Realtime health monitoring system design for children with cerebral palsy using internet of things

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Abstract. The realtime health monitoring system is a typical application of wearable computing in the medical field. However, existing technology does not consider to design monitoring system for supervision for people with cerebral palsy. The advances in internet innovation have made possible techniques for the conveyance of healthcare. The objective of this research was to design and develop innovative technological solutions to offer a more proactive and reliable medical care environment. The short-term and primary goal was to construct IoT4CP. We also describe an experimental model designed for checking the health condition of the children with cerebral palsy based on IoT architecture. The framework depends on sensor shield associated with a cloud platform that gathers the data from the sensors. The sensors measure various parameters, such as a heart rate and muscle contraction which are transmitted via microcontroller by a gateway to a cloud storage platform by google firebase. This research presents the first realtime analyses to be activated within this framework and can send data smoothly with total average 1.77 seconds.

1. Introduction

Cerebral palsy is a group of permanent movement disorders that appear in early childhood. Signs and symptoms vary among people and over time. Often, symptoms include poor coordination, stiff muscles, weak muscles, and tremors [1]. Cerebral palsy refers to a number of neurological abnormalities that appear when babies are due to developing brain lesions. Cerebral palsy greatly affects the level of productivity of children when doing daily activities, where children become limited in their activities and depend on other people as well as assistive devices in their daily lives [2]. Clinical and physiological symptoms in children with cerebral palsy which leads to impaired spathic motion, characterized by stiffness in part or all of the muscle. Children with cerebral palsy is usually characterized by impaired motor function [3].

Due to disability function in children, cerebral palsy has difficulty walking with squatting conditions (crouch gait), this is characterized by flexion movement in the knee and pelvic position which overload the body [4]. Walking in a squatting position causes excessive mechanical pressure on the joints of the hip and knee. This requires greater muscle performance than children with normal conditions. CP children in carrying out walking activities require far greater energy which causes fatigue and impaired heart function [5].

There are types of cerebral palsy that have physical conditions where one of their legs has stiffness so that it can still be possible to carry out walking activities. Energy requirements in walking activities

for children with cerebral palsy can be measured based on indicators of body physiology and muscle contraction in the lower limbs [6]. Physiological condition of the body can be determined by an indication of fatigue based on the pulse during walking activities. When activities more difficult to carry out, it can speed up the pulse beats [7]. Therefore, children with cerebral palsy cannot carry out walking activities for a long time because it can affect the health condition. Coupled with an increase in muscle performance during walking activities, resulting in impaired motor function at the level of motion coordination and balance in walking. When walking, there are muscle activities that works simultaneously, especially in the lower limbs which includes tibialis anterior muscle. This problem arises due to the difference between walking activity and adaptation to the physiological abilities of the body [8]. Gait analysis when walking activities need to evaluate, this information includes data on muscle in the lower limb [8].

Technological solutions can be applied to deal better with current operational problems involving the delivery of healthcare. The application of realtime monitoring to medical treatment has the capacity to transform the present operational environment through activities such as improvement of therapy. There is no ideal way to monitor health condition of a children with cerebral palsy without monitoring physiological conditions and gait balance in Realtime. A popular platform for providing real-time information is the Internet of Things. Internet of Things is a concept that aims to expand the benefits of the connectivity of devices that are continuously connected. Data transmission using a wi-fi connection is used in designing a monitoring system for children with cerebral palsy [9]. Wi-fi connection is used because the information displayed can be seen anywhere via cell phone with android that connected to the internet [10]. The device that can be the link between the microcontroller and Android is the ESP8266 wireless module. ESP8266 is a wi-fi module that is low power, low cost, and wearable. This module uses the MQTT protocol which is used as a means to send data online through a web server that will be forwarded on an Android phone.

This system consists of hardware and software that are interconnected so that the information presented can be directly accessed at that time. Hardware cannot work effectively if the software is not designed properly. This device is designed to display heart rate information and muscle contraction in children with cerebral palsy. This monitoring system makes it easy for users by monitoring information online and can be viewed via an Android phone.

2. Methodology

2.1. Literature study
The problem identification phase consists of the literature study and field studies, problem identification, problem formulation, setting research objectives, research benefits, limitations and assumptions. In the field study phase aims to find out how the real condition of the object to be studied, in this case the object is the Surakarta Child Disability Development Foundation (YPAC). While the literature study aims to obtain the right method to solve problems found from field studies.
The next stage after observation, the problem is formulated, namely how to design a monitoring system for children with cerebral palsy in real-time and simultaneously on different users regarding information on the body physiology and gait balance.

2.2. Identification of user needs
At this stage, the identification of user needs is describe based on observations from subject, children with cerebral palsy. This stage defines user needs based on the layered internet of things architecture as shown in Figure 1.
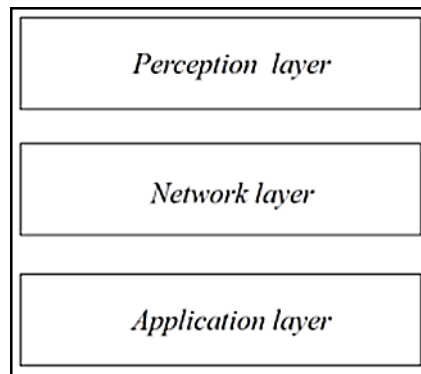
Figure 1. The layered internet of things architectures.

2.3. Hardware design

At this stage the layout design is based on the supporting components of the system to be built based on requirement from Internet of Things architectures. This design consists of a pulse heart rate sensor, muscle sensor, and wireless module. Figure 2 shows a block diagram of a monitoring system for children with cerebral palsy using Arduino. To detect heart rate sensors using a pulse heart rate sensor and to detect muscle sensors using muscle sensor. Arduino functions to process received data and send processed data results to be displayed on a cell phone with Android through wireless module.
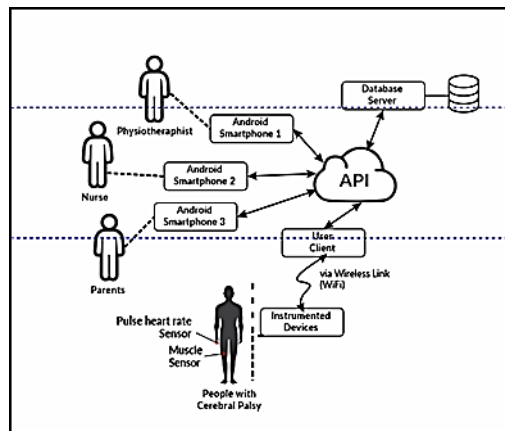

Figure 2. Block diagram monitoring system design.

2.4. Software design

Next step is to write the program code. At this stage the author uses Arduino IDE to compile program from Arduino Uno. Android Studio used to design android application with java and CSS programming language.

2.5. Proposed system design

Proposed system design is built by placing detailed instrumentation devices and connecting with application devices through cloud computing.

3. Results and discussion

Figure 3 illustrates the architecture of the cerebral palsy monitoring system. This system enables health observing and checking vital signs at the house.
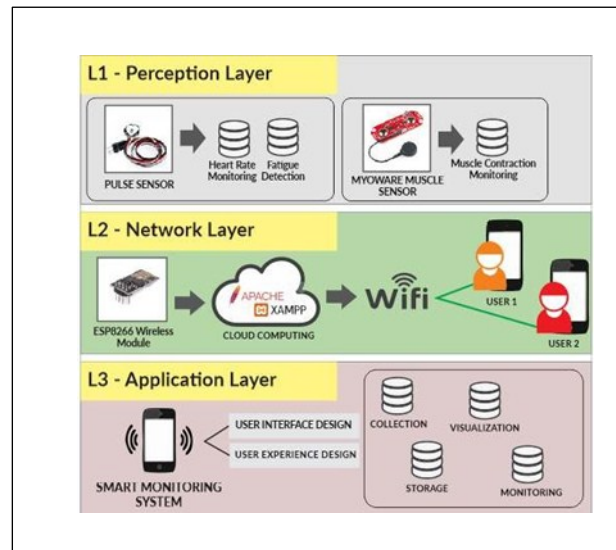

Figure 3. Architecture of proposed system design.

3.1. Perception layer

3.1.1. Microcontroller Arduino uno ATmega328p. Our proposed framework utilized Arduino Uno type R3 as a control unit that incorporated with monitoring system function. Arduino Uno as appeared in Figure 5 is a microcontroller board based on ATMega328p which involves 14 digital pins as input and 6 analogue productions as output, USB port, ICSP header and reset button as shown in Figure 4.

Figure 4. Arduino Uno ATMega328p.

This board is equipped with the elements expected to bolster the microcontroller by interfacing it to a PC utilizing a USB link. The Arduino Uno can be powered via the USB connection or with an outer power supply. The force source is chosen consequently. Outer (non-USB) force can come either from an AC-to-DC connector or battery. The connector can be associated by plugging a 2.1 mm centre-positive plug fitting into the board's energy jack. The board can work on an outside supply of 6 to 20 volts [11]. It has several specifications, for example, 32KB memory with 0.5KB for the boot loader, 16MHz speed, and board length is 68.6 mm with width 53.4 mm with 25g weight. The Integrated Development Environment (IDE) is utilized as a part of this work for programming the board. The Arduino IDE 1.0.1 gathers sensor information and showed the detected worth on PC.

3.1.2. Pulse heart rate sensor. Pulse sensor is a heart rate sensor that is tasked to convert physiological signals to electrical forms or other forms that are easily read or processed so that the microcontroller can manage and provide information to device to find out amount beat per minutes of heart rate (bpm) to know someone in a state normal.

Physical condition during gait activity helps in deciding or diagnoses health condition. This sensor is extremely helpful to detect heart disfunction for children with cerebral palsy. Figure 5 exhibits the patient position sensor.
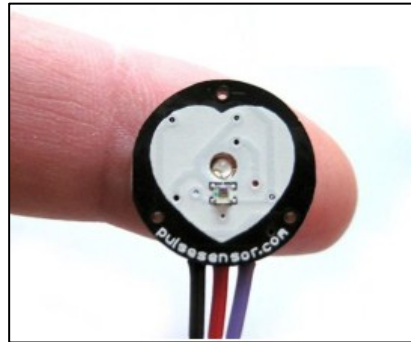

Figure 5. Pulse heart rate sensor.

3.1.3. Myoware muscle sensor. Myoware Muscle Sensor products from Advancer Technologies with series AT-04-001 can capture EMG signals produced by muscles so that they can be directly processed by the microcontroller as shown in Figure 6. Myoware Muscle Sensor works at the supply level of 3.3V - 5V, with the gain settings on the sensor ranging from 0.01Ω - 100Ω and the current supply given between 9 mA - 14 mA. Myoware Muscle This sensor requires 3 electrodes to be able to sample muscle signals (mid-end-reference electrode).
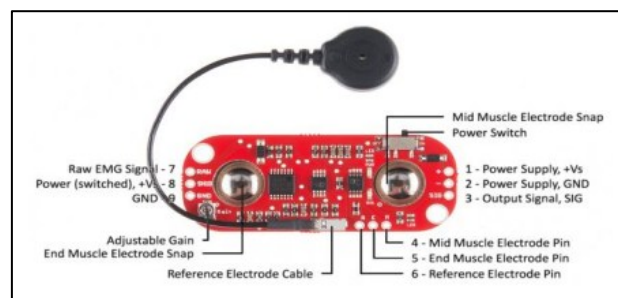

Figure 6. Myoware muscle sensor.

3.1.4. Wireless moduleESP8266. ESP8266 is a wi-fi module that functions as a microcontroller enhancement such as Arduino to be able to connect directly to wi-fi and establish a TCP / IP connection. This module requires around 3.3v of power by having three wi-fi modes namely Station, Access Point and Both (Both). This module is also equipped with processor, memory, and GPIO where the number of pins depends on the type of ESP8266 that we use as shown in Figure 7. The ESP8266 module is connected to the microcontroller using a USART serial connection (Universal Synchronous Asynchronous Receiver Transmitter) using two Tx pins and an Rx pin. For its own programming, we can use Firmware based on MCU Nodes and use putty as a terminal control for AT Command. Besides that, we can program this device using the Arduino IDE. By adding the ESP8266 library to the board manager we can easily program with basic Arduino program.
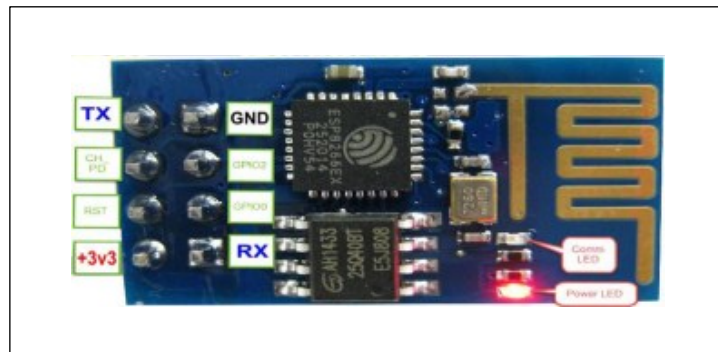
Figure 7. Wireless module ESP8266.

3.2. Application layer

In this section, software system design is carried out to describe the procedures and work processes of the application system. The system is built using UML (Unified Modelling Language) which consists of use case, activity, and class.

For use case, android application users can choose the menu provided in the application. In the menu application, there is form that needs to fulfil such as name, ages, gender, weight, and height. If all form already fulfils, it will display information about the monitored network device.

In activity process, user starts the process by opening the application on an android device. Users open and Google Firebase server or systems will display the splash screen. After splash screen appears, the user enters the form menu that needs to be fulfil. When the user has entered next button, system will display heart activity monitoring page, if an error occurs, application menu page will not appear and system instructs user to enter the information correctly. After entering on form menu screen, users can choose available menu on the android application. After user selects one of the available menus, the system will display network information according to the user selected. If the information displayed has an error, the system will return the display to the application menu screen. If the user has seen the information, the user can close the application and system will be stopped.

Class is an illustration of the structure of objects, classes, packages, and object relations with each other. The importance of class diagrams in this study is able to describe the structure of the system. Class can present things that happen in a system. A system has a flow, by making class of objects and relationships between systems can run sequentially. Class are the basic strengths of interacting methods.

3.3. Network layer

Cloud computing demonstrates a modern innovation that can be utilized in circumstances when PC demands are bigger than resources accessible in a project. This innovation presents a virtual platform that permits the improvement of huge applications, which are scaled as the domain and workload increments. The software and hardware are accessible on a virtual platform of cloud computing displaying Software as a Service (SaaS), Infrastructure as a Service (IaaS), and Platform as a Service (PaaS) via a server with Cloud Service Providers (CSP).

One of the most renowned cloud providers called Google Firebase that give infrastructure as a service with various sorts of favours, for example, Real Time Database was utilized in this project. The services provide by Google Firebase that intended to use the web with cloud computing less demanding for medical sensors that are associated with patients in order to gather and transmit information to the cloud. This services which are accessible in this cloud dependable for getting, saving, treatment, and sharing this information. We assume that this arrangement gives a suitable situation to supply telemedicine service that remotely the processes from gathering patient's information to conveying perfect therapeutic choices taking into account patients' present conditions and their historical medicinal information.

4. Implementation of proposed system

The proposed system as appeared in Figure 8 used to collect health condition of children with cerebral palsy. This Figure demonstrates the link of the considerable number of sensors on the instrument with Arduino Uno board. The synchronized framework will be prepared for persistent observing. It permitted the recording information of documents in a phone utilizing the serial port of the Arduino Uno stage.
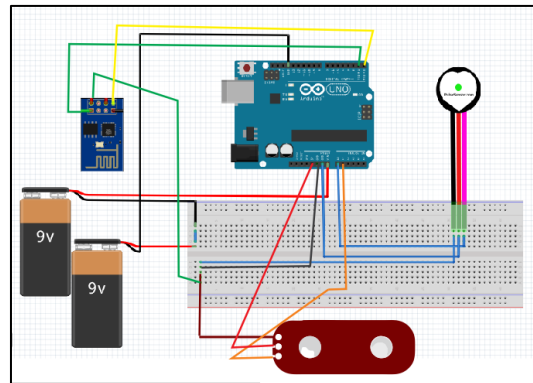

Figure 8. Monitoring system design implementation.

The administrator has fundamental influence in the framework; he can join a user, a new station for example physiotherapy, also he makes a report. In addition, he allows the assent for authorities or therapeutic specialists to see specific information for children with cerebral palsy, profile history and patient information depending upon sensor class as shown in Figure 9.
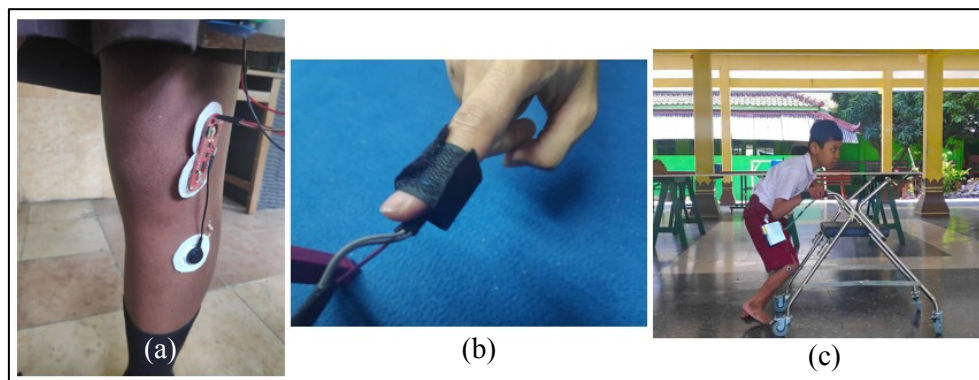

Figure 9. (a) Our IoT device for patient monitoring that contains an Arduino microcontroller. (b) Pulse sensors. (c) Myoware muscle sensor.

Pulse sensors and myoware muscle sensors take measurements at different places. Pulse sensor mounted on the tip of the index finger. The second sensor is a muscle activity sensor that has 3 electrodes that can stick to body skin. Electrodesare mounted on the knee joint, precisely between the thigh and knee.The prototype is placed by attaching the device in a pants pocket or shirt pocket as shown in Figure 9. This is done to minimize the risk of device falling when running activities and so that the sensor can be work properly.Data on the sensor can be seen on the smartphone. IoT4CP application that is built is a mobile-based application, therefore the interface built is an interface with the Android operating system. The design interface is implemented in the Java language and the CSS script is then stored in a file with the .apk extension. The interface of IoT4CP in Indonesia Language can be seen in Figure 10.
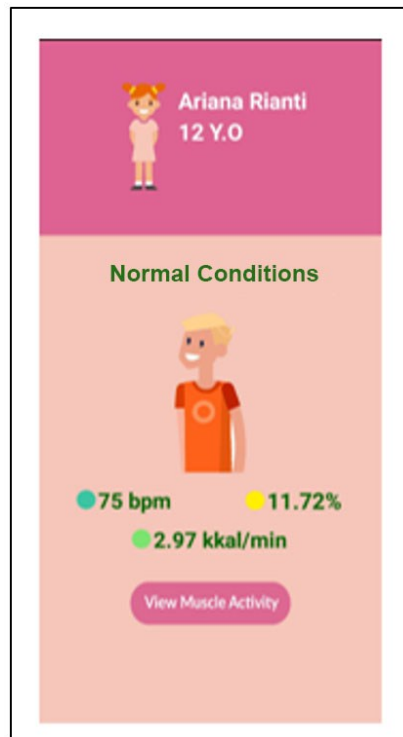
Figure 10. Monitoring system
application in Indonesian
Language.

Tests are carried out to determine whether the device can run properly and able to read and send heart rate data and muscle activity to Google Firebase database server. Response time testing to requests is carried out to determine the length of time the system responds to requests from users. The response time testing mechanism is to measure the length of time when the electronic device starts on or the electronic device starts off as shown in Table 1.

Table 1. A summary of response
time health monitoring system.

Distance (m)	Respond Time (s)
1	0.8
2	0.9
3	1.5
4	1.5
5	1.6
6	1.7
7	1.8
8	1.8
9	2.1
10	2.2

5. Conclusions

The main objective of this paper was to report on the construction of the IoT4CP framework based on a requirements analysis of the IoT architecture. This was accomplished by using framework design techniques and the introduction of software agents in the framework design to allow autonomic behavior [12]. In this paper, we designed the system to gives minimum complexity and very portable for health care observing of the children with cerebral palsy. Furthermore, it disregards the need for the usage of costly facilities. The physiotherapist or parents can readily get to the patient's information at any place with the assistance of cloud computing services. The proposed system used sensors platform integrated with Arduino Uno board. Two sensors have been utilized in this project and which are pulse heart rate sensor and Myoware muscle sensor. All the patient's vital signs sent remotely utilizing the Wireless module and displayed via an android cellphone. The data save in google firebase database and downloaded through android cellphone with average system response to each command request is 1.77 seconds.

6. References

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