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Safety Improved Wheelchair With IoT Functions For Physically Disabled

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***Abstract*— With increasing computation power of mobile devices and the advent of smartphones, Internet of Things is becoming an important part in our modern lives. Moreover, in Thailand, physical disability is most common type of disabilities. This research attempts to increase the capabilities of existing electric wheelchair in two main categories: safety and tracking capability through the internet. The safety features includes collision avoidance system, which uses ultrasonic sensors to determine the distance to obstacles and fuzzy logic to assist the user, stopping 34.1 centimeter, 19.1 centimeter, and 40.1 centimeter in from, side, back respectively. The alert system uses gyroscope and accelerometer to measure the wheelchair's angular position, warning the user when they go 40° uphill or 15° downhill. Monitoring system uses GPS to measure the user's location, with 4.65 meter error outdoor. The position and temperature are reported on a web site using Wi-Fi and cellular network. Wi-Fi network is used when the access point is nearby; otherwise the cellular network is used. In case of accidents, accelerometer measures the impact received by the wheelchair and alerts the supervisor and hospital when acceleration exceeds 1.5g.**

Keywords—Wheelchair/Internet of Things/Collision Avoidance/Fuzzy Logic/Monitoring heart rate.

I. INTRODUCTION

In the modern world where the internet is a part of everyone's lives, computers have exponentially increase in computational power in the smaller package, and the internet can be accessed from everywhere and anytime. Information stored digitally can be much easier accessed than their physical counterparts. By utilizing data stored on the computer, we can bring the advantages of computer systems, especially performance, speed, and precision to our physical world.

Internet of Things is an idea that tries to bridge the digital and physical world through electronic devices, sensors, actuators, software, and network systems. By converting physical data into digital data, devices could communicate "machine to machine" through the internet, while users can have accessed the data stored in the cloud through the internet using computers. This will facilitate

Moreover, there are many people suffering from many types of disabilities. The Thai Department of Empowerment of Persons with Disabilities reports that in December 2017, there were 836,224 people with physical disabilities, out of 1,725,601 disabled people, accounting for 48.84 percent. [1] In addition, the percentage of the elderlies is on a constant increase. In 1994, the National Statistical Office Thailand reported 6.8 percent of the elderlies, or people over the age of 60. However, in 2014, the number increased to 10,014,699, accounting for 14.9 percent of the total population, and predicted to be increasing. [2] Lastly, people with injuries which prevent them from walking and 10.74 percent of disabled people have vision disability [1], will also benefit from this research.

Nirmal (2014) Developed a wheelchair using synchronous DC motor that can be controlled using voice, eye, and joystick. Moreover, it can also monitor the surroundings such as temperature, humidity or obstacles. Furthermore, it can monitor user for their conditions such as heart rate, which can be accessed through a remote display through ZigBee. However, this research only focused on monitoring the user, but not preventing them from harm. Milind et al. (2015) developed a wheelchair for the elderlies and physically challenged by developing a home navigation system which uses infrared sensors to measure important areas such as Turn corner or position of a door. Moreover, the user can also alert the supervisor as needed. However, this research cannot track the location of the user. Hence, there is an idea where a person who live alone or cannot go to hospital can tracking their health such as heart rate, oxygen saturation measurement in blood, temperature or pressure by using wireless connection name ZigBee. However, this research does not work in real time. [4] In part of wheelchair there are research to build wheelchair that can work on many condition, such as an omni-directional wheelchair by using haptic feedback [5], smooth collision avoidance in human-robot coexisting environment [6] or A wheelchair steered through voice commands and assisted by a reactive fuzzy-logic controller [7].

From these researches, collision avoidance systems with fuzzy logic, health monitoring and tracking location of user will be the focus of this research.

II. System Description

Features added to an existing commercial electrical wheelchair to improve its capabilities can be divided into two main categories: safety and monitoring.

- Safety
  - Collision avoidance
  - SMS alert
    - Wheelchair fells
    - On impact
    - Critical health abnormalities
- Monitoring
  - Heart rate
  - Temperature
  - Location

A. *The collision avoidance system*

For the collision avoidance system, the wheelchair has been modified for an Arduino Mega 2560 microcontroller to receive the command from the joystick instead of the wheelchair itself. The microcontroller then determines its distance from the surrounding obstacles using 10 ultrasonic sensors, compute the safe speed, then output the altered user command to the wheelchair.

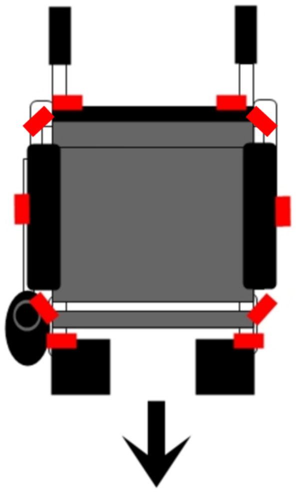


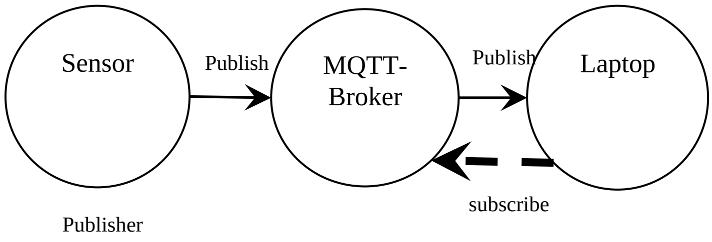
Fig 1. sensor positions

Sensor 1 2 3 and 10 are designed to detect obstacles in the front, 3 4 5 8 9 10 for obstacles on the sides, and 5 6 7 8 for obstacles behind the wheelchair.

Fuzzy logic is used due to its robustness, its ability to work with different rules and inputs, and its ability to work under different conditions and systems.

B. *Monitoring systems*

For monitoring systems, design by using MQTT-protocol There are 3 main part just as below.



1. Publisher or sensor were used for collecting and measure data that we need to know, such as heart rate, temperature or location.
2. MQTT-broker is a center to transfer data or subscribe between publisher and laptop.
3. Laptop used for monitoring changing of data or subscribe such as a changing of weather

III. Design Function

The collision avoidance runs on the Arduino Mega 2560 microcontroller. First, the microcontroller reads the voltage from the analog joystick. Secondly, distance from the ultrasonic are read. Next, the microcontroller normalizes and fuzzify all the inputs, pass them through the fuzzy rules, then defuzzify and denormalize the values. Finally, the microcontroller outputs the values to the wheelchair

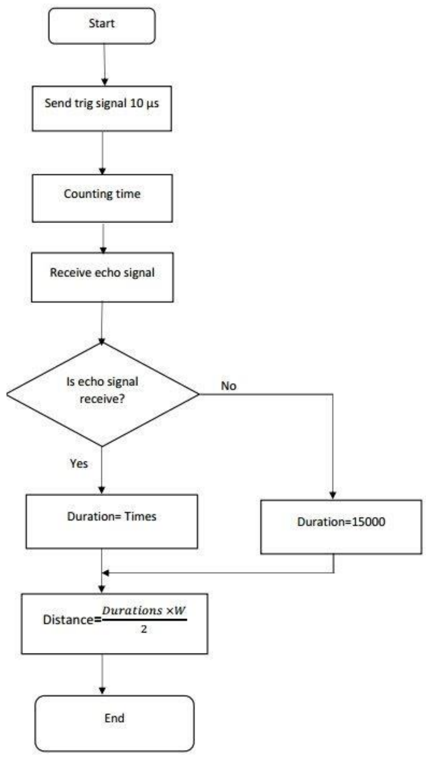


Fig. 2 Flowchart of the collision avoidance system

Membership functions for distance and controller values are illustrated through fig. 3 through fig. 5.

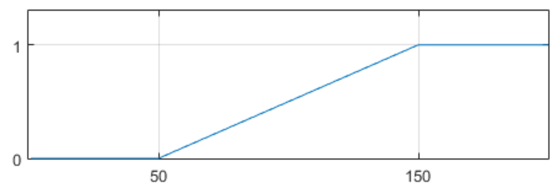


Fig 3 membership function for sensors

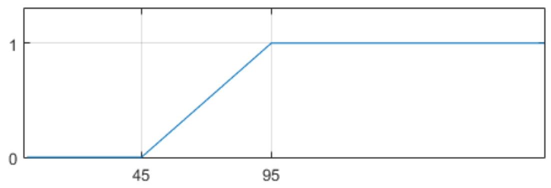


Fig 4 membership function for side sensors

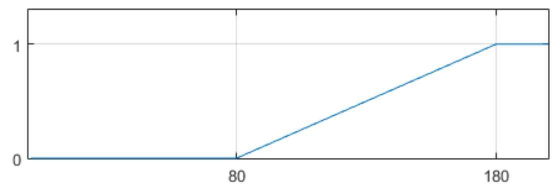


Fig 5 membership function for back sensors

Boolean operations used in this research are defined based on multiplication as followings:

x AND y = x*y

x OR y = 1-(1-x)*(1-y) = x+y-x*y

NOT x = (1-x)

Fuzzy rules used are as following:

1. **IF** Forward **AND** frontFar **AND** frontLeftFar **AND** frontRightFar **THEN** goForward
2. **IF** TurnLeft **AND** frontLeftFar **AND** leftFar **THEN** goLeft
3. **IF** TurnRight **AND** frontRightFar **AND** rightFar **THEN** goRight
4. **IF** Backward **AND** backFar **AND** backLeftFar **AND** backRightFar **THEN** goBackward
5. **IF** Forward **AND** frontFar **AND** frontLeftNear **AND** frontRightNear **AND** leftNear **AND** rightNear **THEN** goForward
6. **IF** Backward **AND** backFar **AND** backLeftNear **AND** backRightNear **AND** leftNear **AND** rightNear **THEN** goForward

Finally, normalize the values and output the commands to the wheelchair.

For the tracking and health feature, an algorithm to determine abnormalities is required. An algorithm that use to determine abnormalities and change threshold is Pan-Tompkins algorithm by calculated from average of the eight most-recent beats. To calculated average of the eight most-recent beats by using equations

$$RR_{avg} = 0.125(RR_{n-7} + RR_{n-6} + \ldots + RR_n)$$

Where RR_{avg} is a distance between peak to peak of most-recent beats.

Where The RR-interval limits are

RR_{Low} = 92%RR_{avg}

RR_{HigH}=116%RR_{avg}

If RR_{avg} has a value below RR_{low} or higher than RR_{HigH}, it will be abnormal conditions. And we calculate error by using latest 100 times of RR_{avg} that we got by using equations.

$$Error_{all} = (\frac{C_{bad}}{C_{all}} \times 100)$$

Where $Error_{all}$ is percent error that we get

C_{bad} is number of RR_{avg} has a value below RR_{low} or higher than RR_{HigH}.

C_{all} is number of RR_{avg} that we use to analyze.

If $Error_{all}$ is over 80%, the tracking and health feature will send SMS that specify conditions of abnormalities and a location of user to supervisor.

IV. Test Results

A. *The collision avoidance system*

Position of obstacle	Distance 1 (cm)	Distance 2 (cm)	Distance 3 (cm)	Average (cm)
0°	52	48	50	50
45°	26	9	33	22.67
90°	22	18	17	19
135°	34	37	35	35.33

180°	41	42	53	45.33
225°	40	37	42	39.67
270°	21	22	15	19.33
315°	34	27	28	29.67

Table 1 Testing the collision avoidance system

The safety features include collision avoidance system, which uses ultrasonic sensors to determine the distance to obstacles and fuzzy logic to assist the user, stopping 34.1 cm, 19.1 cm, and 40.1 cm in from, side, back respectively. Moreover, the collision avoidance system by using fuzzy logic for analyze distance can decrease velocity of wheelchair when it's near obstacle around 29 cm to 33 cm. However, smaller objects such as bottle or table leg cannot be detected.

B. Monitoring systems

Testing	Heart rate from sensor(beats/minutes)	Heart rate from reference sensor(beats/minutes)	Error of plethysmography sensor	Error simulate by using MIT-BIH database	Alert by sending SMS
1	81	75	8%	72%	N
2	66	70	5%	67%	N
3	68	73	6%	69%	N
4	62	93	30%	87%	Y
5	77	78	1%	73%	N
6	78	72	8%	65%	N
7	61	79	22%	84%	Y
8	78	74	5%	61%	N
9	72	75	4%	69%	N
10	74	70	5%	71%	N

Table 2 Testing heart rate sensor compare with reference sensor and checking notification system.

From table 2 we are testing heart rate sensor compare with reference sensor and checking notification system, also we simulate by using MIT-BIH database for a data when $Error_{all}$ value in abnormal conditions. Result is a system can alert by sending SMS when $Error_{all}$ over 80% where a system will alert by sending SMS can show by fig.6.

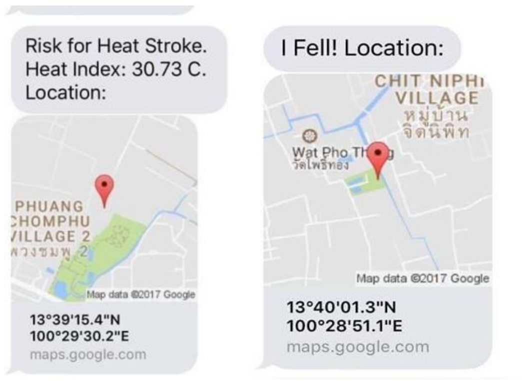


Fig. 6 SMS alert notification.

C. Result analysis

The balance assistance system, which alerts the user when the wheelchair loses balance by using accelerometer and gyroscope will notify the user when the pitch angle exceeds 40° or less than 15°. However, the risk of wheelchair will fall need to have an experiment about relation of velocity of wheelchair and angle of a slope. The health monitoring systems consists of heart rate monitoring, which uses photo plethysmography to determine heart rate of the user with the error of 9.4% and alert to supervisor when the $Error_{all}$ over 80%. And the last point is about the real-time tracking system, which using GPS system to tracking location of user, but there are an error when using in a high building is around 162 m and outside building has an error around 4.65 m. This system can work by using WIFI for connection around 10 m.

V. Conclusion

This research develops and explores the feasibility of systems to be installed on an existing commercial electric wheelchair in two main categories: safety, and monitoring through the internet. The collision avoidance system slows down and prevents the wheelchair from colliding into obstacles, stopping the wheelchair between 29 cm and 33 cm. The heart rate can be accessed from the internet. Abnormalities are determined through Pan-Tompkins Algorithm with 9.4% error, alerting the supervisor via SMS in case of dangers. Finally, MQTT protocol is used to connect the wheelchair to the internet through Wi-Fi, which works within 10 meters range.

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