Optimization of X-ray parameter monitor wireless system based on internet of things

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Abstract. The purpose of this research is to develop a non-invasive X-ray acceptance test device with an internet of things (IoT) based on monitoring system as an interface connection. This experiment uses an application with IoT technology as a graphical user interface for the X-ray acceptance test prototype. The experiment is done by measuring the value of the kilovolt and millisecond on the General X-ray machine. The data result will be compared with the traceable X-ray calibrator as reference value. The overall average percentage of error result is 99.26% and the percentage of accuracy is 0.74%. It is generally concluded that this prototype experiment has good results and can be used as a X-ray acceptance test equipment.

Keywords: X-ray acceptance test, Internet of Things (IoT), development software

1. Introduction
One of the diagnostic techniques in the healthcare industry is X-rays. The generation of X-ray radiation depends on the kilovolt X-ray tube and the exposure time. Diagnostic X-rays use a range of radiation to analyze the patient's body. If the received radiation dose exceeds the threshold, the patient's health can be threatened. This situation can happen due to a malfunction of the X-ray machine. To improve the performance of the X-ray machine, it is necessary to assess the tube voltage and the exposure time to ensure that the values are not exceed the specified threshold. [1-3].

The acceptance test for diagnostic and interventional radiology x-ray is a series of testing activities to ensure the X-ray machine is in reliable condition (passes the parameter test value) [4]. The aim of a quality assurance program is to assist a radio-diagnostic facility in consistently obtaining adequate radiological information with a minimum of dose and cost [5]. An integrated part of a quality assurance program is quality control ascertaining quality by measurements and other procedures [6]. Radiology service standards state that a diagnostic radiology room must have radiation protection for staff, patients and the environment [7]. The radiology room requires an X-ray acceptance test at a specific location to prevent unwanted gaps in X-ray radiation.

This research tries to develop technology in the field of radiology by utilizing internet of things (IoT) technology. IoT is used as an intermediary for the results of X-ray radiation acceptance tests that can cover a large area. The research was conducted by designing a monitoring test system for the optimization of kilovolt and millisecond values on X-ray machine, in the form of X-ray acceptance test prototype and a commercial Android operating system application.
2. Materials and Methods

2.1. Internet of Things
The Internet of Things (IoT) is a new paradigm in modern wireless telecommunications which has a broad concept in digitizing the physical world. IoT connects smart devices to an exponential network with addressing scheme that can interact with each other and work together between IP addresses to achieve common goals. IoT uses machine language which aims to facilitate communication between software and hardware [8].

![Figure 1. IoT architecture [9]](image)

This research refers to the IoT technology which functions as monitoring X-ray acceptance test result. from the IoT architecture in Figure 1, the first layer is a sensor that collects data from X-rays. The second layer is a wireless network for device connectivity with prototypes. The IoT gateways manage data traffic between various networks and protocols. The information then goes to back-end services which involve various servers and processors such as the IoT cloud, to perform different analytics and process large amounts of data in real time which are the third and fourth layers respectively. The top layer is the application layer which is the user interface as the display of data [9].

2.2. Components
Much of the works on x-ray detectors has concentrated on devices especially for the manufacture of x-ray suitability test kits. The development of solid state-based electronic x-ray detectors such as photodiode detectors evaluates fast and real-time parameters in radiological imaging. Since there are many commercial photodiodes with different characteristics, there is interest in using low cost photodiodes with good radiation sensitivity [10,11]. This study used a low-cost x-ray imaging tool based on the commercialization of a BPW-34 silicon PIN photodiode. The photodiode BPW34 takes advantage of the x-ray sensitivity that has been filtered by aluminum to detect and convert it into an analog voltage. The analog voltage is processed on the microcontroller to get kV results with the interpolation linear equation and the calculation of exposure time [12,13].

Arduino is a commercial 8-bit microcontroller development board with a USB programming interface to connect to a computer and additional connection sockets to external electronics. The ESP8266 WiFi board is a SOC with integrated TCP/IP protocol stack that can give any secondary microcontroller access to a WiFi network. Arduino microcontroller processes the data that obtained from the photodiode and sends the data to the backend service database with the ESP8266 WiFi module connection with the local internet network [14,15].

2.3. Operating system development software
The application functioned as a graphical user interface on the test result monitor. It is created using the commercial development application Android MIT App Inventor 2, which functions to form the Android Package Kit (APK) format. This APK format will be used for installation applications on the commercial operating system Android.

MIT App Inventor is an online platform designed to teach computational thinking concepts through blocks-based programming tool which simplifies building Android applications. Android application
development on MIT App Inventor 2, is made using the block editor that has a function to display the processed results from the webview. The webview displays stored data back-end database that processed from the microcontroller [16,17]. The MIT App Inventor 2 Android software development can be seen in Figure 2 and the result of display can be seen in Figure 3.

The radiology room has two rooms, namely the operator room and the examination room. In general, X-ray acceptance test is carried out in that both rooms. This is because the examination room has a wall covered with an X-ray anti radiation shield protection which is used for the safety of X-ray radiation exposure, so that it is not exposed to other rooms especially the operator room.

2.4. Block diagram
The X-rays radiation emitted by X-ray tube and will be detected by the two photodiodes that have been coated with an aluminum foil x-ray filter. The X-ray radiation will be converted into an analog voltage
and transferred to a ratio circuit. The ratio circuit has a function to obtain the value of the transmission ratio between the two photodiodes detector. The analog voltage will also amplified by ratio circuit and transferred to the ADC module which functions to convert the analog voltage into digital voltage. The ADC1115 commercial module also functions to obtain an accurate level of digital voltage readings on the microcontroller. The digital voltage that has been processed by the ADC115 module will enter the microcontroller for processing the interpolation linear equation calculation and the calculation of the voltage emission time.

The processing results will be displayed on the LCD screen and stored on the backend cloud. The ESP8266 module will connect to a local network with the SSID name and WiFi password according to the microcontroller program script. After the ESP8266 module is connected to the local network, the resulting data will be transferred using the local internet network to the backend cloud. The results on the backend cloud will display the test results to the Android application. An overview of the block diagram can be seen in Figure 5.

3. Results and Discussions
The overall analysis results will be compared with an acceptable X-ray calibrator. The average values generated by the calibrator becomes a reference for getting the percentage error and accuracy from the experimental results data. Data analysis refers to a guideline testing and calibration of medical devices accordingly an institutional local standard.

3.1. Results and monitor analysis with IoT
The results of the user interface in Figure 6, show a delay in sending data (pending) of 3-5 seconds from the reference calibrator data transmission. The reason is, data transmission depends on the quality of service from the internet network provider operator. data transmission also affects the distance of the WiFi signal source which is limited by the distance between the control room and the examination room which is coated with anti radiation protection.
3.2. Results and analysis of retrieval data

The percentage error and accuracy of the average voltage and time for three measurements with a parameter setting points: 100 mA with 40 ms for voltage measurement and 100 mA with 50 kV for time measurement, can be seen in Table 1 and Table 2.

Table 1. Results and analysis of retrieval of kV

| Setting kV | Average Calibrator | Average Experiment | Percentage Error (to Calibrator) | Percentage accuracy |
|------------|--------------------|--------------------|----------------------------------|--------------------|
| 45         | 45.12              | 44.71              | 0.91                             | 99.09              |
| 50         | 49.90              | 49.61              | 0.58                             | 99.42              |
| 55         | 54.61              | 54.30              | 0.56                             | 99.44              |
| 60         | 60.06              | 59.77              | 0.48                             | 99.52              |
| 65         | 65.25              | 64.96              | 0.44                             | 99.56              |

Table 2. Results and analysis of retrieval of ms

| Setting ms | Average Calibrator | Average Experiment | Percentage Error (to Calibrator) | Percentage accuracy |
|------------|--------------------|--------------------|----------------------------------|--------------------|
| 40         | 38.70              | 37.85              | 2.18                             | 97.82              |
| 50         | 48.74              | 48.21              | 1.09                             | 98.91              |
| 63         | 61.54              | 61.93              | 0.64                             | 99.36              |
| 80         | 78.35              | 78.25              | 0.13                             | 99.87              |
| 100        | 97.90              | 98.25              | 0.36                             | 99.64              |

The error percentage used to determine the error of the kV and ms values results and the accuracy percentage used to determine the closeness of the measurement results to the reference calibrator value. The average of percentage error voltage value is 99.41% and for accuracy is 0.59%. The average of percentage error time value is 99.12% and for accuracy is 0.88%. The overall average percentage of error result is 99.26% and the percentage of accuracy is 0.74%.

4. Conclusions

Although the delivery of data results is delayed (pending), the result data can be monitored in a broad scope. Smart devices that support the commercial Android operating system, can access applications for monitor test results with the connection to local internet network. this experiment has successfully monitor and give a good result as for the X-ray acceptance test. The analysis result is still in the requirements for all equipment performance in accordance an establish aninstitutional local standard.
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