Diagnostic Tool by Augmented Reality and Internet of Things

Brandon Lee Veng Kit
School of Engineering
Asia Pacific University of Technology and innovation (APU)
Kuala Lumpur, Malaysia
TP035862@mail.apu.edu.my

Lim Chee Cheow
School of Engineering
Asia Pacific University of Technology and innovation (APU)
Kuala Lumpur, Malaysia
lim.cheecheow@apu.edu.my

***Abstract*-The main aim of this project is to develop a diagnostic tool with AR technology using the concept of Internet of Things (IoT) for an elevator. The proposed method to detect faults in elevator was the use of voltage sensor, current sensor, temperature sensor and tachometer. The results shows that system was fully implemented but only certain parameters was able to be recorded due to the inability for more testing on other hardware sensors. Through testing, there was some differences in the measured values from the microcontroller compared to the measuring apparatus used.**

Keywords— Augmented Reality (AR), Internet of Things (IoT), elevator maintenance system, NodeMCU ESP8266

I. INTRODUCTION

Elevators are being used a lot in our daily lives in offices, and high homes. With every moving object, it requires maintenance to ensure the elevator is safe and efficient to be used by the public. Traditional maintenance requires many days of work to diagnose, replace and test the elevator system before it can be open for use for the public again. With the ever-growing technology, newer ways to do such maintenance has been developed as well as more efficient and safer elevator systems that include complicated circuits and controllers. (Huang et al., 2020).

A proposed method to make the maintenance easier is to collect data of the elevator using sensors and making the elevator a smart elevator. The errors are diagnosed by using the data collected from the microcontroller which are specific to the motor voltage, motor current and motor speed. The information is used to calculate the power of the motor and the torque of the motor. This information is then used and compared with the rated values of the motor to show its efficiency of the motor.

To further improve the maintenance process, there is technology that allows for training of maintenance which is currently also in use in some industries which is using Augmented Reality (AR) technology. Industries use AR technology to assist in training personnel for assembly and maintenance process and it has been proven to improve in assembly and maintenance time as well as reduce the errors made by the trainee. (Palmarini et al., 2018)

While the elevator requires maintenance, it is also required to have the personnel to perform the maintenance, which in turn means it requires personnel training as it requires an expert to make the maintenance work more efficient and effective. Usually, it requires more than 2 people to be present at the site of maintenance for safety reasons and training purposes. To reduce the number of people, present at the site and allocate work for the expert somewhere which requires their knowledge, a combination of the systems mentioned above is proposed to ease the maintenance diagnostics of an elevator, allowing it easier to be performed by anyone with the application.

The elevator maintenance system can be improved and allowing it to be more efficient. The current problem with the system is due to the requirement of expert personnel to be on-site together with the trainee to perform personnel training of maintenance. This causes the expert to be occupied in training instead of handling more important jobs that require the attention of the expert. Another problem with the system is that it requires more than one trip to diagnose the maintenance required for the elevator. With that in mind, a system has been proposed to overcome these problems which is to use AR to identify the problems with minimum supervision. There are a few challenges that comes with the proposed solution.

Another problem would be to diagnose the maintenance required to be performed on the elevator without the need for human diagnostics through the use of sensors alone. The control unit of an elevator is limited to the function in which it is allowed to perform and cannot notify the maintenance company when maintenance is required on the elevator.

Wahab, Abdullah & Rasid (2018) did an experiment to analysis a small brushed DC motor fault though thermal analysis. The method proposed used a thermocouple and the steady state temperature is recorded. The results of the experiment shows that the temperature of the faulty bearing produces higher temperature to that of the healthy motor. The researchers have established that the brush of the motor is expected to have the highest temperature due to the electrical components that are present to conduct the current from the supply that delivers the current to commutator that then supplies the stator of the motor. It is found that the bearings of the motor would account for 262% increase in temperature as compared to other parts of the motor.

Huang, Cao & Sun (2019) proposed a design for an elevator power failure warning system. The proposed system is broken down into 3 parts which are the data collector, monitoring platform and the app client. The focus on this subheading would be on the remote monitoring system. The urgency would depend on the if an individual is trapped within the elevator. The same flowchart design can be implemented into the proposed project. The researcher is capable of determining the different states in which the elevator, on or off, and if the elevator is having a levelling problem. The project is limited by the use of an already existing controller present in the elevator system in which the data is collected from using a Controlled Area Network (CAN) bus interface.

Medina-Garcia et al. (2017) proposed of fault detected of motor array using real-time monitoring. The researcher selected a few sensors that would aid in the fault detection of the motor which are accelerometer, current sensor and temperature sensor. The researcher uses the accelerometer to detect the vibrations of the axial from the three-phase squirrel cade motor. The resultant vibrations from the motor is determined to be caused by the motor system and the natural frequencies of the motor. It is also possible to determine the magnetic flux fault through power failure in one phase of the motor. It is determined that the magnetic flux of the current through the winding results in increase of vibrations in the axial.

Li (2018) mentioned of the torque current that is used to control the opening and closing of the elevator door. The maximum and minimum torque current can be measured during the opening and closing of the elevator door which corresponds to the peak torque current of the door. The door closing requires more force with the increased weight resulted in increased friction which, in turn, increased the closing torque. The instant of the peak torque that varies with the external force is compared to the peak torque current without external force and resulted in 28.53% change which is thought to be the performance degradation increase due to friction.

On the same topic of elevator door, Wang et. Al. (2018) listed the potential faults that occur in the elevator door system. These are stated at improper human operation resulting in the door lock short circuit and non-human factor resulting in door lock switch contacts which are not opened, door lock replay delayed opening or door lock short circuit due to fault. A proposed solution to prevent so to have a remote monitoring of the elevator door and fault warning system. This allow for predictive maintenance to be performed on the elevator door before the fault can occur, which then minimises the occurrence of the fault.

Merizalde, Hernandez-Callejo and Dequie-Perez (2017) researched on the common failures that occur on an induction motor. The common errors that occur are mainly related to the mechanical failure of the bearings, stator and the rotor. The takeaway from the result is that the highest risk of motor failure are mainly based the aging of the motor and human error due to the lack of maintenance performed on the motor and the failure of proper testing. Therefore the monitoring of conditions of the motor is implemented in order to perform predictive maintenance allowing the longer life span of the system that is driven by the motor in a less risk and cost saving environment.

Kunthong et. al. (2017) discovered that temperature can be used to detect problems with the motor bearings. Although this is only limited to the location of the motor bearings, it is also an indicator that this method of detecting faults in a motor is viable. Although the temperature changes would only be noticed after a long period of the motor running. The temperature sensors are placed on the motor casing, the motor front and the rear ball bearings and these are the common areas that is possible to detect temperature changes to the motor.

Djagarov et al. (2019) recommended the methods to diagnose an induction motor categorized to two different methods, being invasive and non-invasive methods. These involves the need to interact directly with the motor in order to analysis the issues with the motor. The non-invasive methods utilize mathematical models in order to analyse the measured signals and train an intelligent system to distinguished fault data collected. Combining these systems through the use of sensors allows easier diagnostics of motor faults through the collection of data. This is especially important if the said motor is to be onboard a ship in which case the researcher is mainly referring to.

Huang et al. (2020) researched on the method of which to collect and transfer data received from the elevator. The researcher proposes the use of Spark streaming data processing technology in order to process the data from the elevators in real-time. For the use of fault detection, data should be collected for a period of time which can affect the efficiency of the detection. The researcher proposes the use of sliding window mechanism in the preprocessing of the stream data. The figure below shows the concept of the sliding window mechanism.

Dou & Gou (2016) stated that is it important to have an elevator control system that is reliable for the safety of the passengers and the maintenance personnel. The researchers determined that the failure of the elevator control system can be situated in the programming development of the microprocessor. The more bytes that the information contains, the greater possibility of failure, and thus suggested that a single byte be used, and single byte instruction can also be repeated, resulting in instruction redundancy. This would affect the efficiency of the microprocessor control system. The researcher then concludes that a correct sampling time delay be required to ensure the effectiveness of the system to prevent interference of the input.

Palmarini et al. (2018) reviews the uses of applications of AR in maintenance. The researcher found the majority of the applications of AR system to be related to mechanical maintenance. The researcher justifies that it is necessary due to the competitive and profitability nature of the project. The involvement of AR technology has improved the maintenance process in the aspect of time by 79% and reduced error rate up to 94.2%. The researcher summarizes that the AR technology is implemented to resolve 2 issues which are to change traditional manuals to electronic multimedia and provide a tool to assist in training new technicians.

Del Amo et al (2017) proposed a framework for the maintenance using AR. It links the maintenance processes and the maintenance information systems and environment. It is explained that it requires a lot of data collection to achieve AR visualization and interaction abilities. The researchers mentioned that the framework enables the development of AR systems in maintenance that allows a different level of interaction with the real work and the virtual work. It is discussed that the focus of AR in maintenance should be on the reason for the data being acquired and the method of which the data is acquired for the AR system. Due to the immaturity of AR in research, the framework would still require more validation.

Masoni et. Al. (2017) proposes the use of AR in remote maintenance from an expert to an operator that is equipped with the device that is being used to perform the maintenance.

The maintenance is done by taking pictures from the AR application itself and sending the picture to the maintenance expert to evaluate the maintenance that should be performed through the use of drawings and symbols on the picture which is sent back to the operator. These drawing and symbols and text are used to instruct the operator on the procedures that should be followed in order to perform successfully perform the maintenance. The researcher used Unity3D for the application environment which is also integrated with Vuforia tool for tracking the image in 3D. Vuforia tool is noted by the researcher as an image tracking tool which allows to display 3D visuals based on the visual information that is being sent though the application.

The aim of this research is to develop a diagnostic tool with AR technology by using the concept IoT for an elevator to ease the diagnostic process and quick maintenance work on the elevator. The proposed ideas to solve the main problem is to have an elevator monitoring system which can communicate with a handheld application to display and highlight the problemed area within the elevator using AR. The highlighted area will be displayed in AR to specify which item within the elevator system that requires to be changed to ensure the elevator is in safe working conditions with detailed information on the parameters that is being measured. This system allows the maintenance to run more smoothly as the maintenance team would have the data collected over the period of the elevator running. This also allows little troubleshooting on the problems that would be present in the elevator thus for potentially less personnel to be present at the location at a time to perform the diagnostic and maintenance required on the elevator. The proposed idea also aims to reduce the amount of time required to evaluate, perform and complete the maintenance process which in turn can save cost, increase efficiency and ensure the safety of the users of the elevator. Due to the advancement of technology, the proposed idea would also allow the modernization of the maintenance sector, especially when it is still a necessity to perform maintenance to ensure the system is up to date, and efficient.

II. DESIGN METHODOLOGY

Fig1. shows the finalized block diagram of the project and it is more detailed as compared to the proposed block diagram. The hardware system uses a NodeMCU ESP8266 to collect and send the sensor information to the cloud database. The sensors used in the final design has not changed from the previous proposed idea where it is using 4 different sensors which are the voltage sensor, current sensor, IR sensor and temperature sensor.

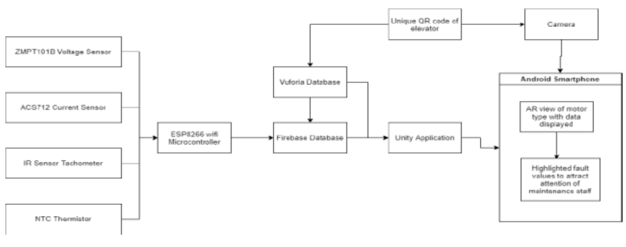

Fig. 1. Finalized block diagram

The elevator or motor system has its unique QR code which tells the different elevators apart and this is use as the AR tracking for the application.

The QR code is saved in a the Vuforia engine database and the actual QR code is used to track the 3D model of the design. The data from the sensors are fetched by Unity engine application from the firebase database and the data is displayed on the 3D model of the motor. If there is fault detected in the motor system, the program will highlight the fault value in a red colour.

Fig 2. shows the final hardware schematic design. It shows the 4 different sensors which are the voltage sensor, current sensor, IR sensor and temperature connected to a NodeMCU. The schematic design also includes the multiplexer as the voltage sensor, current sensor and temperature sensor are all analogue signals and requires it to be connected to an analogue input of the NodeMCU, and because there is only 1 analogue input in the NodeMCU, the multiplexer is used. However the IR sensor can be sent as a digital signal as it only requires to be turned on and off in order to calculate the rotational speed of a motor. The breakout board that is shown in the schematic is not exactly the one used in the final project implementation but it generally it uses the same 74HC4051 8-channel multiplexer chip and the connections is very similar to the model obtained. The open ends of the ZMPT101B voltage sensor and ACS712 current sensors are to be connected to the motor line inputs in order sense the voltage and current that is going into the motor.

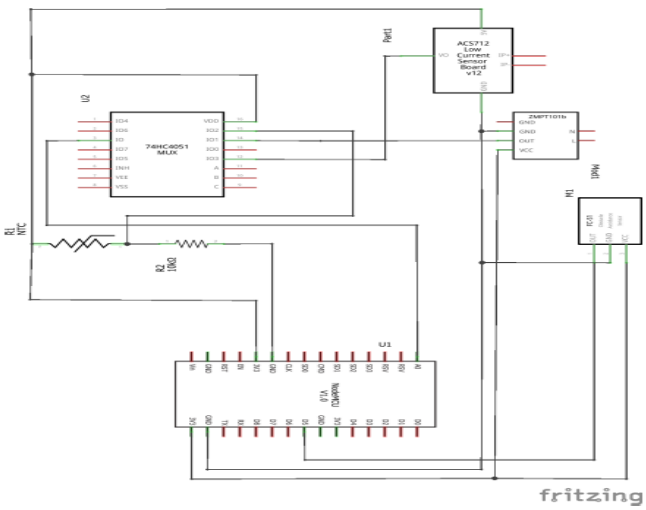

Fig. 2. Finalized circuit diagram

Fig 3. shows the finalized flowchart of the software system. It starts with the powering the elevator systems which in change would also power the microcontroller that is used to collect and send the data to the cloud. To prevent the constant data that is being received from overloading the cloud database, the IR sensor is used to detect is the motor is running and if it is, then the data is collected from the sensors and sent to the database. In the smartphone unity application, if there are any faults within the motor detected, the values displayed on the AR image would highlight the number with a red colour to inform that is the location that the fault of the motor is detected. Otherwise, the data would still remain to be displayed only with a green colour to indicate that the motor is running in optimal condition. This process repeats indefinitely until the elevator itself is turned off or in not in service at the current moment. The differences between this final flowchart design and the proposed design is the indicator used to show the user of the application the location of the motor fault. It also shows that the system would continuously loop with each other until the elevator itself it turned off.

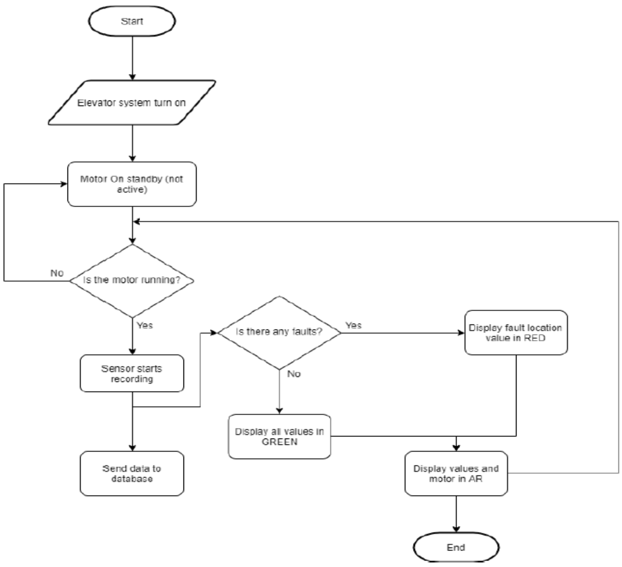

Fig. 3. Finalized flowchart of the software

Fig 4 and 5. shows that the motor is successfully displayed on the on program and the values are extracted successfully from the firebase database. The values also change colour depending on the readings and the code that was set for the specific motor based on the optimal working conditions of the motor. The colour green indicate that the motor condition is in optimal working condition where as the colour red indicate that the motor has an error occur and the issues of that specific area should be looked into. Both images are taken from different angles to show that the values being displayed follows the motion of the camera which is to always display directly to the camera allowing the values to always be seen as long as the camera is tracking the target image properly.

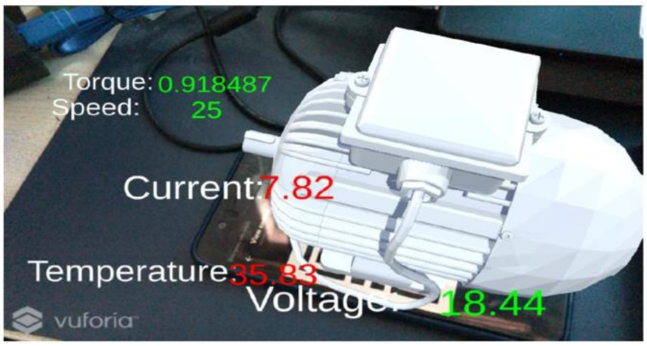

Fig. 4. Values and motor being displayed in ar with highlighted colours

Fig. 5. Values and Motor being displayed in AR to show text tracking

III. Testing of the Proposed Design

A. *Current Sensor Accuracy Testing*

This section test the sensitivity of the current sensor ACS712 with reference to a multimeter. The readings of both the sensor and multimeter are recorded a long with the reading of the dial on the voltage controller lab equipment in order to ensure a controlled environment for testing purposes as well as the ability to vary the voltage for the sake of this test. The circuit is connected according to the schematic diagram in Fig 2. The live and neutral lines are connected to the inputs of the ACS712 sensor where ensuring that the whole circuit is connected in series with a multimeter that is set to detect the current value. The power supply is turned on and the power setting is adjusted to give varying current values to the motor and the values on both the Arduino serial and the multimeter are recorded.

Table I. shows the results of the testing done with different power percentages in a power laboratory. The results show that there is a small percentage of error in values recorded between the multimeter and the current sensor. It also shows that the error percentage is very large when the current is close to 0. This shows that the current sensor shows a more accurate value when there is current running through the sensor as compared to when the there is no current. The error percentage of the reading is calculated simply by using the formula:

$$\frac{\text{Sensor}-\text{Multimeter}}{\text{MultimeterX}} \times 100\% \qquad (1)$$

TABLE I. Current Sensor Accuracy Result

Multimeter Reading (A)	ACS712 Reading (A)	Power %	% Error
0.058	0.77	0	92.46753247
0.352	0.34	5	-3.529411765
0.295	0.31	10	4.838709677
0.32	0.31	15	-3.225806452
0.382	0.37	20	-3.243243243

B. *Temperature Sensor Accuracy Testing*

This section test the sensitivity of the temperature sensor using the thermistor with reference to proper digital laser thermometer. The readings from both the temperature sensor and digital laser thermometer are recorded. The circuit is connected according to the schematic diagram in Fig 2. The thermistor is placed on the motor cover located close to the motor rotor. The motor is then allowed to run for a period of time before stopping and allow the motor to cooldown. During this process, the values of the thermistor is recorded every 5 minutes obtained from the Arduino serial and the temperature recorded from the IR thermometer is also recorded.

Table II. shows the results of the testing done with different temperature settings. The results show that the error value varies with different temperature setting with the highest error recorded at 8.52%. There is a negative error recorded in with higher temperature where the temperature measured by the IR thermometer is smaller than that obtained from the thermistor. There is also a positive error recorded in the lower temperatures starting at about 44°C where the temperature recorded from the IR thermometer is higher than that is recorded from the thermistor. Once again, the error percentage of the readings is calculated using the formula from equation 1.

TABLE II. THERMISTOR ACCURACY RESULT

IR Thermometer Reading (°C)	Thermistor Reading (°C)	% Error
53.4	57.38	-7.453183521
49.4	50.89	-3.016194332
44.2	44.98	-1.764705882
44.2	43.1	2.488687783
39.3	35.95	8.524173028
38.3	35.83	6.449086162

IV. CONCLUSION

The aim of the project is to develop a diagnostic tool with AR technology by using the concept of IoT for an elevator to ease the diagnostic process and quick maintenance work on the elevator. Develop an AR system with was shown and the 3D model of the motor is displayed on a camera with its sensor data measurements being displayed. The research limitations involves that the current system implemented only involves measuring the parameters of the elevator motor which are limited to the voltage, current, motor speed, torque, and motor temperature. It does not take account to the other parameters of the elevator such as the condition of the elevator ropes, the door gear resistances, dust formations, vibrations and so on that would affect the overall performance of the elevator. The research software application used is also limited in customization of the application without going to the original application editor itself. This includes the optimal working conditions of the motor which vary from different types of motor and from different manufacturers as well.

REFERENCES

Abdulla, R., Eldebani, A. A., Selvaperumal, S. K., & Abbas, M. K. (2020). IoT based Pet Feeder. Test Engineering & Management, 83(March-April 2020), 269–279.

Del Amo, I.F., Erkoyuncu, J.A., Roy, R. and Wilding, S. (2017) 'Augmented Reality in Maintenance: An information-centered desgin framework', Bermen.

DJAGAROV, N., GROZDEV, Z., ENCHEV, G. and DJAGAROVA, J. (2019) 'Ship's Induction Motors Fault Diagnosis', International Conference on Electrical Machines, Drives and Power System, Varna.

Dou, Y. and Guo, L. (2016) 'Research on the Reliability of Elevator Control System', 3rd International Conference on Materials Science and Mechanical Engineering, Chang Shu, 110-112.

Haziq, M. I., Noor, I. M. B. M., & Abdulla, R. (2022). Smart IoT-Based Security System for Residence. Journal of Applied Technology and Innovation, 6(1), 18–23.

Hon, F. S., Abdulla, R., Selvaperumal, S. K., Nataraj, C., & Ratnadurai, D. (2020). Wheelchair-Person Fall Detection with Internet of Things. Solid State Technology, 63(1S), 911–922.

Huang, J., Jiang, X., Tong, Y. and Gu, F. (2020) 'Research of elevator real time monitoring method based on spark', IOP Conference Series: Materials Science and Engineering, Nanjing, 1-5.

Huang, Q., Cao, J. and Sun, R. (2019) 'Design and Implementation of an Elevator Power Failure Warning System', Journal of Physics: Conference series, vol. 1621, pp. 1-10.

Kalilani, M., Lai, N. S., & Abdulla, R. (2021). IoT Based Neonatal Incubator for the Developing World and Conflict zones. Journal of Applied Technology and Innovation, 5(4), 44–50.

Kunthong, J., Sapaklom, T., Prapanavarat, C., Mujjalinvimut, E., Boonjeed, S. and Ayudhya, P.N.N. (2107) 'IoT-Based Traction Motor Drive Condition Monitoring in Electric Vehicles: Part 1', International Conference on Power Electronics and Drive Systems (PEDS), Honalulu.

Lakshmanan, R., Djama, M., Selvaperumal, S. K., & Abdulla, R. (2020). Automated Smart Hydroponics System Using Internet of Things. International Journal of Electrical and Computer Engineering, 10(6), 6389–6398.

Li, J. (2018) 'Fault Point State Monitoring of Elevator Door Based On Modulus Maximum Wavelet Transform', International Journal of Mechatornics and Applied Mechanics, no. 3, pp. 170-176.

Masoni, R., Ferrise, F., Bordegoni, M., Gattullo, M., Uva, A.E., Fiorentino, M., Carrabba, E. and Di Donato, M. (2017) 'Supporting remote maintenance in inducstry 4.0 through augmented reality', 27th International Conference on Flexible Automation and Intelligent Manufacturing, Modena, 1296 - 1302.

Medina-Garcia, J., Sanchez-Rodriguez, T., Gomez Galan, J.A., Delgado, A., Gomez-Bravo, F. and Jimenez, R. (2017) 'A Wireless Sensor System for Real-Time Monitoring and Fault Detection of Motor Arrays', Sensors, vol. 17, no. 3, p. 469.

Merizalde, Y., Hernandez-Callejo, L. and Duque-Perez, O. (2017) 'State of the Art and Trends in the Monitoring, Detection and Diagnosis of Failures in Electric Induction Motors', energies, vol. 10, no. 7, July.

Palmarini, R., Erkoyuncu, J.A., Roy, R. and Torabmostaedi, H. (2018) 'A Systematic Review of Augmented Reality applications in Maintenance', Robotics and Computer Intergrated Manufacturing, vol. 49, pp. 215-228.

Rasheed, W. M., Abdulla, R., & San, L. Y. (2021). Manhole Cover Monitoring System Over IOT. *Journal of Applied Technology and Innovation*, *5*(3), 1–6.

Samson, A. M., Dhakshyani, R., & Abdulla, R. (2020). IoT Based Sustainable Wallet Tracking System. *International Journal of Advanced Science and Technology*, *29*(1), 1301–1310.

Singh, H., Abdulla, R., & Selvaperumal, S. K. (2021). Carbon Monoxide Detection Using IoT. *Journal of Applied Technology and Innovation*, *5*(3), 7–12.

Wahab, A.A., Fatimah Abdullah, N. and Rasid, M.A.H. (2018) 'Mechanical Fault Detection on Electrical Machine: Thermal Analysis of Small Brushed DC Motor with Faulty Bearing', MATEC Web of Conferences, Pahang, 225.

Wang, Q., Leng, Y., Li, D., Zhang, X., Li, R., Zhu, H. and Zhang, H. (2018) 'MCU System-based Intelligent High-speed Elevator Door Operator Fault Analysis and Research', IOP Conf. Series: Material Science and Engineering, Tianjin, 428.

Yong, L. Y. I., DHAKSHYANI, R., & Abdulla, R. (2020). Intelligent Book Returning and Sorting System Using IoT. *Solid State Technology*, *63*(1S), 899–910. http://www.solidstatetechnology.us/index.php/JSST/article/view/780