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DISASTER MITIGATION FOR PEOPLE WITH CEREBRAL PALSY BASED ON BEHAVIORAL ARCHITECTURE IN RESIDENTIAL USING WIRELESS SENSOR NETWORK

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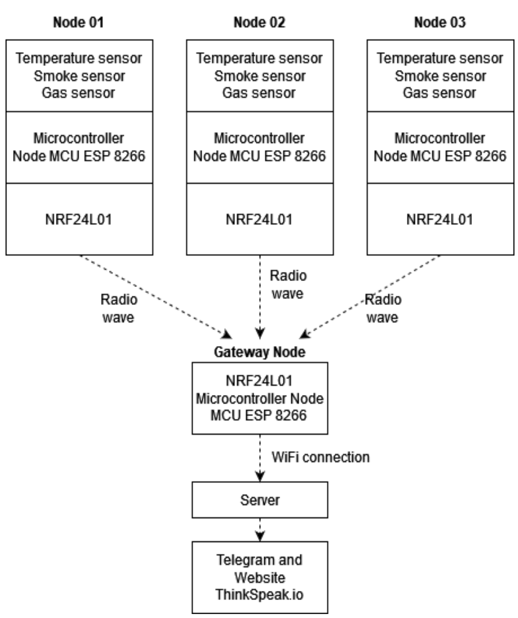
Nifty Fath[a]*, Harfa Iskandaria[b], Moh Adinur Saputra[a], Jasmine Fatima[b]

[a]Department of Electrical Engineering, Faculty of Engineering, Universitas Budi Luhur, Jakarta, Indonesia
[b]Department of Architecture, Faculty of Engineering, Universitas Budi Luhur, Jakarta, Indonesia

*Corresponding author
nifty.fath@budiluhur.ac.id

Graphical abstract



Abstract

At this time, most houses for persons with disabilities are not yet equipped with a disaster mitigation system. It may be difficult for persons with disabilities to be able to save themselves when a disaster occurs. Therefore, in this study, a system for disaster mitigation, especially fires in the residence of a child with cerebral palsy, has been successfully designed. The optimal placement of the wireless sensor network is decided based on a behavioral architectural analysis using the DepthMapX-0.7.0 software. Behavioral architecture assessment begins by observing patterns of daily activities and a simulation of human movement in the house to find out the most frequent activity places used by children with cerebral palsy. Based on the test results with DepthMapX-0.7.0, it can be concluded that the optimal location of the sensor node points is in the child's bedroom, kitchen, and TV room. The designed wireless sensor network consists of three sensor nodes and a gateway node. Data sampling is performed every 15 seconds. If a fire is identified, the buzzer will emit a warning signal. In addition, the child's family can monitor home conditions from the ThingSpeak.com website and Telegram.

Keywords: Wireless sensor network, cerebral palsy, behavioral architecture, disaster mitigation, sensors

1.0 INTRODUCTION

Disasters are unexpected, devastating, and dangerous events that disrupt life of the community, village, or city. This can lead to economic losses and environmental damage. In Indonesia, fire, floods, and earthquakes is still dominated. In DKI Jakarta province, there have been 543 cases of fire disasters from January 2022 to April 2022 [1]. However, the disaster mitigation system in the residential areas is still inadequate. In addition, some houses are not designed as a disabilty-friendly building. A society is formed by people including children, adults, and elderly. Currently, it is estimated that about 15% of the world's population lives with a disability [2]. People with disabilities with physical limitations, for example, are cerebral palsy. Cerebral Palsy (CP) is a disorder characterized by abnormal tone, posture and movement and is clinically classified by syndrome dominant motor—spastic hemiplegia, spastic diplegia, spastic quadriplegia, and extrapyramidal or dyskinetic. The incidence of CP is

2-3 per 1000 live births [3]. Thus, a person with physical limitations such as cerebral palsy is very vurnerable to the effects of a disaster.

The disaster impact on persons with disabilities depends on the characteristics of persons and their environment, the type and severity of the hazard, and the disaster management system. To help the public become aware of emergency situations, a series of disaster monitoring and warning systems have been widely implemented. However, most of the warning system cannot collaborate with household appliances or embedded controllers and are still not disability-specific. People with disabilities have difficulty evacuating themselves during disasters such as floods, fires and earthquakes.

Disaster mitigation problems for people with disabilities can be solved with wireless sensor networks technology and redesigning the house so as it becomes disability-friendly buildings [4]. Wireless sensor networks are interconnected devices containing software, electronics, and actuators that can interact and exchange data [5], [6]. Some research on wireless sensor networks as a disaster mitigation has been designed in [7]–[13], and facilitating the daily activities of people with disabilities and the elderly has been carried out in [14]–[20]. However, there are still not many studies that involve the process of selecting sensor placement locations in wireless sensor networks. Therefore, in this research, sensor placement in wireless sensor network is carried out based on behavioral architecture analysis using space syntax. Behavioral architecture is a concept that pays attention to the behavior of people with cerebral palsy when they are at home and carry out various daily activities independently. Through space syntax, the characteristic of the space configuration can be obtained so that spatial analysis and decision making can be carried out, in this case the decision is in the form of sensor placement [21].

Several studies have used behavioral architectural analysis for building design and decision making such as child-friendly buildings [22] and designing houses to deal with pandemic disasters [23].

In this study, a novel deployment method of wireless sensor network-based systems as disaster mitigation for people with cerebral palsy based on behavioral architecture is proposed. In addition, recommendations for changes in house plans are also made. The main focus disaster that will be discussed in this research is fire disaster.

2.0 METHODOLOGY

Behavioral Architecture

The method used in behavioral architectural research is descriptive qualitative where the data analyzed is observation data and field observation data as primary data. Observation is done to obtain information related to cerebral palsy. After the observation, a field study will be conducted to collect information about buildings/residences for people with cerebral palsy and analyze the severity of cerebral palsy. The data analysis techniques used in this study are:

a. Data selection

At this stage, the process of classifying data and discarding unnecessary data is carried out, then organizing the data so that conclusions can be drawn from the data.

b. Data presentation

Data presentation of research reports is the preparation of concepts that have been carried out so that they can be understood and analyzed in accordance with the research objectives. Data can be presented in diagrams, tables or charts.

Behavioral architecture is architecture that includes behavioral considerations in the design process, emerging around 1950. Architectural planning and design cannot be separated from human behavior because it accommodates human activities as users [24], [25].

Based on this understanding, the research method of behavioral architecture can be formulated if the results of the behavioral architecture have the following principles:

a. Able to communicate with people and the environment. The design must be understandable to the user. The form presented can be fully understandable by building users.
b. Accommodate the activities of its occupants comfortably, both physically and psychologically.

The basis of behavioral architecture is to conduct intensive observations for seven consecutive days for 24 hours, starting from the morning until bedtime. After observing daily activitiy pattern, human movement simulation in the house was carried out to find out the places of activity that are most often used by children. In this study, human movement simulations were carried out using space syntax method with DepthMapX-0.7.0 software. The simulation results will determine the optimal placement of the wireless sensor network.

Wireless Sensor Networks

The disaster mitigation system designed in this study utilizes WSN technology to provide home environment monitoring consisting of smoke and gas sensors, fire and flame sensors, and temperature sensors. Each sensor node will send information in the form of sensor data to the anchor node. The situation in each room can be monitored by other family members in the house remotely and connected to the internet.

Hardware Design

The wireless sensor network-based disaster mitigation system in residential areas with cerebral palsy consists of several main components: Arduino Uno microcontroller, NRF24L01 communication device NodeMCU ESP8266, buzzer, temperature sensor, smoke sensor, gas sensor, and fire sensor, as described in Table 1 (see Figure 1). In the communication system, NRF24L01 module with a frequency of 2.4 GHz is used to transmit data from nodes to base with a star network topology and NodeMCU ESP286 to transmit data collected at the base to server via the internet network.

The disaster mitigation system begins with the reading of temperature sensors, smoke sensors, gas sensors, and fire sensors placed at several points in the house. Each node consists of several sensors that placed based on the behavior architecture of people with cerebral palsy. The overall system block diagram is shown in Figure 2.

The system monitors the environmental conditions in the house. There are three nodes placed in the child's bedroom as Node 01, the kitchen as Node 02, and the television room as Node 03. Each node consists of a temperature sensor, smoke sensor and gas sensor. The microcontroller connected to each sensor functions to process data from sensor readings.

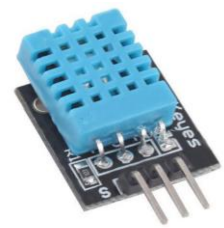
A set of data from the three nodes will be sent to the gateway node with the NRF24L01 communication module. The data received by the base will be processed and sent to the database via internet network. If one of the sensors detects the ambient temperature in the room of more than 50°C, or detects smoke, fire or gas, the microcontroller will activate the buzzer and send a notification via telegram. The monitoring system can be accessed through the ThingSpeak website platform.

Software Design

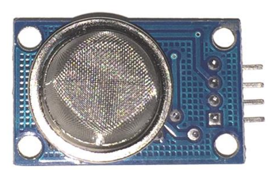
The first stage in designing a software system is to initialize data on the ThingSpeak web. ThingSpeak is an IoT platform that has complete facilities. NodeMCU ESP8266 module must be successfully connected to the internet via WiFi. The next step is that the data on the NodeMCU ESP8266 will be monitored on the ThingSpeak web. The visualized data is real-time sensor data in the form of a graph. Figure 3 shows the flow chart to visualized the data obtained with ThingSpeak.

Table 1 Specification of system [26]

Components	Type	Function
Microcontroller	Node MCU ESP-8266	To process sensor reading data and send it to the server via the WiFI network
Sensor	Temperature DHT – 11	To measure air temperature and humidity
	Flame and smoke 5 channel	To detect fire and gas
	Gas MQ – 02	To detect gas leaks
Radio Communication Module	NRF24L01	To send and receive data with 2.4 GHz radio waves.
Buzzer	Buzzer active	To provide sound notification if a fire is detected



(a) Temperature sensor DHT 11



(b) Smoke sensor MQ 135

(c) Flame and gas sensor - 5 channel
Images Source: https://components101.com

Figure 1 Specification of sensor

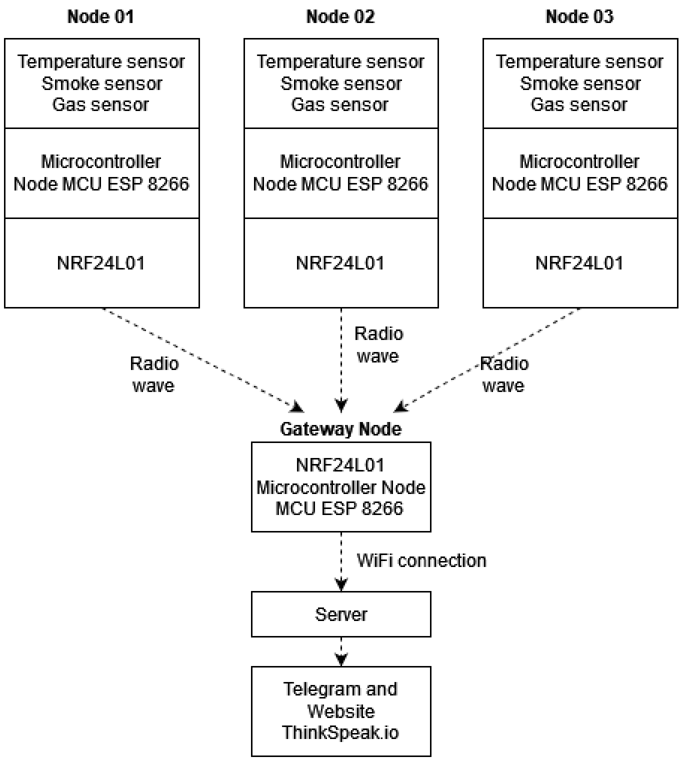


Figure 2 Wireless sensor network design

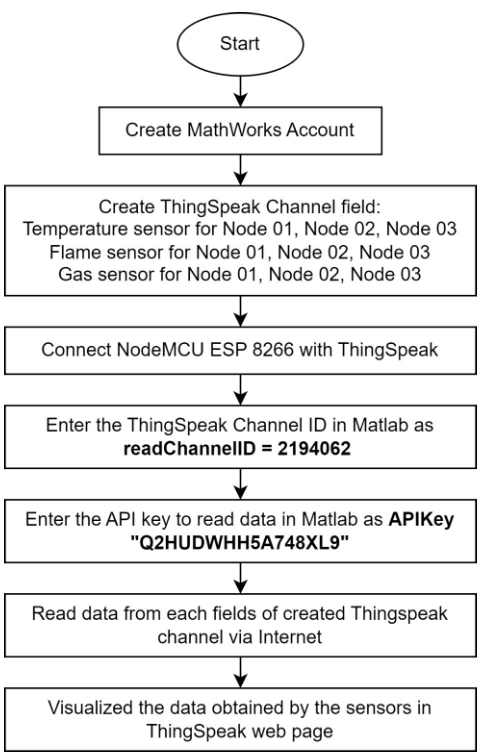


Figure 3 Flow chart to visualized the data obtained with ThingSpeak

3.0 RESULTS AND DISCUSSION

Research Object

The object in this study is a house of a person with cerebral palsy (with initials NPL). The house is located in Grand Bukit Dago, Cluster Victoria, Bogor Regency, West Java Province, Indonesia. Figure 4 and Figure 5 show the object research houses used in this study.

Children's Activity Patterns

The analysis of children's activity patterns is displayed in the form of Visual Graphic Analysis (VGA). This is shown through the distribution of gradations with color notation as an analysis parameter in an area.

DepthMapX-0.7.0 can produce different depths of analysis by displaying a spectrum of colors ranging from red, yellow, green to blue. Red or yellow colors represent areas where there is a lot of movement. Besides, green or blue represents areas of little movement. Space syntax analysis is carried out based on the pattern of children's activities during one week of activities. The child movement analysis using DepthMapX-0.7.0 on the 1st floor of the house are shown in Figure 6.

Based on Figure 6, it can be seen if the activities of NPL children have a tendency to be active in the living room (2), the dining room which is also the TV room (3) and bedroom (7). The movement of NPL children in rooms 2 and 3 based on the activity pattern table is because these two rooms, if based on the floor plan, become one and are separated imaginarily by using a guest chair.

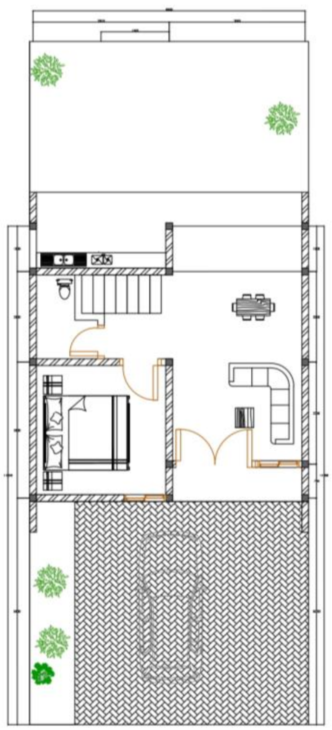


Figure 4 First floor plan

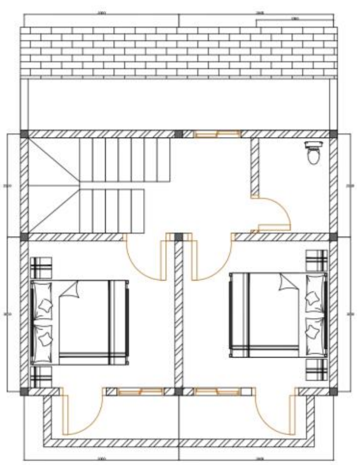


Figure 5 Second floor plan

Meanwhile, the bedroom is the activity that is often visited because based on the activity pattern table, NPL children have a two-hour nap schedule between 13.00-15.00 and night sleep starting at 21.30 – 04.30 so that the total use of the bedroom used by NPL children for 24 hours is nine hours.

Figure 7 is a pattern of children's activities on the second floor which looks quite rare. Activities on the second floor were limited to lifting clothes that had been washed on the balcony (14) and then placing them in the bedroom which was converted into a laundry room (11). While the activities in the living room (9) only function as a place of circulation or a place of transit from the first floor to the second floor. Children were also observed doing activities in office room (12) and occasionally going to the balcony (13). If seen in Figure 7 the pattern of activities between rooms 12 and 13 has a green intensity, which means that the balcony and bedroom are only limited to circulation in the inner space.

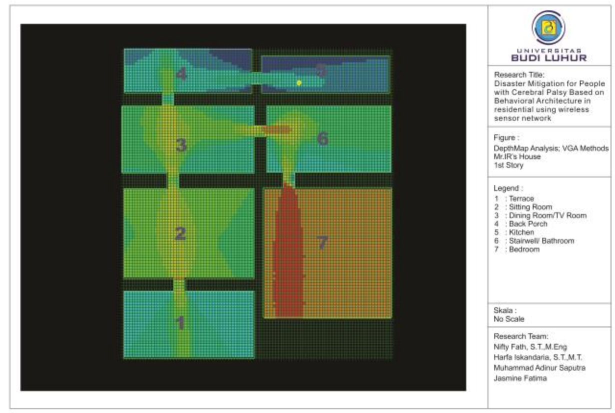


Figure 6 Analysis of Children's Movements using DepthMapX-0.7.0 on the 1st Floor of the house

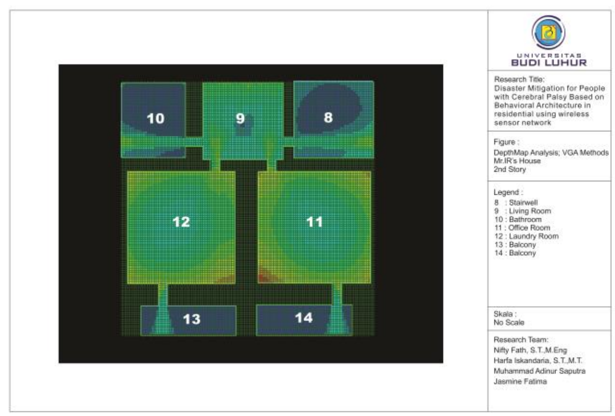


Figure 7 Analysis of Children's Movements using DepthMapX-0.7.0 on the 2nd Floor of the house

Cerebral Palsy Friendly Home Design Recommendations

The child was diagnosed with cerebral palsy at the age of 1 year, with hemiplegic spastic cerebral palsy. Based on the family's condition, it is hoped that there will be some adjustments that can be made so that the house can be "friendly" for people with cerebral palsy. The home adjustment plan is done so that the house can be spared. Thus, when the child has a seizure, the house is not too cramped and provides enough space for child to move.

The house change plan is shown in Figure 8. At the back of the house, the dining room and kitchen are added so that the living room and family room become more spacious.

Changes in the pattern of space use by children can be simulated using DepthMapX-0.7.0 software. By carrying out this simulation, it is hoped that the child will get a wider portion of space to move so that when a seizure occurs, it does not endanger herself due to colliding with the furniture around her.

Figure 8 Plan Change Recommendations

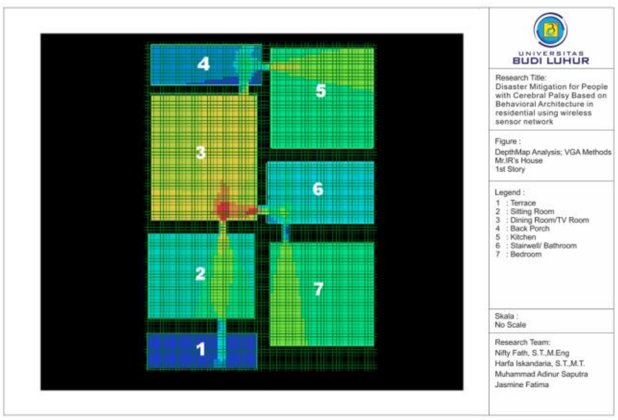


Figure 9 NPL Child Movement Analysis using DepthMapX-0.7.0 based on plan change recommendations

Based on Figure 9, it can be seen that the area marked in orange, the living room (3), is more spacious. This is because the dining room has been moved to the back (5) in line with the kitchen (4). Based on the simulation results, children's activities have focused on the living room/TV (3). This can provide an advantage for parents to pay attention to their children in the TV room without having to go to another room. In addition, the use of children's bedrooms is much less when compared to not doing renovations. Therefore, based on the results of this simulation, the best point for placing the wireless sensor network can be determined. Based on space utilization, the optimal points for placing the wireless sensor network are in the children's bedroom, kitchen and TV room. With the space syntax method, sensor placement will be more optimal and efficient.

Wireless Sensor Network Experiment

The results of the wireless sensor network design as disaster mitigation in residential areas with cerebral palsy are discussed in this chapter. The monitoring system is integrated into the browser interface and sensor data storage using the NodeMCU ESP8266. Figure 10 shows part of one of the nodes. There are four tools packaged namely Node 01, Node 02, Node 03, and Node Gateway, as shown in Figure 11(a) – Figure 11(d).

This test was conducted to determine the maximum distance of data communication between each node and the gateway node using the NRF24L01 module. Based on the datasheet, the NRF24L01 module operating in the 2.4 GHz frequency has a range of up to 1 km. For utilization in research that uses a house as a research location, distance testing is carried out as written in Table 2. The Gateway node is placed in the living room.

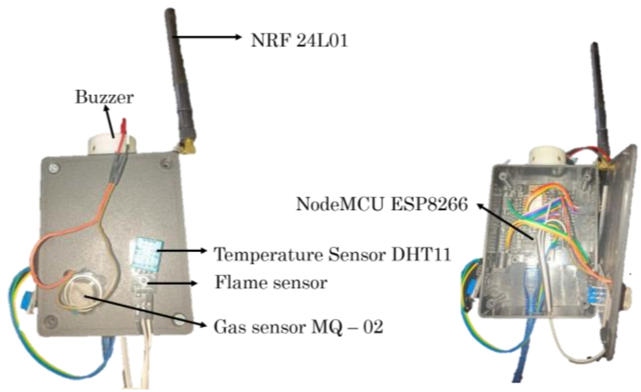
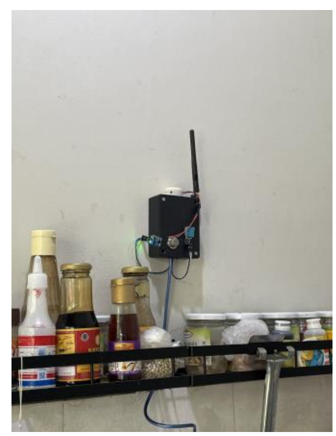


Figure 10 A hardware setup

a) Gateway node in living room



(b) Node 01 in kitchen

(c) Node 02 in child's bedroom

(d) Node 03 in television room

Figure 11 Node placement

Table 2 Sensor node transmission range measurement

	Distance (meter)	Status
Node 01 to Gateway node	2	Connected
	4	Connected
	6	Connected
Node 02 to Gateway node	2	Connected
	4	Connected
	6	Connected
Node 03 to Gateway node	2	Connected
	4	Connected
	6	Connected

The monitoring system is carried out using a platform based on the Thingspeak.io website and Telegram. Users can monitor from each sensor installed.

Figure 12 – Figure 16 show the graphical output at the ThingSpeak cloud after logged in to the website. ThingSpeak home page shows the condition of fire, smoke, gas and temperature in the house. The graph consists of live stream data visualization. Each graph holds data to display the last 30 minutes of data. ThingSpeak website is highly recommended for IoT system as it is integrated with MATLAB [27].

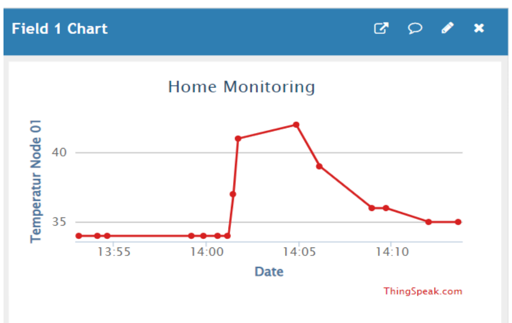


Figure 12 Temperature data at Node 01 from ThingSpeak website

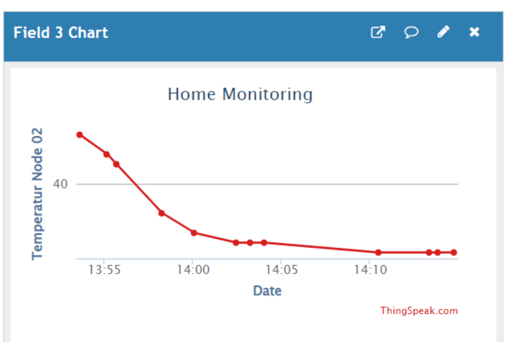


Figure 13 Temperature data at Node 02 from ThingSpeak website

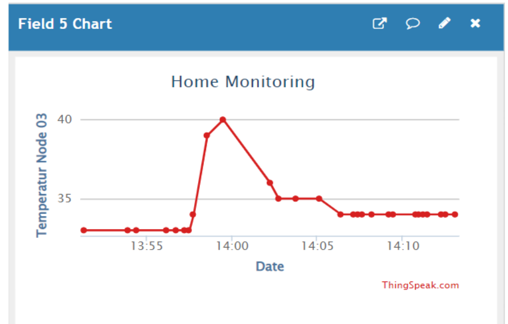


Figure 14 Temperature data at Node 03 from ThingSpeak website

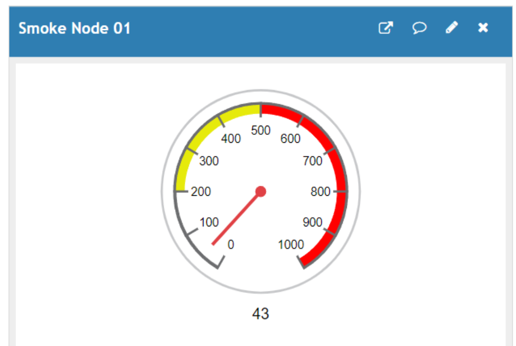


Figure 15 Smoke indicator from Node visualized in ThingSpeak

Figure 16 Flame indicator from Node visualized in ThingSpeak

Figure 17 shows the Telegram application that display the hazard notification. Telegram is considered easier to use for users because it is quite easy to use and operate as a means of communication to provide notifications in the case of a fire disaster. In one hand, parents of cerebral palsy patients can continue to monitor environmental conditions at home and can respond quickly in the event of a fire hazard.

Figure 17 Telegram notification for fire mitigation

4.0 CONCLUSION

The design of a system for mitigating the danger of fire disasters in occupants of persons with cerebral palsy has been successfully designed. The placement of the wireless sensor network was carried out based on a behavioral architectural analysis using DepthMapX-0.7.0 software. The process of assessing the behavioral architecture is carried out by observing patterns of daily activities and a simulation of human movements in the house to find out the most frequent activity places used by children with cerebral palsy. Based on the test results with DepthMapX-0.7.0, it can be concluded that the optimal location of the sensor node points is in the child's bedroom, kitchen, and TV room. Monitoring the condition of the house as a fire hazard mitigation measure is carried out in each designated room. Data recorded from each sensor node can be seen on the website page. Sampling of data that enters the database is every 15 seconds.

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Conflicts of Interest

The author(s) declare(s) that there is no conflict of interest regarding the publication of this paper.

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