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Noise Level Measurement to Reduce the Risk of Injury with the Internet of Things and Ergonomic Approach

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Abstract

The noise caused by the sound of machinery can hurt the work environment. Sound exposure that is above the threshold causes health risks, premature fatigue, and loss of concentration. Workers must control the noise level they receive. It takes a tool where workers can monitor the noise level they receive through sensors attached to themselves and take preventive action when the noise threshold will be reached. This can be done using the internet of things approach to expand internet connectivity that is connected continuously. The purpose of this research is to create a system in the workplace that can monitor noise conditions, which can be set remotely based on Arduino so that the data generated can be real-time. This will provide comfort for workers and can reduce the adverse effects of noise. The final result of the study shows that the Internet of Things system has worked well and can identify noise levels and provide feedback to workers through the received signal when the noise threshold is reached.

Keywords: Noise, Ergonomics, Internet of Things

INTRODUCTION

In carrying out their production activities, there are significant differences in environmental factors even though the company produces the same product. Health and comfort factors will have a significant influence on workers so as not to affect the ability and best performance of workers (Peña et al., 2019). The impact of discomfort in the work environment will cause a decrease in productivity and will lead to company profits. Noise or noise is the most important factor in a company that also requires attention. Sound exposure that is above the threshold causes interference for workers in receiving warning signs, as a result, it will affect worker safety because it affects concentration so that health, early fatigue, and workers often make mistakes, the product quality is not uniform (Basner & McGuire, 2018) (Mhamdi et al., 2012). A noisy environment causes workers to tire quickly, reducing the ability to work well due to loss of concentration (Habibi et al., 2013)

As a company that produces export-quality products, PT XYZ has many machines that produce high-intensity sounds. Of course, this will interfere with the operator's performance in carrying out the operation of the machine, so it is necessary to make improvements through the resulting improvements. Setting the work system that needs to be done in the production process so that the operator is not disturbed by the noise arising from the machine and does not cause injury to the operator in the long and short term.

Paper machine parts start from paper pulping until the finished product goes to the rewinder to be cut to the specified size. The problem that arises in the paper machine is the levels that interfere with workers. Initial measurements of the paper machine ranged from 91-112 dB. It is above the standard exposure limit set by the government, which is 85 dB with a maximum exposure of 8 hours per day. What is done is that there is no attribute warning so that operators and visitors do not know the magnitude of the discovery of the area and the level of danger in the area.

Workers must control the rates they receive. In addition to having to control the level, workers must also control the overall physical condition so that the influence does not have an impact that will cause work accidents. Of course, it will be a problem if these levels are not controlled, because if you rely on warnings from the leadership, it cannot be done simultaneously, so it needs to be equipped with

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controllers so that it can be done in real-time. Therefore, we need a tool that can unify the level through the sensor attached to itself and take precautions when the threshold will be reached. This can be done using the internet of things system approach which is a concept that aims to expand internet connectivity that is connected continuously (Cachada et al., 2019). The data generated from the sensor will be processed by the server and sent back to the workers by giving a shock or sound when approaching the set threshold.

Based on the characteristics of the problems described above, it can be found that the problem to be solved is to identify the noise level on the production floor to minimize the risk of work accidents by using the internet of things and an ergonomic approach. The long-term of this research will help the company in reducing work accidents due to uncontrolled noise. The purpose of this research is to create a system in the workplace that can monitor noise conditions, which can be remotely controlled based on Arduino so that the data generated can be real-time. This will provide comfort for workers and can reduce the adverse effects of noise. To reduce bias on the results of the study, a limitation is given, namely, the monitoring carried out is monitoring the noise conditions that are directly faced by workers. Noise that is outside the production floor but also affects worker noise is a limiting problem. The control that is implemented is the control of noise and ignores the occurrence of delays when sending data. So all data sent is assumed to be real-time.

LITERATURE REVIEW

Noise Framework

Noise in the workplace will turn into an occupational hazard when the sound generated from the sound source is felt to be physically and psychologically disturbing/unwanted (interfering with concentration and concentration of communication). When this condition occurs, the sound status changes to pollutant and the voice identity changes to noise.

The National Institute of Occupational Safety & Health (NIOSH) defines noise in working conditions as a pollutant if the level is greater than 104 dB. and working conditions result in workers continuing to experience exposures greater than 85 dB for more than 8 hours of work (Elfeituri & Taboun, 2002).

Noise is one of the physical factors in the form of sound that can have a bad effect on occupational health and safety (Németh et al., 2014). Two groupings are consisting of steady noise and non-steady noise. Fixed noise is separated into two types, namely groups with discontinuous frequencies, namely sounds with various frequencies, and broad sound collections, namely those with various frequencies. the same as the intermittent frequency but the difference occurs at a more variable frequency (Fredianelli et al., 2020)

The tool used to measure is the Sound level meter (SLM), the results of which can be compared with various available standards (Hamza et al., 2020). Noise is often measured using the dB (decibel) scale. The measuring instrument has a weighting mechanism that resembles the sensitivity characteristics of the human ear to sound intensity at different frequencies.

To determine the sound power (dB) cannot be measured by any method. The sound pressure reading is produced at a known distance from the sound source measured using a sound level meter, so that the sound power can be determined using the womack formula, namely:

$$\text{power dB} = \text{pressure dB} + \text{distance } 20 \text{ logs (feet)} - 2.5 \text{ dB} \tag{1}$$

Sound power is measured by reading the sound pressure dB with a sound level meter at a known distance from the center of the pump, where the -2.5 dB factor is an estimate for the approximate sound from the wall. Using equation 1, if the machine level from reading the sound level meter is 86 dB which is taken 8 meters from the machine. Then power dB = 86 + [20 × (log 8)] - 2.5 = 101.56 dB. The pressure generated by the output will be reduced if the object or worker is not too close a distance to the sound source. So it can be said that the change in sound power will change with distance. Apart from the workplace, a person can be found because of daily activities, such as racing cars, playing bands, etc. For such activity, the level can reach more than 100 dB (Iridiastadi & Yassierli, 2019)

Internet of Things

IoT is a set of physical networks in the form of electronic circuits, software, sensors, RFID, and connectivity placed on objects that collaboratively transmit information. Each object is represented as data and becomes information that can be used as decision-makers. In other words, IoT is an interface that connects the real world into a virtual world to be re-applied in the real world. The idea is to turn a physical system into an intelligent system.

In the IoT architecture, 3 important elements are consisting of the Network Layer, Perception Layer, and Application Layer. The use of cloud computing-based technology is found in (Fan et al., 2020). Besides that, (Majikes et al., 2017) defines IoT as a technology with an emphasis on RFID or Bluetooth and the potential benefits of IoT lie in (Zavareh et al., 2018) to provide an overview between the application and the theory. Cloud Computing provides an open opportunity to develop big data technology through the extraction of knowledge and data obtained from that data.

IoT provides market opportunities to solve problems in the industry, one of which is the problems that exist in the industry. Relevant monitoring supports interventions to reduce workplace accidents (Marques & Pitarma, 2020). IoT computing interacts with various sensors into data that is calculated according to its suitability so that the system is able to adapt to environmental conditions (Ze et al., 2019)(Boyes et al., 2018).

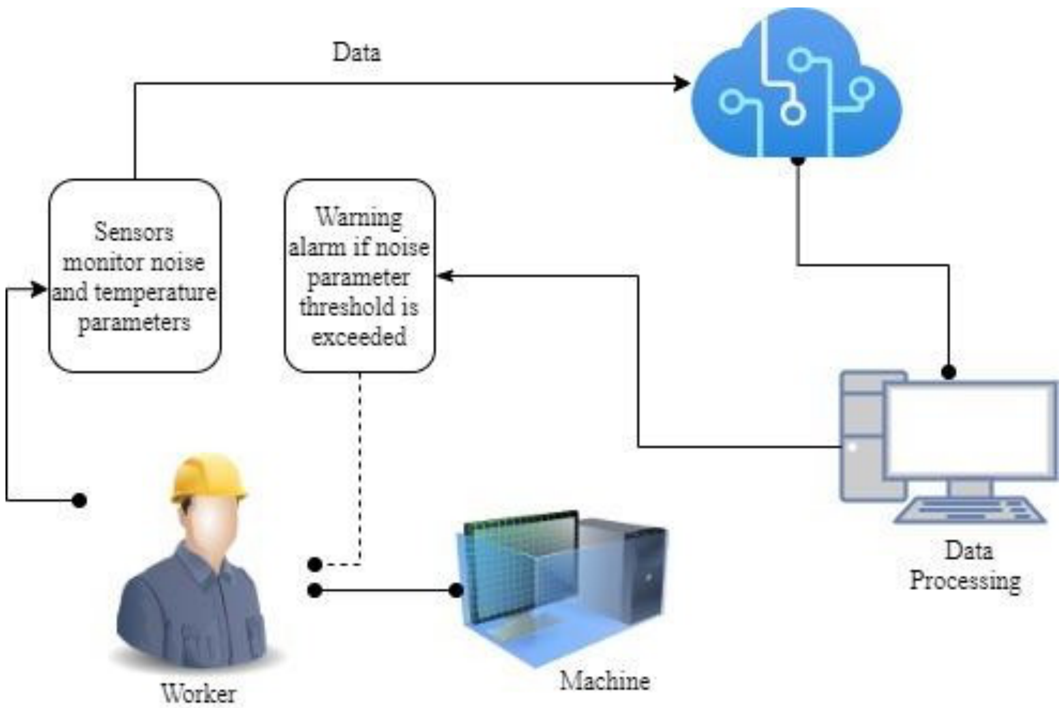

Figure 1. IoT Architecture on Observation

RESEARCH METHOD

The data source comes from the system running in this study to produce a monitoring system on the production floor. To achieve this goal, it is necessary to understand the ideal environmental conditions, especially the various parameters that exist. This system is expected to provide real-time information about the results produced by machines on the production floor. The information generated from the IoT system is utilized by stakeholders to support various policies in a healthier work environment.

Identification of system requirements provides an overview of the various system requirements that will be developed, namely the IoT approach in uniting the plots. In completing this system on the inside of various levels that describe the structure from the IoT design to the implementation level. The monitoring system is carried out starting from determining the database and determining the receipt and transmission of data to be monitored.

Workers who become the object of research will be briefed on the system usage and its application so that the system runs as expected. Workers will use earplugs that have been censored. Workers continue to carry out work processes by routine habits. The system works to read the observation parameters at the sensor node. Sensor node system data is sent, stored, and displayed on the interface of each sensor system to stakeholders. So that the system can be read and used on the production floor as a mapping of the resulting quality parameters. From the system requirements, a monitoring system is designed according to Figure 2.

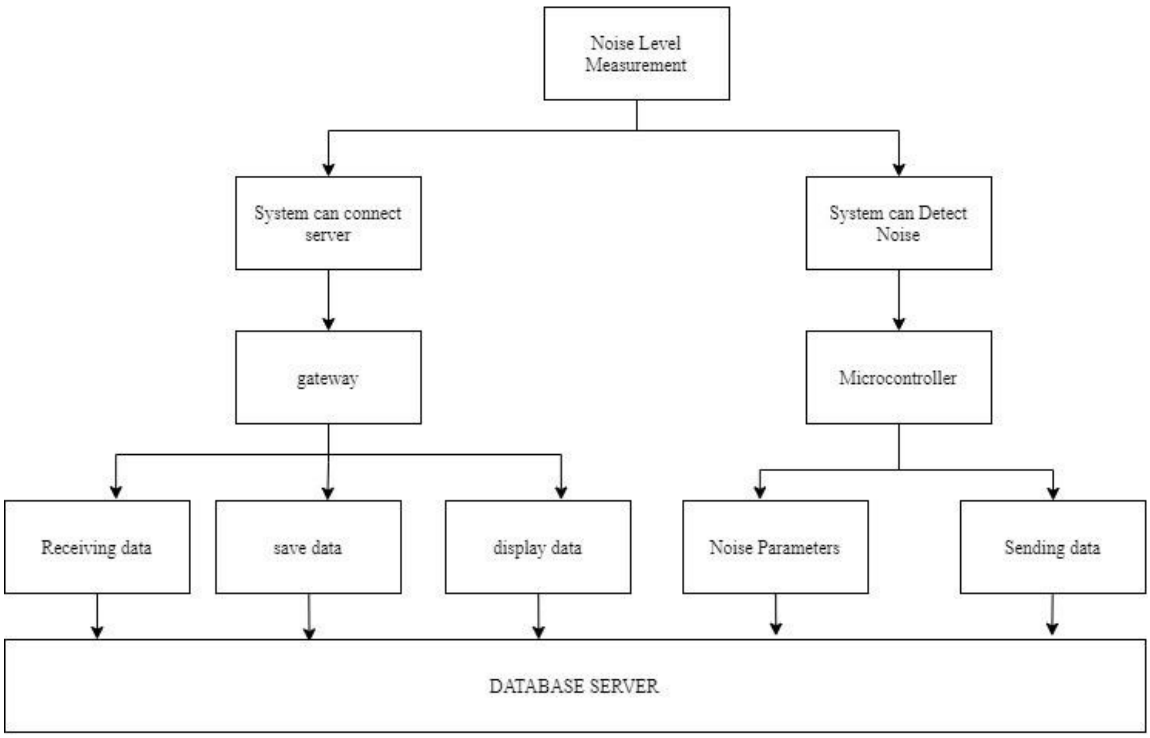

Figure 2. System Requirement Identification

In this system, the admin will do the work to set the parameters needed by the system on the sensor node and server gateway to be able to generate data and send it to the server. The server has a geographic information system interface that is displayed to stakeholders.

Figure 3. The Realm of IoT implementation in video monitoring

FINDING AND DISCUSSION

Initial State

Data collection is carried out to minimize the risk of injury from the resulting operator. Carried out in the paper machine, PT. XYZ Magelang. Data that can describe the noise value is generally needed to get the power dB value. Data retrieval is done with a variation of 30 minutes with random conditions to the condition of the machine. The data collection process is carried out with the condition that the workers have been running the machine for 1 hour. This is intended so that when the observation machine is in a stable state so that the noise produced becomes more valid. Measurements are carried out to determine the levels at a point. After measuring the parts of the paper machine. The unit used in the measurement of levels is the decibel (dB) as shown in table 1.

Table 1. The Approximate Measurement Results Received by the Operator on the Area Paper Machine

No	Station	Radius (m)	North (dB)	West (dB)	South (dB)	East (dB)	Noise (dB)	Exposure Duration Per Day
1	*Wire*	1	108	93	94	95	93	8 *hours*
		2	105	93	92	95		
2	*Press*	1	112	99	95	95	93	8 *hours*
		2	107	102	94	96		
3	*Dryer*	1	107	100	94	94	92	8 *hours*
		2	105	102	93	94		
4	*Popreel 1*	1	102	99	95	94	92	5 *hours*
		2	97	99	93	93		
5	*Popreel 2*	1	107	103	107	106	104	1,5 *hours*
		2	103	101	101	103		
6	*Rewinder 1*	4	99	98	101	97	93	3 *hours*
		5	98	103	101	89		
		8	99	104	100	88		
7	*Rewinder 2*	8	98	106	102	86	103	2 *hours*

10	99	99	98	85
12	99	103	102	82

The second step is to define the problem that is carried out to find out the causes of the factors that lead to the main problem and see the performance that should be done. The problem factor table can be seen in Table 2 below.

Table 2. Noise-Causing Factors

No.	The current situation	Problem factors	The state that should be
1	The sound generated by the machine is more than 85 dB with an operator exposure of 8 hours/day	• Machine maintenance repair schedule	Maximum sound 85 dB with maximum exposure for 8 hours/day
2	Noise alarm display facility is not available	• There is no information display or danger zone warning display on the area paper machine	There are hazard display facilities
3	Workers do not always use PPE	• Low operator knowledge related to problems that arise	Always use PPE
4	OHS handling efforts related to noise in the paper machine area are not running efficiently	• There is no special division that records occupational safety and health problems	Efforts to handle occupational safety and health related to paper machinery

Experimental design

In the IoT implementation design stage, it is done first through hardware design and connectivity between these devices. The hardware uses the ATmega8535 microcontroller on the Arduino Uno module as the system control center. The microcontroller is connected to the sensor system and data transmission. This system becomes the key to an entity called a sensor node. The server node gateway is tasked with receiving data sent by the sensor node and storing it in the database. The design of the device software is done by using Arduino to read the data generated by the sensor. Furthermore, the data is processed and converted into string variables generated by the microcontroller. The system's microcontroller data is then transmitted wirelessly to become a database.

This system consists of client applications, server applications, and dashboards. The client application is an android-based application that can be run on a smartphone. PHP-based server and dashboard applications that can be accessed via the internet. The programming language uses Java with SQLLite database and Android Studio 3.5. The server application and database are placed on a computer server with the specifications of the server computer having software specifications used are windows 10 with PHP Ver 7.0.26 and MySQL database ver 5. On the client-side using android pie ver 10 software and SQLite version 3.2

This sensor system functions to obtain room noise data on the production floor. The sensor is placed on the earplug that is used by workers during activities on the production floor. The noise detector uses the FD10-621-10 sensor. This sensor module will take noise data and then be processed by the microcontroller. The microcontroller functions to process noise data from sensors and regulates the internet network used for sending data to the server. This internet network setting includes setting the IP Address used and setting the transmission of noise data on the server.

The test system is divided into several things, including reading tests for each sensor, scheduling sensor readings, sending data, and receiving data on the server. Testing each sensor and scheduling its readings is done by activating all sensors and displaying the readings in a data array. The data is in the form of a sequence containing the sensor node number. After reading the sensor is successful, the data will be sent to the gateway node as a system server. Data is sent in the form of an array with a differentiator between parameters in the form of a comma pin. The differentiator works to separate the received array data into data variables only for each sensor parameter. Table. 2 is the result of serial communication that displays sensor data readings. The data stored in the database is used by the geographic information system to display then read the recorded sensors.

The system describes the information obtained from system testing. The analysis was carried out on several tests of reading sensor data, data transmission, and system interfaces. The sensor is used as a reading module for the discovery value. Testing the sensor module is done by comparing the sensor reading value with a comparison measuring instrument (manual). The comparative measuring instrument used is the Sanfix GM1356 sound level meter. Tests are carried out on all machines manually simultaneously with data collection through sensors so that the environmental conditions and the sound emitted by the machine are in the same condition. Table 3. Shows the results of testing sensors and measuring instruments for comparison.

Table 3. Testing the storage on the database

#	ID	model	QR Code ID	status	battery %	Model	longitude	noise	create at
1	1	Fd 621	20920520291	Active	69	-8,786822	176,908181	106	2021-07-19 10.21.12
2	1	Fd 621	39552479131	Active	73	-8,786822	176,908181	104	2021-07-19 10.21.13
3	1	Fd 621	62177440490	Active	71	-8,786822	176,908181	108	2021-07-19 10.21.14
4	1	Fd 621	26549733806	Active	70	-8,786822	176,908181	107	2021-07-19 10.21.15
5	1	Fd 621	46644703408	Active	70	-8,786822	176,908181	108	2021-07-19 10.21.16
6	1	Fd 621	16199249930	Active	73	-8,786822	176,908181	107	2021-07-19 10.21.17
7	1	Fd 621	14278606252	Active	70	-8,786822	176,908181	107	2021-07-19 10.21.18
8	1	Fd 621	34836118595	Active	69	-8,786822	176,908181	102	2021-07-19 10.21.19
9	1	Fd 621	19225034272	Active	71	-8,786822	176,908181	104	2021-07-19 10.21.20
10	1	Fd 621	56219459207	Active	71	-8,786822	176,908181	104	2021-07-19 10.21.21
11	1	Fd 621	63788143044	Active	73	-8,786822	176,908181	107	2021-07-19 10.21.22
12	1	Fd 621	61926411086	Active	70	-8,786822	176,908181	103	2021-07-19 10.21.23

In making software on a microcontroller system using Arduino. In this program, there are three parts, namely initial declaration, setting function, and looping function. In the sensor reading function, there are several functions to perform the working mechanism of each sensor. Each sensor function is scheduled in the form of a time lag for each sensor to work. The sensors used in this research are temperature sensors, humidity sensors and room sensors

Figure 4. Display IoT Monitoring

Can be observed on the system display, the noise will change with time. But overall the noise value is above the predetermined threshold of 86 dB. This is a concern so that high noise does not interfere with worker productivity because it will cause fatigue and range of hearing disturbances.

Table 4. Sensor Test Results

No	Observation		Difference
	Sensor	Manual	
1	106	95	11
2	104	95	9
3	108	95	13
4	107	96	11
5	108	94	14
6	107	94	13
7	107	94	13
8	102	93	9
9	104	102	2
10	104	103	1
11	107	97	10
12	103	89	14
13	103	88	15
14	109	86	23
15	108	85	23
16	104	82	22

The difference in results indicates the actual value received by the worker. Manual measurement is done with a distance that can be tolerated when data collection. This causes the resulting sound level meter value has not shown the accuracy of the work received by workers. The accuracy of the use of IoT in this study did not show a significant difference from that felt by workers. Including when workers use earplugs, the results generated by the use of IoT are by those felt by workers. The difference between the readings of the test results is by the accuracy value provided in the product datasheet specification. For a comparison chart of the difference in measurements, see Table 4.

CONCLUSION AND FURTHER RESEARCH

This ergonomics research has developed an IoT-based measurement system so that it can develop aspects of monitoring, analysis and control simultaneously and in real time. The performance of the application for measurements shows results that are in accordance with the reality experienced by workers compared to measurements made with a sound level meter.

Overall the system is able to read parameters in accordance with the existing sensor system. The sensor system reads according to a predetermined schedule. The results using a 16 node sensor produces an average measurement of 101. This sensor is also able to measure real measurements by comparing the daily average differences.

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