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Development of Machine Down-Time Monitoring System for Production Line Efficiency Evaluation

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ABSTRACT

Manufacturing industries often face challenges in optimizing machine performance due to the limitations of traditional downtime monitoring methods, which are time-consuming and prone to errors. The lack of real-time capabilities in these methods leads to delayed identification and resolution of machine issues, ultimately affecting productivity. This research aims to develop a real-time machine downtime monitoring system that leverages sensors, vision systems, and LabVIEW software to enhance the detection and analysis of production line performance. The system uses image processing techniques for product quality assessment, enabling the detection of good and defective products, and integrates vibration sensors to monitor equipment conditions. The Arduino microcontroller is employed to manage sensor data and motor functions, while LabVIEW software facilitates real-time visualization and data analysis. The system demonstrated high accuracy in detecting both product defects and equipment vibrations, although sensitivity to lighting conditions and low-powered motors presents areas for future improvement. The integration of this system into production lines has the potential to significantly reduce downtime and improve operational efficiency, contributing to more automated and reliable industrial processes.

1. Introduction

Manufacturing industries continuously strive to optimize machine performance, but traditional methods, such as paper records or Excel spreadsheets, are often time-consuming and prone to errors, as highlighted in previous studies [1,2]. These manual approaches, where workers record downtime and transfer data to spreadsheets, are susceptible to human errors, inconsistencies, and inaccuracies, making it difficult to track issues accurately, as noted in previous studies [3-6].

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Moreover, these methods lack real-time capabilities, which result in delayed identification and resolution of downtime causes [7-9]. However, with advancements in technologies like sensors, data analytics, and machine learning, real-time machine downtime monitoring systems have become feasible. For instance, camera vision systems, commonly used in production line inspections, are integrated with LabVIEW software, as demonstrated by Chulakit *et al.,* [10]. These systems capture real-time visuals, assisting in defect detection and the analysis of product attributes, significantly reducing the time required to detect issues and improving productivity and economic efficiency. By collecting and analyzing large volumes of real-time data, these systems provide manufacturers with accurate insights into machine performance, enabling quicker problem identification and overall productivity enhancement.

Machine downtime poses a major challenge for manufacturers, affecting process efficiency, productivity, and customer satisfaction. However, many current downtime monitoring methods lack real-time capabilities and predictive insights, resulting in delayed detection and resolution of issues. Addressing this gap is critical for improving the accuracy and speed of downtime tracking and analysis, which are key to optimizing production line efficiency. The objective of this study, therefore, is to develop a real-time machine downtime monitoring system using sensors, IoT devices, and LabVIEW software to automate the inspection process and provide actionable insights for improving production line performance.

1.1 Applications of Image Processing Techniques in Quality Assessment and Object Recognition

One example of previous research that used image processing techniques for object detection and recognition is the study by Du and Da-Wen [11]. The research focused on three methods, which include image restoration, aimed at removing or decreasing degradations or noise suffered by the image during its acquisition, image segmentation used for pre-processing, and classification. Acquiring images poses certain challenges, especially when using low-quality cameras, which can result in compromised image quality. Issues such as poor focus, reduced resolution, decreased accuracy, and inadequate capture of internal structures are common limitations. These challenges highlight the need for more advanced and innovative approaches to overcome the obstacles associated with object recognition. Other previous research on the application of image processing techniques is summarized in Table 1.

Table 1
Previous studies of the application using image processing technique

Application	Technique	Description
Recent developments in the applications of image processing techniques for food quality evaluation [11].	i. Image acquisition ii. Image restoration iii. Image segmentation iv. Object detection v. Object recognition vi. Classification	This study tests the quality of food using image processing techniques, including image acquisition, image restoration, image segmentation, object detection, object recognition, and classification with the help of a vision system.
Application of image processing techniques in plant disease recognition [12].	i. Image acquisition ii. Image preprocessing iii. Color space transformation iv. Segmentation v. Feature extraction vi. Classification	This research determines plant leaf diseases using a vision system. The classification process utilizes three types of classifiers which are linear, nonlinear, and ANN.
Image processing techniques for coin classification using LabVIEW [13].	i. Data acquisition ii. Pre-processing iii. Feature extraction iv. Classification	This study develops a simulation for detecting and classifying currency coins using a vision system and smart cameras.

The comparison shows that image processing is necessary to eliminate noise, blurry images, and other issues to obtain a clearer acquired image. These techniques can be implemented using LabVIEW software with the Vision Assistant tool. This approach helps produce clearer, non-blurry images. Additionally, these techniques assist in classifying objects by setting feature vectors. In this project, image processing techniques are used to detect the shape and color of objects through camera vision using a webcam.

1.2 Integration of Webcam and LabVIEW Software for Automated Vision Systems

A webcam, also known as a digital camera, is used for video or image capture and is connected to a computer using USB to visualize on the computer for live streaming or meeting purposes via the internet. The reason for using a webcam in this project is that it is affordable and adaptable due to its high-quality video, autofocus function, and zooming capability. On the other hand, LabVIEW software is a graphical-based programming environment, and according to Ursutiu *et al.,* [14], LabVIEW's graphical interface enhances the speed and efficiency of code development by allowing users to easily drag and drop pre-built functions. This simplifies tasks such as acquisition, analysis, control, and data sharing, reducing the time spent on fixing syntax errors and enabling more focus on the creative aspects of application development.

LabVIEW is utilized in this research to develop a vision system. The implementation of this system has the potential to minimize human involvement in agricultural practices. Image processing techniques are extensively employed in the field of agriculture to identify and analyze essential parameters within images. The previous study of the application of webcam and LabVIEW software is summarized in Table 2 to aid in understanding the differences between them.

Table 2
Previous studies on webcam integration with LabVIEW software

Application	Advantages	Disadvantages	Result
Real-time object detection and selection with the LabVIEW program [15].	i. Compatibility with a low budget webcam.	i. High quality of lighting is needed. ii. High resolution of the camera.	Accuracy rate 95.349%
Vision based weed recognition using LabVIEW environment for agricultural applications [16].	i. Reducing human intervention ii. Able to interface with Arduino iii. Providing controlled decisions for herbicide application.	i. High cost ii. High quality of the captured images needed.	The Arduino react correctly to spray the herbicide.
Facial expression-based computer cursor control system for assisting physically disabled person [17].	i. Provides an alternative method for physically disabled individuals to interact with computer applications.	i. High quality of lighting is needed	Accuracy rate of 90% in detecting nodding and shaking in the raw motion parameters.

Based on the comparison of previous studies, it can be inferred that vision systems generally achieve commendable accuracy rates exceeding 80%. The table also highlights the importance of adequate lighting conditions in ensuring high-quality images and accurate results. Insufficient lighting can adversely impact both image quality and the system's overall accuracy. Additionally, the integration of LabVIEW software with microcontrollers has proven to be highly effective. The microcontroller successfully controls various input devices such as Infrared (IR) sensors and piezoelectric sensors. Given the system's suitability for detecting objects at short distances and its compatibility with low-speed conveyor systems, the proposed method demonstrates favourable characteristics.

1.3 Applications of LabVIEW and IoT in Real-Time Monitoring Systems

The Internet of Things (IoT) is widely used across industries, smart homes, intelligent energy systems, and more, with the potential to contribute to the development of smart cities. These systems reduce human dependency while enhancing productivity. LabVIEW software is commonly employed to develop automated research and production test systems. In this section, the application of such systems is discussed. Research conducted by Swain *et al.,* [18] describes an eHealth monitoring system, LI-Care, which utilizes IoT and LabVIEW. The system integrates the NI myRIO-1900, an embedded microcontroller programmed via LabVIEW, to connect various sensors and a webcam positioned by the patient's bed. This setup enables real-time data collection and video monitoring, with the data stored in the cloud for remote access by healthcare providers via mobile devices or tablets. The system operates using Wireless Fidelity (Wi-Fi) to ensure real-time monitoring. Table 3 presents a summary of LabVIEW and IoT applications, facilitating an easy comparison with other studies.

Table 3
Previous studies of LabVIEW and IoT-based application

Application	Component used	Software	Description
A LabVIEW and IoT based e health monitoring System [18].	i. Ni myRIO-1990 ii. Blood pressure sensor iii. Temperature sensor iv. RFID card v. Closed-Circuit Television (CCTV)	i. LabVIEW	This system monitors a patient's health using LabVIEW and a webcam to visualize the patient's condition. If any sensor parameter exceeds the safe level, an alert is sent to the doctor via a tablet using IoT technology. The CCTV monitors the patient's condition.
Smart industry pollution monitoring and controlling using LabVIEW based IoT [19].	i. Arduino Mega 2560 ii. DHT-11 iii. MG-811 CO2 sensor module iv. pH sensor	i. LabVIEW ii. PHP Scripting iii. Database	Data from the sensors is sent to Arduino and then transmitted to LabVIEW. LabVIEW stores the parameter values in a database. The data is then stored on a website and displayed on the user's mobile device, where the user can control the system via the mobile interface.
IoT based patient monitoring system using raspberry pi 3 and LabVIEW [20].	i. Raspberry Pi ii. Pulse sensor iii. Temperature sensor iv. Respiratory sensor v. Pulse oximeter vi. RS232 vii. Arduino UNO	i. LabVIEW ii. Website	Bio-signals from the sensors are sent to Arduino UNO, which transfers the data to Raspberry Pi. The bio-signals are then transmitted via IoT technology to alert the doctor. Raspberry Pi interfaces with LabVIEW using RS232, which acts as a communication bridge.

Based on the table, it is evident that most of the applications use the same software, LabVIEW, which interfaces with IoT technology to alert users when there is a change in parameter values. These applications are valuable references for this project, as LabVIEW is used to store data sent from sensors and display it in a Graphical User Interface (GUI). Additionally, IoT technology enables real-time alerts to users when parameter values change, allowing them to take necessary actions to address potential problems at an early stage. However, the current system does not yet incorporate IoT technology, though its integration is intended for future iterations of the project.

2. Methodology

2.1 Operational Block Diagram

In Figure 1, the block diagram illustrates the vision system designed to monitor real-time machine downtime in a conveyor system. The central control hub for the hardware is a laptop, serving as the primary interface. Arduino UNO boards are employed and connected to the laptop for programming via the Arduino Integrated Development Environment (IDE) software. One Arduino is designated to manage the stepper motor responsible for the production line, along with a button to control the servo motor. Additionally, a webcam is linked to the laptop for object detection and tracking on the conveyor system. The second Arduino is tasked with receiving data from the analog piezoelectric ceramic vibration module, enabling the system to detect motor vibrations. The detection of objects, including pattern matching and object tracking, as well as the monitoring of motor vibrations, is visualized through a GUI in the LabVIEW software.

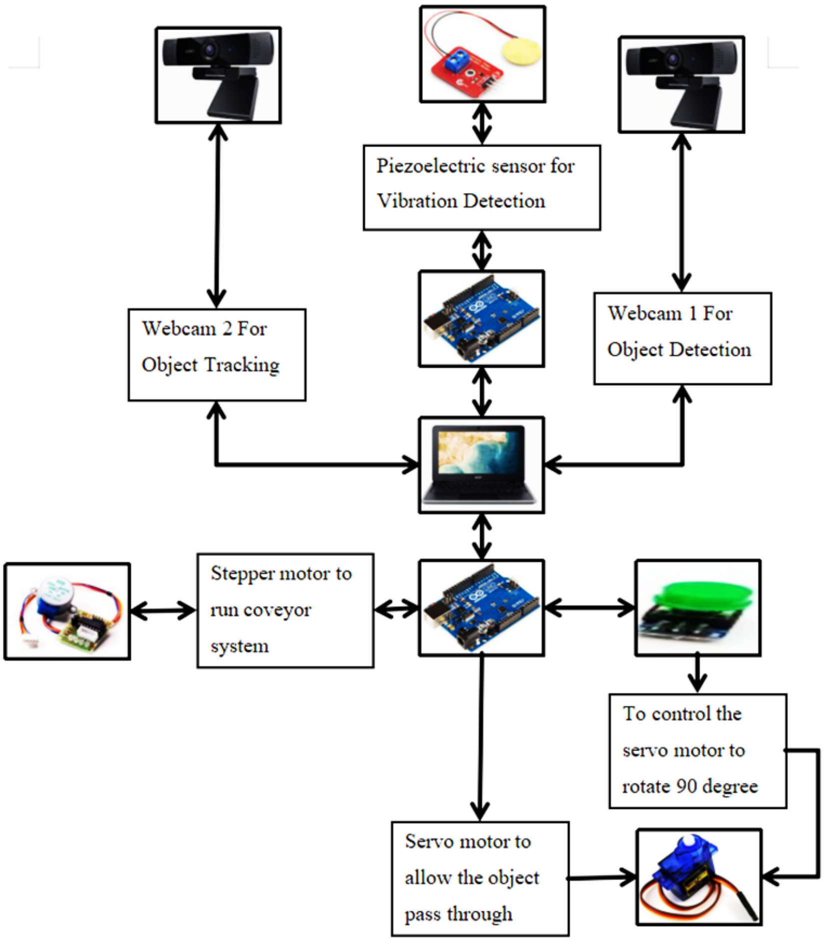


Fig. 1. Operational block diagram

2.2 Experiment Setup

Figure 2 displays the 2D and 3D diagrams representing the top, front, side, and isometric views of the experiment setup. The Arduino is enclosed within a box, which not only protects the hardware but also enhances the aesthetic appeal of the overall design. The camera holder and conveyor system, essential components of the experiment setup, are fabricated using a 3D printer, and their precise dimensions are depicted in the figures. These components are arranged to facilitate the real-time monitoring of machine downtime in the conveyor system.

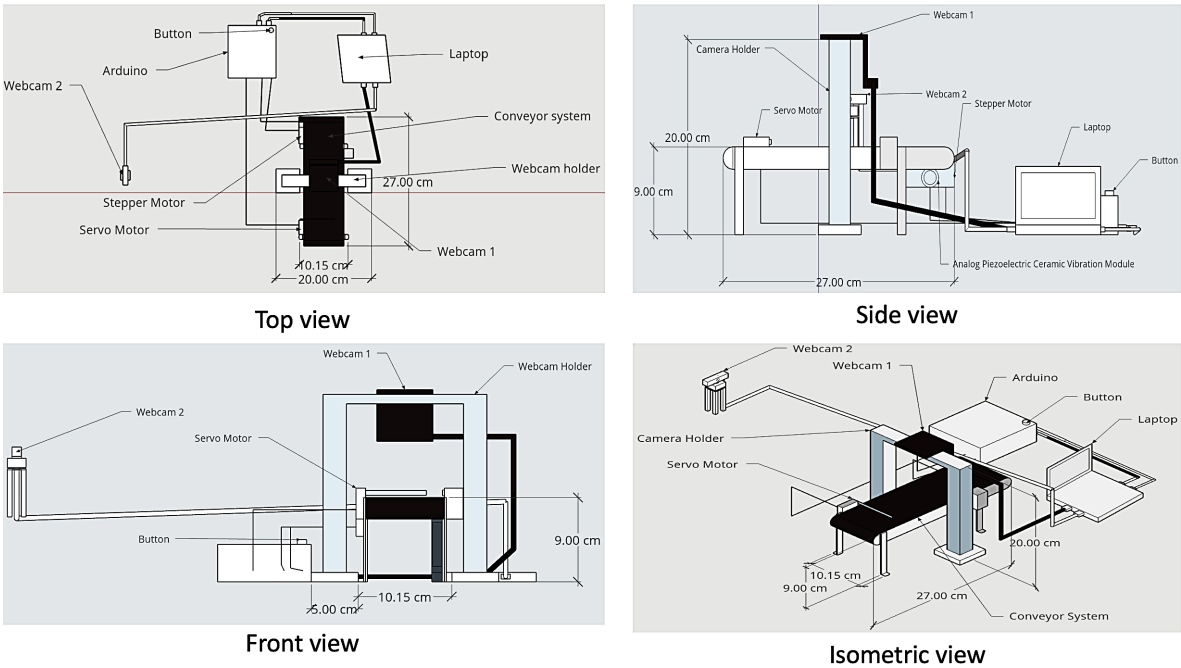
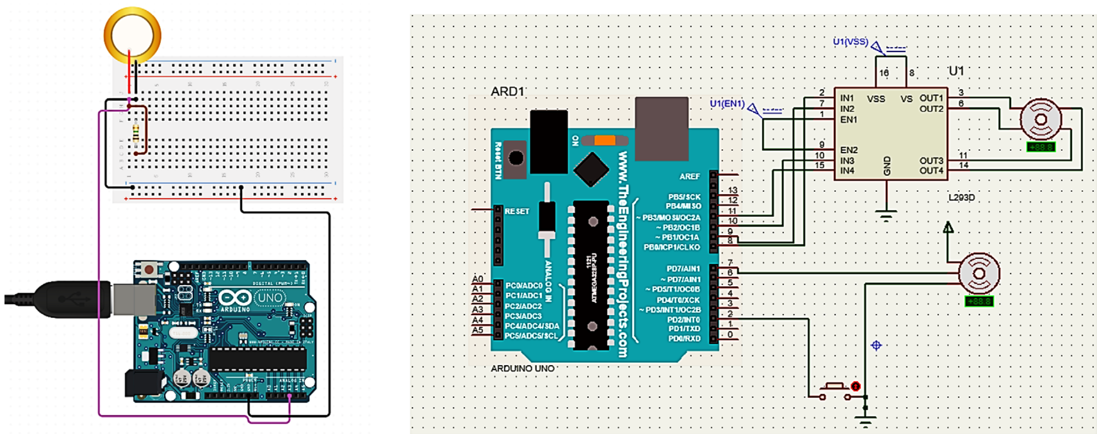


Fig. 2. Experiment setup isometric drawing

2.3 Electronic Design

Figure 3 depicts the circuit designed for the proposed system, created using circuito.io and Proteus software. The circuit consists of an Arduino UNO microcontroller, which serves as the primary controller for both the sensor and motor components. It includes a stepper motor that controls the production line, a servo motor, a button, and an analog piezoelectric ceramic vibration module. The system uses two Arduino microcontrollers, one to manage the piezoelectric component, while the other handles the stepper and servo motors. The connections are illustrated in Figure 3, with the piezoelectric sensor linked to pin A0 to detect vibrations from the stepper motor. The servo motor is connected to pin 7, controlling whether objects can pass through the conveyor system. The stepper motor is connected to pins 8, 9, 10, and 11, controlling the rotation of the conveyor system. The button, connected to pin 2, regulates the servo motor's permission to allow or prevent the passage of objects.



(a) (b)

Fig. 3. Circuit design (a) Piezoelectric sensor (b) Servo motor and stepper motor

2.4 Hardware Setup

Before implementing the project, physical design was prioritized. Figure 4 illustrates the hardware design, where the Arduino is placed inside a protective box, and the analog piezoelectric ceramic vibration module is attached to the stepper motor of the conveyor system. The webcam is positioned on a stand to monitor the entire conveyor system, ensuring that it operates correctly and to track objects. Another webcam is placed above the conveyor system to detect objects as they move along the conveyor.

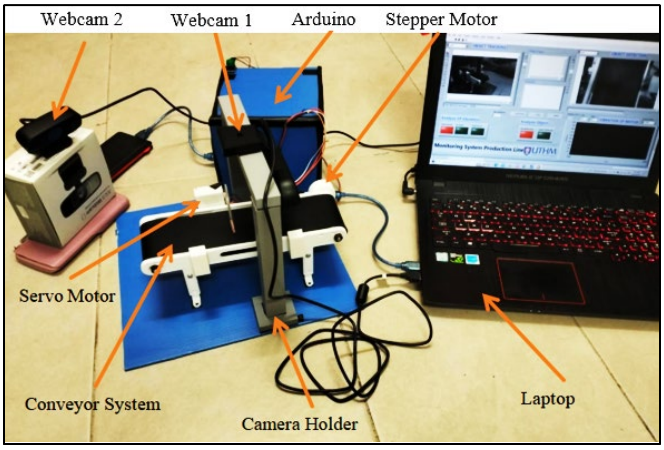


Fig. 4. Hardware setup

2.5 Software Setup

Figure 5 shows the LabVIEW software block diagram, where the Virtual Instrument Software Architecture (VISA) programming is used to read data from Arduino and present it on the GUI as a waveform chart. Additionally, the vibration value is displayed, and if it falls within the set range on the GUI, the corresponding indicator lights up. Otherwise, it indicates either an over-range or under-range condition. If either over-range or under-range conditions are detected, the Machine Downtime is also indicated. The VISA functionality utilizes the National Instruments Vision Acquisition (NI-MAQ) software to display captured images in LabVIEW.

Three Virtual Instruments (VIs) are used in the system. These include creating a camera session, configuring the camera grab, grabbing the image, and displaying it. These VIs function together to display the image in LabVIEW. First, a session is created, and the parameters for image acquisition are then set up. The vision assistant is connected to IMAQ grab, and it is configured for detection. There are two vision assistants used in this process. One is responsible for detecting the desired object, while the other is used to detect undesired objects. The vision assistants are connected to an overlay rectangle, which focuses on specific areas, measures features, and indicates regions for further analysis. Finally, the camera captures the image, which is then displayed in LabVIEW.

An indicator is used to identify the desired objects. If the correct object is detected, it is marked as desired. If it is not the correct object, it is marked as a foreign object. When a foreign object is detected, the system triggers machine downtime detection. The programming block diagram for object tracking uses pattern matching to follow the object. The user can specify which object to track by capturing a real-time image using the "snap frame" button on the front panel. After framing the object to be used as a template, pressing the "learn" button enables the system to recognize the object. Finally, pressing the "match" button starts the real-time object tracking process based on the learned template.

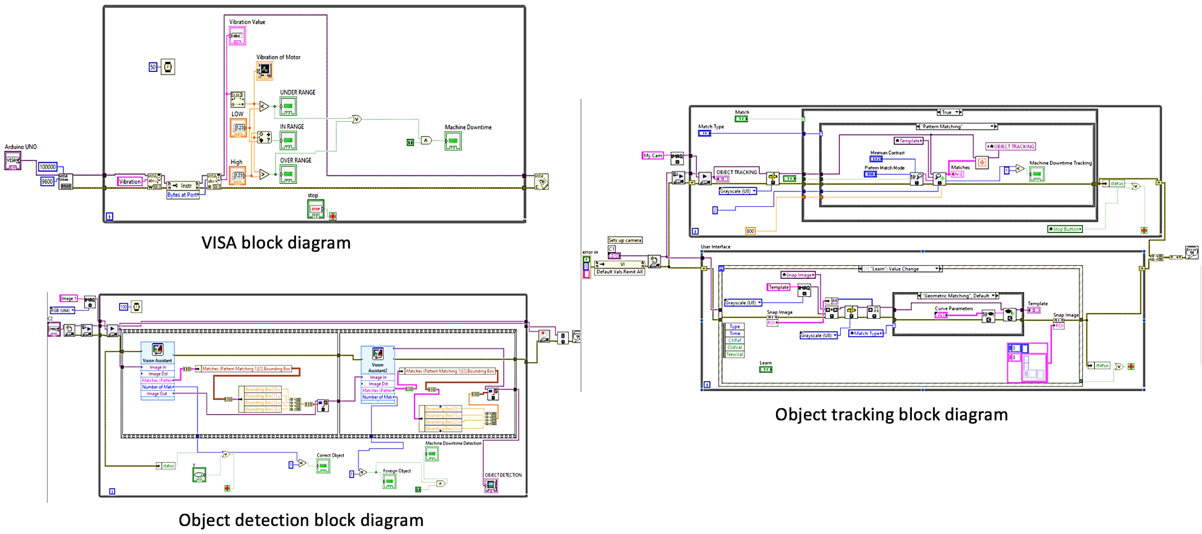
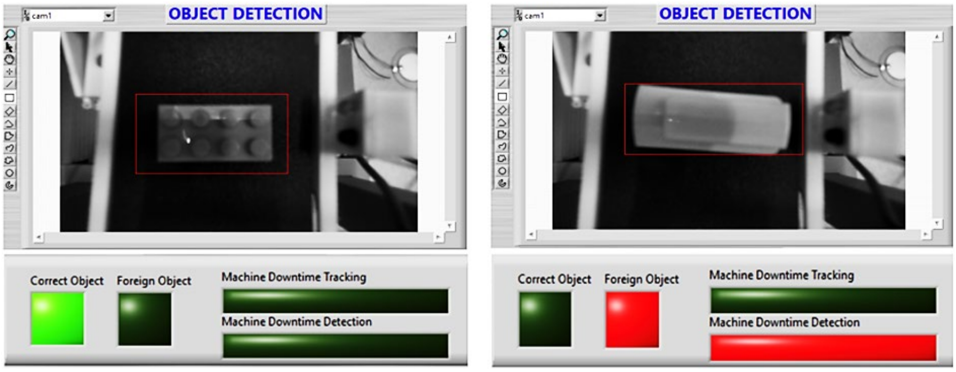


Fig. 5. LabVIEW software block diagram

3. Results

3.1 Result for Good Product Versus Defect Product

Figure 6 illustrates how the system, utilizing a webcam, effectively distinguishes between good and defective products. The display captures and highlights a good product by enclosing it in a frame when the system correctly identifies it. Conversely, when the system detects a defective product, it also frames the object for emphasis. The results demonstrate the system's ability to accurately determine whether a product is good or defective. For a good product, a "correct" indicator confirms the system's accurate identification. In contrast, when a defective product is detected, a "foreign object" indicator is triggered, along with a "machine downtime" detection, signalling a potential issue with the machine. This approach not only ensures precise product identification but also aids in identifying possible machine malfunctions, contributing to a more efficient production process.



(a) (b)

Fig. 6. GUI Result (a) Outcome of good product (b) Outcome of defect product

3.2 Results for Equipment Vibration Detection Simulation

Three methods were employed to test vibration detection using LabVIEW, aimed at assessing the reliability of detecting machine downtime in the production line. Figure 7 displays the GUI graph from LabVIEW, showcasing the result of the first method, which involved tapping. The results indicate that each tap corresponds to a peak on the graph, meaning the more taps, the more peaks appear. The second method involved using the vibration from a phone to allow the sensor to detect vibrations. The third method tested the vibration of a stepper motor. In this method, an indicator is triggered when the vibration value exceeds the upper limit or falls below the lower limit, indicating an over-range or under-range condition. If either of these conditions is met, machine downtime is also indicated. Conversely, if the vibration value remains between the upper and lower limits, an "In Range" indicator is triggered.

In the figures, two light indicators are shown to represent the upper and lower limits, allowing for easy identification of whether the vibration falls within the range or outside it. The vibration from the stepper motor was more difficult to detect due to the motor's relatively low power, which makes it less sensitive to the sensor. The graphs also reveal occasional fluctuations in detection, where the vibration readings drop to low values or zero or exhibit significant variation. This inconsistency may be caused by external sources of electromagnetic interference affecting the sensor's accuracy.

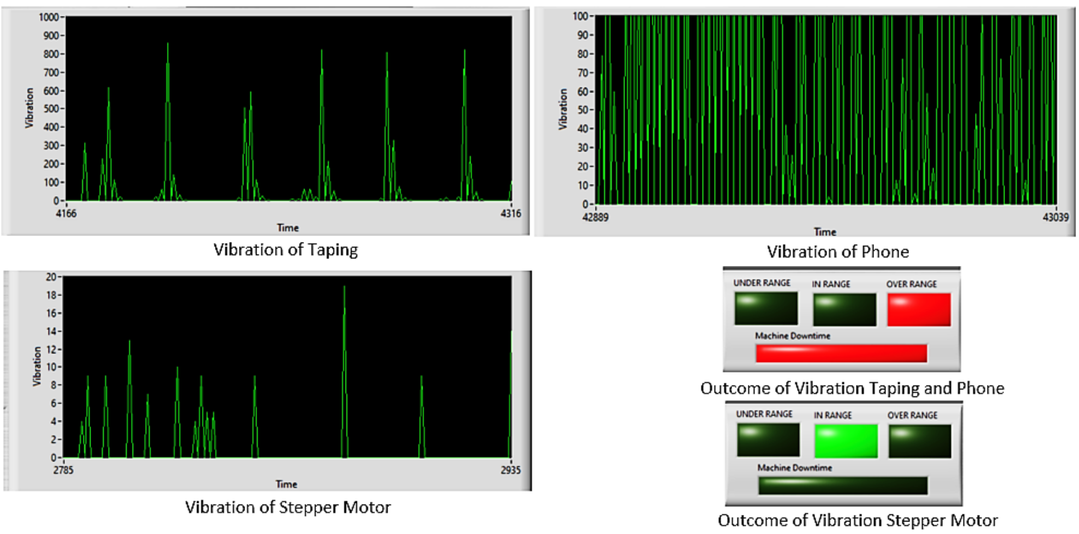


Fig. 7. Equipment vibration detection simulation

4. Conclusions

This study successfully developed a real-time machine downtime monitoring system utilizing LabVIEW, Arduino microcontrollers, and a vision-based system integrated with sensors. The system effectively addressed the limitations of traditional downtime monitoring methods by providing real-time capabilities and reducing human errors. Through the application of image processing techniques, the system accurately detected and classified good and defective products, significantly improving the precision and efficiency of production line inspections. Additionally, the system demonstrated versatility in monitoring equipment vibrations, although its sensitivity was affected by the stepper motor's low power and external interferences. Despite these challenges, the system reliably identified out-of-range conditions, signalling potential machine downtime.

The study also highlighted the potential for integrating IoT technology in future versions of the system, paving the way for advanced real-time monitoring and predictive maintenance capabilities. Future work should focus on refining the object tracking algorithms, improving performance under variable lighting conditions, and enhancing vibration detection for lower-powered motors. Expanding the system with additional sensors could further increase its robustness and versatility across a wider range of industrial applications, contributing to more efficient and automated production monitoring.

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References
[1] Chulakit, Saranjuu, Amirul Syafiq Sadun, Nor Anija Jalaludin, Jamaludin Jalani, Suziana Ahmad, Muhammad Haziq Md Hanapi, and Nur Aminah Sabarudin. "A centralized IOT-based process cycle time monitoring system for line balancing study." *Journal of Advanced Research in Applied Mechanics* 105, no. 1 (2023): 58-67. https://doi.org/10.37934/aram.105.1.5867
[2] Ammar, Mohd, Abid Haleem, Mohd Javaid, Shashi Bahl, and Ajay Singh Verma. "Implementing Industry 4.0 technologies in self-healing materials and digitally managing the quality of manufacturing." *Materials Today: Proceedings* 52 (2022): 2285-2294. https://doi.org/10.1016/j.matpr.2021.09.248
[3] Aikhuele, Daniel Osezua, and Faiz Mohd Turan. "A hybrid fuzzy model for lean product development performance measurement." In *IOP Conference Series: Materials Science and Engineering* 114, no. 1, p. 012048. IOP Publishing, 2016. https://doi.org/10.1088/1757-899X/114/1/012048
[4] Adrita, Mumtahina Mahajabin, Alexander Brem, Dominic O'Sullivan, Eoin Allen, and Ken Bruton. "Methodology for data-informed process improvement to enable automated manufacturing in current manual processes." *Applied Sciences* 11, no. 9 (2021): 3889. https://doi.org/10.3390/app11093889
[5] Yahya, Fatin Diyana, and Muhammad Mahbubur Rashid. "Study on smart downtime monitoring system in glove production." *International Journal of Engineering Materials and Manufacture* 8, no. 4 (2023): 124-131. https://doi.org/10.26776/ijemm.08.04.2023.04
[6] Kumar, Siva, L. Subramaniam, Siti Huzaimah Binti Husin, Yusmarnita Binti Yusop, and Abdul Hamid Bin Hamidon. "Real time production performance monitoring system a production aid for all industries." In *International Conference on CIRCUITS, SYSTEM, ELECTRONICS, CONTROL & SIGNAL PROCESSING*, p. 181-184, 2007
[7] Turan, Faiz Mohd, and Kartina Johan. "Assessing sustainability framework of automotive-related industry in the Malaysia context based on GPM P5 standard." *ARPN Journal of Engineering and Applied Sciences* 11, no. 12 (2016): 7606-7611.
[8] Selamat, Siti Norhana, Nik Hisyamudin Muhd Nor, Muhammad Hanif Abdul Rashid, Mohd Fauzi Ahmad, Fariza Mohamad, Mohd Fahrul Hassan, Faiz Mohd Turan, Mohd Zamzuri Mohd Zain, Elmi Abu Bakar, and Yokoyama Seiji. "Review of CO_2 reduction technologies using mineral carbonation of iron and steel making slag in Malaysia." In *Journal of Physics: Conference Series* 914, no. 1, p. 012012. IOP Publishing, 2017. https://doi.org/10.1088/1742-6596/914/1/012012

[9] Yusof, Nurul Hannah Mohd, Nurul Adilla Mohd Subha, Nurulaqilla Khamis, and Norikhwan Hamzah. "Named entity recognition of an oversampled and preprocessed manufacturing data corpus." *Journal of Advanced Research in Applied Sciences and Engineering Technology* 36, no. 1 (2023): 203-216. https://doi.org/10.37934/araset.36.1.203216

[10] Chulakit, Saranjuu, Amirul Syafiq Sadun, Nor Anija Jalaludin, Jamaludin Jalani, Suziana Ahmad, Lilywati Bakar, Muhamad Syafiq Suhaimi, and Nur Aminah Sabarudin. "A webcam and LabVIEW-based system for efficient object recognition based on colour and shape features." *Journal of Advanced Research in Applied Mechanics* 104, no. 1 (2023): 33-45. https://doi.org/10.37934/aram.104.1.3345

[11] Du, Cheng-Jin, and Da-Wen Sun. "Recent developments in the applications of image processing techniques for food quality evaluation." *Trends in Food Science & Technology* 15, no. 5 (2004): 230-249. https://doi.org/10.1016/j.tifs.2003.10.006

[12] Renugambal, K., and B. Senthilraja. "Application of image processing techniques in plant disease recognition." *International Journal of Engineering Research & Technology* 4, no. 3 (2015): 919-923. https://doi.org/10.17577/IJERTV4IS030829

[13] Dilip, R., and V. Bhagirathi. "Image processing techniques for coin classification using LabVIEW." *OJAI 2013* 1, no. 1 (2013): 13-17. https://doi.org/10.12966/ojai.08.03.2013

[14] Ursutiu, Doru, Cornel Samoila, and Vlad Jinga. "Creative developments in LabVIEW student training: (Creativity laboratory—LabVIEW academy)." In *2017 4th Experiment@ International Conference (exp. at'17)*, p. 309-312. IEEE, 2017. https://doi.org/10.1109/EXPAT.2017.7984399

[15] Pamuk, Nihat. "Real-time object detection and selection with the LabVIEW program." *International Journal of Electrical And Computer Engineering Systems* 13, no. 8 (2022): 661-668. https://doi.org/10.32985/ijeces.13.8.6

[16] Raveendra, P., V. Siva Reddy, and G. V. Subbaiah. "Vision based weed recognition using LabVIEW environment for agricultural applications." *Materials Today: Proceedings* 23 (2020): 483-489. https://doi.org/10.1016/j.matpr.2019.05.389

[17] Vasanthan, M., M. Murugappan, R. Nagarajan, Bukhari Ilias, and J. Letchumikanth. "Facial expression based computer cursor control system for assisting physically disabled person." In *2012 IEEE International Conference on Communication, Networks and Satellite (ComNetSat)*, p. 172-176. IEEE, 2012. https://doi.org/10.1109/ComNetSat.2012.6380800

[18] Swain, Kunjabihari, Murthy Cherukuri, Sunil Kumar Mishra, Bhargav Appasani, Suprava Patnaik, and Nicu Bizon. "Li-care: A labview and iot based ehealth monitoring system." *Electronics* 10, no. 24 (2021): 3137. https://doi.org/10.3390/electronics10243137

[19] Swain, Kunja Bihari, G. Santamanyu, and Amiya Ranjan Senapati. "Smart industry pollution monitoring and controlling using LabVIEW based IoT." In *2017 Third International Conference on Sensing, Signal Processing and Security (ICSSS)*, p. 74-78. IEEE, 2017. https://doi.org/10.1109/SSPS.2017.8071568

[20] Mohanraj, K., N. Balaji, and R. Chithrakkannan. "IoT based patient monitoring system using raspberry PI 3 and LabVIEW." *Pakistan Journal of Biotechnology* 14, no. 3 (2017): 337-343.