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# Machinery Healt Monitoring System with Arduino

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***Abstract*— Machinery safety is the most important aspect needed around manufacturing or other engineering equipment. Machine guarding provides a means to protect humans from injury while working nearby or while operating equipment. Machinery that has rotary part such as turbines, pumps, fans, rollers, are needed to be monitored to report the vibration whether they are safety or not. Thus the preventive action is needed to ensure the safety of machinery before being used. This paper is about the monitoring system for machinery health which is developed with Arduino. It detects the vibration from the machine and information to mobile application. The information may include the vibration pattern, acceleration (g) value, recorded event, and also gives alert via mobile application in the form of vibration and ringtone.**

***Keywords — Arduino, Mobile application, Alert system, Machinery***

## I. INTRODUCTION

Unguarded moving parts of machines/equipment and the sudden or uncontrolled release of their power systems can result in serious injuries. The machine safety must be applied in order to avoid any casualties and property loss. Personnel working with machines must be aware of the risks involved and follow safe work practices. The machineries or equipment that bear rotating parts have high chance to cause hazardous event for example the machine may eject some of its part and harm the people and object around it. The loose part is one of the causes of such event. The unstable machine may create non-static vibration when it is being operated. Accelerometer vibration data allows the user to monitor machines and detect these faults before the rotating equipment fails completely. Thus the identification of the vibration to ensure the machinery health is very crucial for safety purpose.

The utilization of mobile device and Arduino are chosen to make a system that capable to detect machinery vibration and give alert to the users. The choosing of mobile device is because of its mobility. The application that carries the system can be used anytime and anywhere. One of the essential functions of mobile devices is that people may perform various tasks anytime and anywhere. For example, a user of mobile device able to send a message or make a call to another mobile device's user while walking.

The accelerometer ADXL335 will be used as the sensor for detecting machine vibration. The accelerometer is chosen because it is suitable to detect vibration in three axes which are x axis, y axis and z axis. The low power consumption is also become the consideration of choosing accelerometer as the vibration sensor.

This paper will discuss about the system that act as the supporting system that capable to detect machine vibration using Accelerometer Sensor and create alarm via mobile application. The system will have related aspect from the seismograph. The sensor will detect the machine vibration created from the environment and send the information data to the mobile application. The data will be displayed in the application as a graph plot and also the acceleration (g) values. The application may give alert notification if the level of acceleration is high enough to indicate there is something wrong with the machine.

## II. RESEARCH METHODOLOGY

This research began with an industrial visit to several industries in Cikarang. The author sees firsthand how a product was created by machine. Then, study about the employee risks posed by machine damaged. From all of that, then it is proposed a research with RAD (Rapid Application Development) methodology [1].

RAD is a rapid prototyping which is a model of developing application by technical incremental in a short and fast time. Fig. 1 is show how the application methodology using RAD.

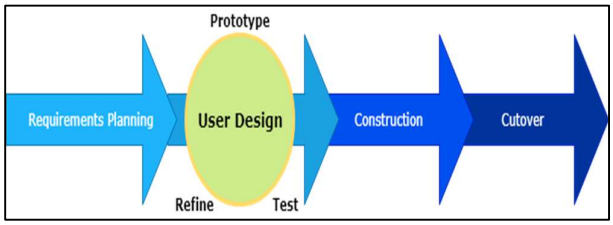


Fig. 1. RAD Diagram

### A. Requirements

This is where the clients and author (developer) do system planning and analyses. Generally, this preliminary investigation aims to establish system requirements, constraints, and scope. Problems, solutions, and alternative solutions are discussed here while overall sketch of the program is discussed. When everything is settled, all related parties are allowed to go to the next phase.

### B. User Design Phase

During this phase, the model of system's processes is the main focus. The team should be able to model its inputs, outputs, processes, and user interface model—breaking them into parts and visualizing them in diagrams. Team should create a system design based on the planning that was already prepared in previous phase. The design will be continuously discussed, reviewed, and updated until the best version is found.

### C. Construction Phase

This phase is where the team executes ideas discussed in the two previous phases. It focuses on application development, including: coding, unit integration, and testing. Developers create an application that is acceptable according to a predefined standard.

### D. Cutover Phase

This phase is where the team executes ideas discussed in the two previous phases. It focuses on application development, including: coding, unit integration, and testing. Developers create an application that is acceptable according to a predefined standard.

## III. LITERATURE REVIEWS

Machinery is safety guards that are applied to both machinery and the operators who work with them. Example are interlocks that stop a motor if a person gets too close, guards that cover moving gears and blades and goggles and protective clothing. The lack of machinery safety may cause hazardous event for example people can be stroke and injured by moving parts of machinery or ejected material. The kind of machine that will be used for the system is machine that has rotary part such as turbine, fan, roller, etc.

### A. Arduino

Arduino is an open-source single-board microcontroller, derived from wiring platform, design to ease the use of electronics in various fields. The hardware has an Atmel AVR processor and the software has its own programming language. Microcontroller itself is a chip of IC (Integrated Circuit) that can be programmed using a computer [2] [3].

#### 1) Arduino Uno

Arduino Uno is a microcontroller board based on the ATmega328P (datasheet). It has 14 digital input/output pins (of which can be used as PWM outputs), 6 analog inputs, a 16 MHz quartz crystal, a USB connection, a power jack, an ICSP header and a reset button.

#### 2) Arduino Mega

Arduino or Genuino uses C Arduino language for the program. Other than that, Arduino can be used to create an attractive application project for electronic because this controller hardware has a port for input and output.

### B. ADXL 335 Accelerometer Sensor

The accelerometer sensor is a small, thin, ultra flow power, 3-axis accelerometer with high resolution (13-bit) measurement up to ±16. It will be used to detect 3-axial vibration movement which is X axis, Y axis, and Z axis converted to acceleration (g) value.

### C. Mercalli Intensity Scale

It is a seismic intensity scale used for measuring the intensity of an earthquake. Even though the scale is for earthquake, but it can also be used to determine the vibration of the machinery. The intensity itself may describes the severity of machine problems in terms of its effects on the earth's surface and on humans and their structures. The table below is the Instrumental Intensity Table developed by The United States Geological Survey (USGS) which map acceleration (g) value and velocity.

TABLE I. USGS MERCALLI INTENSITY TABLE

| Instrumental Intensity | Acceleration (g) | Velocity (cm/s) | Perceived Shaking | Potential Damage |
|---|---|---|---|---|
| 1 | <0.0017 | <0.1 | Not felt | None |
| II – III | 0.0017 – 0.014 | 0.1 – 1.1 | Weak | None |
| IV | 0.014 – 0.039 | 1.1 – 3.4 | Light | None |
| V | 0.39 – 0.092 | 3.4 – 8.1 | Moderate | Very light |
| VI | 0.092 – 0.18 | 8.1 – 16 | Strong | Light |
| VII | 0.18 – 0.34 | 16 – 31 | Very strong | Moderate |
| VIII | 0.34 – 0.65 | 31 – 60 | Severe | Moderate to heavy |
| IX | 0.65 – 1.24 | 60 – 116 | Violent | Heavy |
| X+ | >1.24 | >116 | Extreme | Very heavy |

## IV. RESULT AND ANALYSIS

The system is the combination of Arduino, HC-06 Bluetooth, and ADXL 335 that serves as the machine vibration detector that capable to detect machine vibration and send the information to the mobile phone. There are some steps to create it, starting from designing the hardware circuit, database, analyzing the functionality, and testing result.

### A. Arduino and Circuit Design

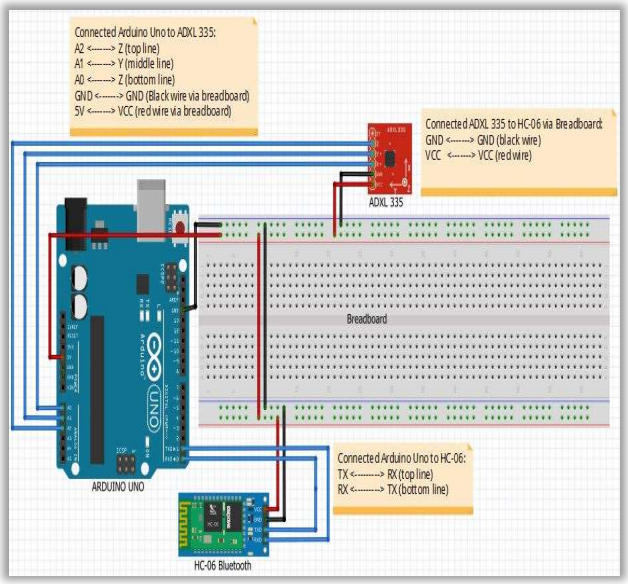


Fig. 2. Arduino circuit design

The design of Arduino is very necessary to create reliable and efficient system. A good grasp of the electronic design of Arduino hardware will help to learn how to embed an Arduino in the design of a final product, including what to keep and what to omit from the original design. The design

of Arduino can be seen in fig. 2 and table 2 is the detail of information about the circuit development.

Table 2. Detail Information of Arduino Uno Circuit

| Module | Module Pin | Arduino Uno Pin |
|---|---|---|
| ADXL 335 Accelerometer | Z | A2 |
| | Y | A1 |
| | X | A0 |
| | VCC | 5 V |
| | GND | GND |
| HC-06 Bluetooth | RX | TX |
| | TX | RX |
| | VCC | 5V |
| | GND | GND |

*B. Database Design*

Database design is the organization of data to be stored and how the data elements interrelate. It involves classifying data and identifying interrelationships. The purpose is to provide an overview of database that able to produce the information. It is only using a single table to store the sensor data value as shown in table 3.

Table 3. Database Table

| Field Name | Data Type | Required | Primary Key |
|---|---|---|---|
| HistoryID | Integer (11) | - | √ |
| xValue | Double | √ | - |
| yValue | Double | √ | - |
| zValue | Double | √ | - |
| Scale | Text | √ | - |
| Damage | Text | √ | - |
| Date_time | Datetime | √ | - |

*C. Functional Analysis*

To make sure the users able to operate the machine detector and alert system using the Arduino and mobile application, there are some requirements should be performed to complete the objectives as shown in table 4.

Table 4. Functional Analysis

| No. | Function description |
|---|---|
| 1 | Allows the users to establish Bluetooth connections from mobile application to Arduino |
| 2 | Allows the users to monitor machine vibration event with the real-time line chart graph plot. |
| 3 | Allows the system to give the users alert notification about machine issues |
| 4 | Allows the users to navigate the history to see the list of recorded machine event. |
| 5 | Allows the users visualize the recorded history list into Bar Chart |

*D. System and Hardware Testing*

There are some testing to be done for the system and hardware testing. In this case, the test will be focused on the Arduino hardware test, to test the Arduino Hardware system.

*1) Connecting The Application to Arduino*

This is the first step to test the Arduino hardware. In this step, it tries to connect the application to Arduino using the Bluetooth module which is a HC-06 Bluetooth. Firstly, user will be asked to choose a Bluetooth on the screen of the application. It developed in JAVA code, to establish the Bluetooth connection. The list of paired devices will be listed inside the "ListView" and as shown in fig. 3 is the psudo code of Bluetooth pairing devices.

Then, after user clicks one of the items, mobile phone will automatically connect to selected device. Fig. 4 is the code of connecting device.

```
Paired device = Array list
If paired device > 0
        Then get address (Bluetooth paired)
    Else
        Bluetooth not found
End
```

Fig. 3. Pseudo code of Bluetooth pairing devices

```
If Bluetooth = paired
        Then get view (graphic)
    Else
        Return to pairing Bluetooth
End
```

Fig. 4. Code of connecting devices.

*2) Sensor Module Test*

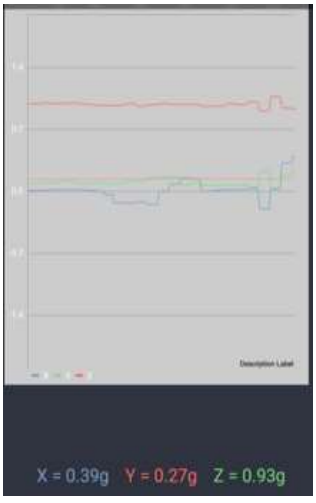


Fig. 5. Graph of the sensor

To test the sensor, it created a dummy machine vibration to shake the Arduino with the sensor that is mounted on the

top of breadboard or place the Arduino inside the rotating machine in the firm position. The circuit is placed inside the enclosed and safe place like the brick pillar inside the building. This test is resulted a real time data from accelerometer ADXL 335 which is shown in graph as in fig. 5.

*3) Alert System*

The next test is test the alert system. The alert system of machine vibration is developed with JAVA code as in fig. 6. The alert system is in the form of alarm, it will be triggered if a certain value of the sensor is detected. The value of the sensor will decide the scale of the machine vibration and the potential damage. The scaling is based on Mercalli scale. In this system, alarm is only triggered by the intensity of VI until X+ because the alarm is supposed to warn the threatening occurrence while intensity from I – V is not considered as threat. Fig. 7 is system alerts shown in mobile application.

```
If
   0.09 <= X1 <= 0.18 and -0.18 <= X2 <= -0.09
   0.09 <= Y1 <= 0.18 and -0.18 <= Y2 <= -0.09
   1.01 <= Z1 <= 1.10 and -1.10 <= Z2 <= -1.01
   Then Scale: Stronge
        Damage: light
Else if
   0.18 <= X1 <= 0.34 and -0.34 <= X2 <= -0.18
   0.18 <= Y1 <= 0.34 and -0.34 <= Y2 <= -0.18
   1.10 <= Z1 <= 1.26 and -1.26 <= Z2 <= -1.10
   Then Scale: Very stronger
        Damage: moderate
Else if
   0.34 <= X1 <= 0.65 and -0.65 <= X2 <= -0.34
   0.34 <= Y1 <= 0.65 and -0.65 <= Y2 <= -0.34
   1.26 <= Z1 <= 1.57 and -1.57 <= Z2 <= -1.26
   Then Scale: Severe
        Damage: Heavy
Else if
   0.65 <= X1 <= 1.24 and -1.24 <= X2 <= -0.65
   0.65 <= Y1 <= 1.24 and -1.24 <= Y2 <= -0.65
   1.57 <= Z1 <= 2.16 and -2.16 <= Z2 <= -1.57
   Then Scale: Extreme
        Damage: Very heavy
Else
   Stop
End
```

Fig. 6. Code of alert system


Fig. 7. System alert

*4) Recorded Event*

Recorded event is a way to see what happened to the machine. It stores everything that has been experienced by the machine as history. As fig. 8, it shows a history page of the machine.


Fig. 8 History page

*5) Visualize Recorded History*

Visualize recorded history is a history page shown in chart diagram. By visualizing in the form of chart diagram, it make easy to analyze the history of the machine as show in fig. 9.

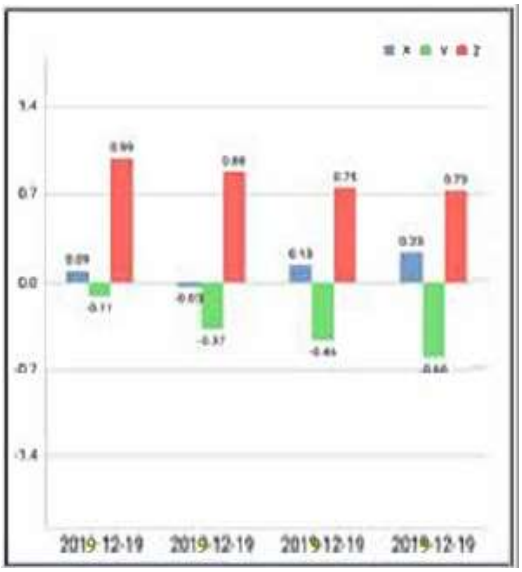


Fig. 9. History chart

## V. CONCLUSION

There were 5 steps of the test conducted on monitoring machinery health and it also able to give alert to the user through a mobile application. First test, is connecting application to Arduino through Bluetooth HC-06 and the result is connected. Then, the second is testing the sensor. The sensor is able to show the result by capturing the acceleration (g) in 3 axial vibration movement (X, Y, Z) and in the specified result, it can give the alert to the mobile application as shown in the third test. Then, for the event also recorded which is stored as history as it has been tested in test four. And the last, it can visualize the history in chart form so it makes easy to analyze and understand.

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