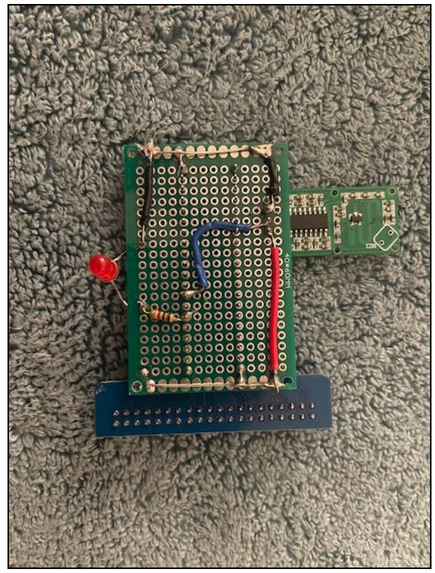
G. Database

An SQLite database was created on the client-subscriber device to store data. This database contains one table with columns for device identification, sent time, bath start time, bath end time, duration rounded to the nearest whole number, and the status of the device when the data was sent.

H. Physical Hardware

The sensor and LED were soldered on a perforated PCB board to minimize errors with connection and to allow a more precise fit with the hardware. The case is a box with a lid with space consideration for cabling, was 3D printed. The Raspberry Pi was installed on the bottom half and the perforated PCB with the sensor was installed on the lid to be closer to the person it is sensing. The case would be able to be adhered to surfaces within the bathing environment to best sense relevant movement.





3. Challenges

During testing, a vibration sensor and accelerometer were trialed for use to be able to sense the bathtub vibrating when someone steps inside, however these sensors were not sensitive enough to pick up meaningful signals. Therefore, a Doppler microwave sensor was used to detect movement as it was able to sense small movement through many common bathtub materials, like acrylic, steel, iron, etc.

There were also challenges with the sensitivity of the Doppler microwave sensor where it was sometimes not sensitive enough to small movements, especially where a person has stopped walking (like standing in the shower) and would ignore small hand gesture movements. To solve this, an algorithm was used to try to ignore potential LOW signals when a person is present but not moving enough.

A large, unsolved challenge is that with this particular sensor, it has a large sensing distance so can pick up non-bathing activity, like someone brushing their teeth. This would be assumed to be a bath.

A consideration that needs to be considered in future implementations is what if there is more than one person in the bathroom at a time – how can the device tell who is doing what and if either of them is taking a bath?

4. Future Improvements

Some future improvements that may be considered are additional sensors to measure humidity and temperature to confirm that a bath is occurring. It may be useful to have a secondary sensor (perhaps a capacitance sensor) to check that a person is truly in the bath.

Other improvements would be to the device set up procedure (i.e. setting up an account, a WiFi connection, etc.), and an application where a user can track the activity.

Making the device smaller would be a key improvement as well.

With the addition of more sensors, predictive models may be used to look for dangerous events like falls or scalds.

Creating an anomaly detection model would be useful to help alert users of when senior's may be deviating from regular routine. Depending on the severity of the anomaly, a wellness check may be automatically requested.

5. Conclusion

In conclusion, I believe such an idea can be useful for those who are worried about their loved ones being able to care for themselves. The end device may change or could be integrated into other common bathroom appliances like faucets or shower controls, but the ability to be able to track bathing activity may provide peace of mind as well as alerts for potentially harmful events that may be or are occurring.

6. References

[1] S. C. Ahluwalia, T. M. Gill, D. I. Baker, and T. R. Fried, "Perspectives of Older Persons on Bathing and Bathing Disability: A Qualitative Study," Journal of the American Geriatrics Society, vol. 58, no. 3, pp. 450–456, Feb. 2010, doi: https://doi.org/10.1111/j.1532-5415.2010.02722.x.