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Smart Systems for Health and Safety Monitoring in Industrial Fields

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***Abstract*— The project focuses on the development of a comprehensive system aimed at enhancing workplace safety and monitoring employee well-being in industrial environments. Utilizing a combination of computer vision techniques, wearable health monitoring systems, and data visualization platforms, the project addresses critical aspects of safety and health monitoring. The initial phase involves the utilization of MATLAB's Image Labeler tool to accurately detect and identify essential personal protective equipment worn by employees. By training machine learning models with annotated images, the system can effectively recognize items such as helmets, safety jackets, and earmuffs. Data augmentation techniques further enhance the model's robustness by introducing variations in the appearance of personal protective equipment items, ensuring accurate detection in diverse scenarios. The Aggregate Channel Features object detector, integrated into the system, leverages channel features and boosting techniques to achieve high accuracy in personal protective equipment detection tasks. The algorithm's ability to capture object appearance and context information plays a crucial role in ensuring reliable safety compliance monitoring. In the second phase, a wearable health monitoring system is implemented using ESP32 Wi-Fi modules and sensors to track vital health parameters like humidity, room temperature, body temperature, heart rate, and oxygen levels in real-time. The two phases of the projects are combined by integrating the sensors into the design of earmuffs worn by the industrial workers. The collected data is transmitted to Power BI for analysis and visualization, providing insights into employee health trends and enabling proactive interventions. The Power BI dashboard showcases detailed tables, average health metrics, and dynamic visualizations, facilitating real-time monitoring and analysis. The project's innovative approach to integrating advanced technologies for safety and health monitoring in industrial settings sets a precedent for effective workplace safety solutions. By emphasizing data-driven insights and user-friendly interfaces, the system aims to create safer and healthier work environments while ensuring compliance with safety protocols and regulations. (*Abstract*)**

***Keywords*— Workplace safety, wearable health monitoring systems, data visualization, machine learning models, real-time monitoring, Power BI, health data visualization** (*key words*)

I. Introduction

Industrial workplaces are inherently hazardous environments where workers are exposed to various risks, including physical harm, health hazards, and environmental dangers. To mitigate these risks, personal protective equipment (PPE) and health monitoring systems have become essential components of industrial safety protocols. Currently, the use of PPE such as earmuffs, helmets, and safety jackets are mandated in many industries, while health monitoring systems track vital signs and environmental conditions to prevent occupational illnesses and injuries. Despite the widespread adoption of PPE and health monitoring systems, the effectiveness of these measures is often compromised by human error, inadequate enforcement, and limited monitoring capabilities. The reliance on manual checks and self-reporting by workers can lead to non-compliance with safety protocols, while the lack of monitoring hinders prompt responses to emerging health risks. Furthermore, the accuracy and reliability of traditional health monitoring systems can be compromised by various factors, including sensor calibration and data interpretation. This project proposes an approach to addressing these shortcomings by integrating artificial intelligence (AI) and wearable technologies. The AI safety system utilizes image processing and computer vision to detect and recognize PPE, ensuring compliance and alerting authorities to any non-compliance. The wearable health monitoring system tracks vital signs and environmental conditions, enabling prompt responses to emerging health risks. By leveraging AI and wearable technologies, this project offers a more accurate, reliable, and monitoring system that can substantially reduce the risk of accidents, injuries, and occupational illnesses in industrial workplaces, thereby contributing significantly to the solution and enhancing the well-being and protection of workers worldwide.

II. Background

A. Motivation

The primary motivation behind this project stems from the critical need to enhance the safety and well-being of workers employed in industrial environments. The work has been undertaken to address the inherent risks and challenges faced by industrial laborers daily, aiming to provide them with a comprehensive safety solution that integrates advanced technologies. This project is specifically designed for the workers employed in industry labs, where exposure to hazardous conditions and potential health risks is a constant concern. By developing an artificial intelligence safety system and a wearable health monitoring system, this project aims to ensure that workers are adequately protected through the accurate detection of personal protective equipment and real-time monitoring of their health conditions. The importance of this work lies in its potential to significantly reduce workplace accidents, injuries, and occupational illnesses, ultimately safeguarding the physical well-being and safety of industrial workers and enhancing their overall quality of life. The report presents a comprehensive study on enhancing worker safety and health monitoring in industrial settings through the integration of artificial intelligence (AI) and wearable technologies. The project aims to address the inherent risks faced by industrial laborers by developing an AI Safety System for detecting personal protective equipment (PPE) like earmuffs, helmets, and safety jackets using image processing, alongside a wearable health monitoring system to track vital signs and environmental conditions in real-time. The report includes the project's motivation, constraints, adherence to standards like ISO 45001 and IEEE 802.15.4, and provides a detailed outline covering chapters on Background, Design and Implementation, Results and Discussion, and Conclusion and Future Work. The project's significance lies in its potential to significantly enhance worker safety, reduce accidents, and improve occupational health by leveraging AI and wearable technologies to create a more accurate, reliable monitoring system. The report also discusses the use of Power BI for data visualization and monitoring, emphasizing its role in enhancing decision-making and ensuring worker well-being. Additionally, the report delves into the importance of AI in construction safety, the training process for object detection models, and the circuit design for the wearable health monitoring system, providing a thorough analysis of the project's technical aspects and implications. Overall, the report showcases a well-structured and meticulously planned approach towards revolutionizing worker safety in industrial environments through innovative technological solutions.

B. *Aims of the paper*

The primary objective of this project is to create a comprehensive safety system that leverages artificial intelligence and wearable technologies to safeguard the well-being of industrial workers. This system will consist of two interconnected components: an AI-powered safety system and a wearable health monitoring system. The AI safety system will utilize image processing and computer vision to detect and recognize personal protective equipment (PPE) such as earmuffs, helmets, and safety jackets, ensuring that workers comply with safety protocols. This system will be trained on a database of images to achieve high accuracy in identifying the presence and proper use of PPE. The wearable health monitoring system will track vital signs, including body temperature, peripheral oxygen saturation (SpO2), and heart rate, as well as environmental conditions like temperature and humidity. This will provide a detailed assessment of the worker's health status and the surrounding environment. The integration of these two systems will create a seamless platform for industrial worker safety, with the AI system analyzing images from workplace cameras to detect PPE compliance and the wearable system transmitting real-time health and environmental data to a central monitoring station. A user-friendly interface will be designed to facilitate monitoring and management of the safety system, enabling supervisors and safety personnel to track worker compliance, monitor health conditions, and receive alerts in case of emergencies. The success of this paper will be evaluated based on the accuracy of the AI safety system, the reliability of the wearable health monitoring system, and the overall effectiveness of the integrated system in enhancing worker safety and reducing workplace accidents and illnesses.

III. Literature review

The application of sensors to provide information on the safety of the workplace had been attempted on a large scale. Real-time deployment caused a lot of challenges since the system must continuously gather and understand field data. This was one of the reasons why the system became problematic. In light of the fact that the processing and decision-making aspects proved to be particularly challenging to manage, it was necessary to incorporate artificial intelligence into the decision-making process. Because of this, there was no longer a requirement for manual testing, which was not only more time-consuming and costly but also slower and less effective [1], [2], [3]. The Aggregate Channel Features (ACF) object detector in MATLAB was able to correctly identify a variety of personal protection equipment (PPE) items, such as helmets, safety jackets, and earmuffs, among other things. Both Convolutional Neural Network (CNN) and deep learning models dramatically enhanced system performance by responding to ambient factors such as fluctuations in illumination and elaborate backgrounds. As a result, the accuracy of the system increased while the number of false positives decreased [1], [2], [4], [5], [6].

Wearable health monitoring devices have shown to be highly effective in a variety of industries, including construction and oil in particular, where continuous health monitoring is of utmost importance. Technology advancements such as the MAX30100 sensor, which measures heart rate and SpO2; and the DHT11 sensor, which measures temperature and humidity; these sensors also allow for the early identification of indications of tiredness, heat stress, and hypoxia. These sensors make it possible to continuously track health indicators with the help of technological advancements [7], [8], [9]. When paired with wireless communication modules like ESP32, wearable sensors make it feasible to do remote health monitoring by transferring data in a continuous way. This makes it possible to monitor a person's health remotely. Because of this, it is much simpler to participate in timely therapies.

Chen et al. underlined that wearable devices are vital for construction safety [10]. This is because continuous health monitoring enables proactive control of safety problems, which is a result of the fact that it enables proactive control. Within a similar vein, Hernandez and Wong demonstrated that wearable devices are among the most effective alternatives for minimizing accidents that occur in industrial settings as a result of physical stress [11], [12]. This sort of information highlights how essential it is for industrial safety systems to integrate health monitoring devices that may be worn by workers.

Power Business Intelligence is a significant visualization tool that integrates data from a range of sources, including health measures and records of compliance with personal protective equipment regulations. For the purpose of industrial decision-making, it is vital to take early action in response to concerns regarding non-compliance or anomalous health indicators [13], [14], [15]. The ability to visualize data in real time, which is made possible by Power BI, makes this conceivable. The introduction of real-time visualization into safety systems was yet another issue that Zhang brought up in his presentation. The ability to monitor safety trends and take preventative steps would be made feasible for supervisors as a result of this [16].

A research study was conducted to determine how risk patterns may be identified through the use of predictive analytics in safety monitoring [17]. In another study, artificial intelligence-based personal protective equipment (PPE) systems enhanced compliance monitoring by reducing the amount of human mistake that takes place [18]. The combination of computer vision for the identification of personal protective equipment (PPE) and wearable health monitoring offers a comprehensive safety solution that is particularly developed for high-risk workplaces [1], [6], [19]. This solution is aimed to eliminate the need for individuals to wear health monitoring devices.

Research on post-construction safety was carried out in MATLAB, and it made use of artificial intelligence, image processing, and computer vision. The research was centered on the detection of intruders and the misplacement of things. The standards for workplace safety were improved by the implementation of methods for locating lost objects . Both the ACF model and the Viola-Jones Algorithm (VJ) algorithm produced positive results when it came to identifying potential invaders. CiteSpace software has been used to conduct research that has shed light on trends and problems in the field of wearable technology. The findings of this research imply that this technology has the potential to control safety concerns and promote sustainable development [5], [10], [18], [20].

The in-ear photoplethysmography (PPG) devices that measure heart rate during physical activities have been verified by hopeful research into health monitoring. These devices assess heart rate during physical activities. In place of electrocardiography, these pieces of equipment provide an alternative. It has been demonstrated that in-ear pulse cytometry, also known as PPG, is a method that is reliable for detecting pulse rates and tracking the intensity of physical activity [21]. An option that is both practical and useful to the traditional approaches that have been utilized is provided by this.

IV. Design and Implementation

In the upcoming design and implementation section of the paper, the detailed planning, development, and execution of the AI-based safety system is presented for monitoring worker safety and health in industrial settings. This section outlines the design considerations, methodologies, and technologies employed in creating a robust system that integrates sensor data, image processing algorithms, and machine learning models to detect and recognize personal protective equipment (PPE) worn by workers. The section provides insights into the practical application of these design concepts, detailing the steps taken to bring the AI-based safety system to life and its integration into the industrial environment for real-time monitoring and analysis. Fig. 1 shows a block diagram describing the design phase.

A. Building a Dataset

Building a comprehensive database of images is a crucial step in training the AI-based safety system to accurately detect and recognize personal protective equipment (PPE) worn by workers in industrial settings. To achieve high accuracy, many images are required, which are captured using a webcam. Images of each PPE item, such as earmuffs, helmets, and safety jackets, were captured from various angles and positions to ensure that the object detection algorithm can detect the equipment regardless of its orientation or placement. The images were taken in a well-lit area to minimize shadows and reflections that could affect the accuracy of the detection algorithm. The images were captured from different angles, including front, side, and rear views, to provide a comprehensive dataset for training the AI model. This approach ensures that the system can detect PPE items in various positions and orientations, increasing the accuracy and reliability of the detection algorithm. Some examples of the images captured for dataset are shown in Fig. 2, Fig. 3 and Fig. 4 illustrate the diversity of the dataset and the attention to detail in capturing images from different angles and positions. The images were labeled and annotated to provide ground truth data for training the AI model, which is essential for achieving high accuracy and reliability in object detection tasks. By building a comprehensive and diverse database of images, the project ensures that the AI-based safety system is trained to detect and recognize PPE items in a wide range of scenarios, increasing the accuracy and effectiveness of the system in promoting worker safety and health in industrial settings.

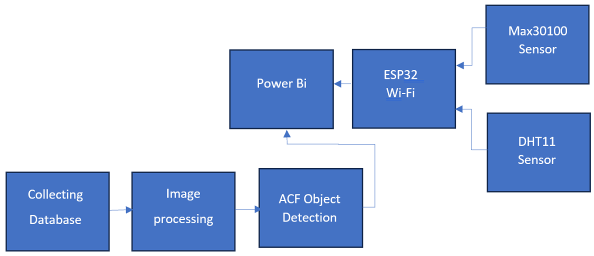

Fig. 1. Block diagram of the design and implementation

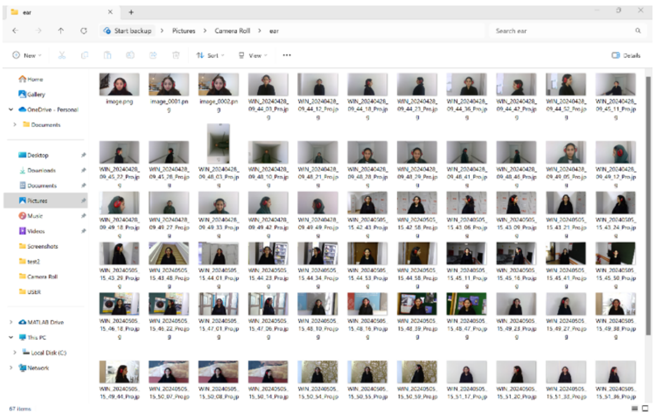

Fig. 2. Training Data for Earmuffs

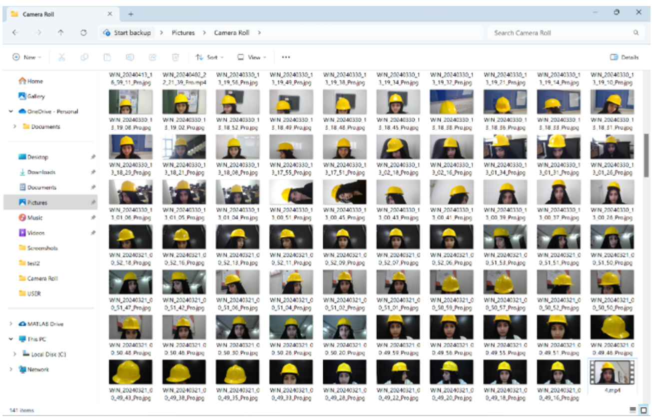

Fig. 3. Training Data for Helmet

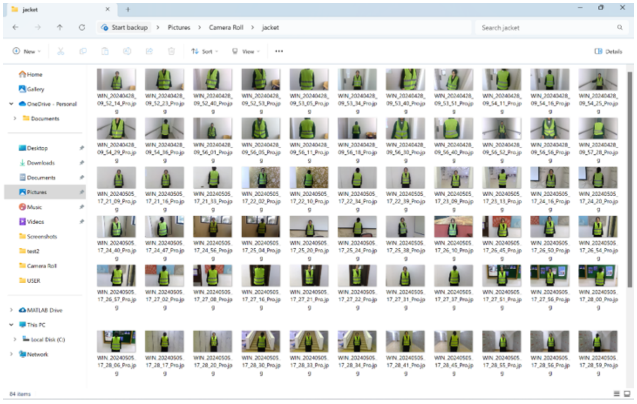

Fig. 4. Training Data for Safety Jacket

B. *Image Annotation*

To incorporate annotations into photographic images and to train a safety system that is artificially intelligent to consistently identify and recognize personal protective equipment (PPE) worn by workers in industrial settings, the process of annotating images with bounding boxes is one of the most critical steps that must be completed. This is one of the procedures that are included in the training process. The use of the Image Labeler program, a component of the Computer Vision Toolbox that is integrated into MATLAB, significantly simplifies this process. This application facilitates the rapid and precise annotation of images with bounding boxes by providing a user-friendly interface and complex capabilities that facilitate the annotation of photographs. These features enable the addition of annotations to photographs. The positive photos that were intended for training were placed in a container that had been designated for the purpose of training instruction in order to commence the annotating process. The purpose of this action was to commence the instructional procedure. Following the acquisition of these photographs from a variety of perspectives and orientations using a webcam, they were subsequently imported into the Image Labeler application. These actions were executed subsequent to the acquisition of the images. The application's intuitive user interface made it effortless to access the photographs and modify them. Subsequently, this enabled the effortless and efficient annotation of the personal protective equipment (PPE) components depicted in each photograph. The Image Labeler application may implement intricate algorithms, including Selective Search and Faster R-CNN, to automatically generate bounding boxes around items of interest. This enables the application to generate bounding boundaries automatically. This is a critical component of the program, which encompasses numerous other functions. These algorithms evaluate the contents of the image, subsequently identifying the locations that are most likely to contain objects and providing recommendations for those locations. Additionally, this significantly diminishes the quantity of manual labor required for annotation. This is an enormous advantage. Users are given the option of either producing new boundary boxes or modifying the ones that are automatically generated by the program. Users are presented with both alternatives. The objective of this action is to guarantee that the components of personal protective equipment (PPE) depicted in each photograph are accurately rendered. The designated areas of interest (ROIs) that are contained within the images are the focal points of object identification algorithm training. As a result, the model will be able to recognize the relevant characteristics and attributes of the personal protective equipment (PPE) objects. Images Labeler is an application that offers users a diverse selection of options for customizing the bounding boxes they use in their work. By employing these personalized alternatives, users can modify the box's proportions, contours, and colors to suit their personal preferences and the specific needs of the project. This adaptability guarantees that the annotated images will generate ground truth data that is unambiguous and free of any ambiguity, which is essential for the training of object detection algorithms. This is imperative for the purpose of training the algorithms. Image Labeler is a tool that enables users to annotate images with a wide range of labels and to generate bounding boxes. Semantic segmentation masks and critical regions are among the designations that fall under this category. It is feasible to furnish exhaustive ground truth data as a result of these sophisticated annotation capabilities. In addition to identifying the precise location of the personal protective equipment (PPE), these capabilities also identify the semantic characteristics and spatial connections between them within the regions of interest (ROIs) that have been designated in accordance with the situation's requirements. This degree of specificity is essential for the training of robust and accurate object identification models that can navigate complex industrial scenarios and a wide range of illumination conditions. In order to ensure that the data derived from the ground truth was accurate and consistent, it was imperative to conduct a comprehensive examination and verification of the annotated images generated by the Image Labeler program. This was done to guarantee that the data were consistent and accurate throughout the entire experiment. As part of this quality assurance strategy, a comparison was conducted between the original photographs and the annotations. The bounding boxes were scrutinized to ensure that they accurately represented the personal protective equipment (PPE) components present in each image, and any errors or inconsistencies that were identified were removed. We were able to produce a comprehensive and high-quality dataset of annotated images for the purpose of training the artificial intelligence-based safety system by focusing on the regions of interest that were present in the photographs and utilizing the extensive annotation capabilities of the Image Labeler application. Our focus was on the areas of interest that were depicted in the images in order to attain this objective. The ground truth data that was generated served as the foundation for the purpose of training robust object recognition models. This data comprised semantic labels and bounding boundaries that were appropriately described. The health and safety of workers are enhanced by the ability of these models to accurately identify and differentiate between various items of personal protective equipment (PPE) that are worn by workers in industrial settings.

C. *Training Images*

In order to obtain the highest potential level of performance from the ACF detector in the detection of personal protective equipment (PPE), the design process involves the selection of the most suitable parameters. The number of steps, the number of window sizes for pupils with limited learning abilities, and the boosting parameters are all factors that are included in these parameters. The detector's ability to precisely capture the unique characteristics of personal protective equipment (PPE) products, including earmuffs, helmets, and safety vests, is ensured by the methodical updating of these settings. This is done to ensure that the detector is capable of accurately detecting these properties, which is necessary to achieve the desired results. The detector is capable of adapting to the distinctive issues and variations that are common in industrial environments, as these characteristics may be modified. This enables the detector to adjust to the unique challenges and variations. A few examples of these include the creation of intricate backdrops and the utilization of a diverse array of illumination settings. The ACF detector is trained during the implementation phase using labelled images generated by a program known as Image Labeler. The detector is trained using these photographs. The ground truth data is this collection of images, which have been appropriately labelled with semantic metadata and bounding frames. The detector is intended to be trained using these images. The data augmentation techniques that have been implemented in the training images are intended to enhance the dependability and resilience of the model that has been created. In order to broaden the purview of the training dataset and enhance the model's ability to generalize to novel situations, these strategies aim to produce modifications in the visual appearance of the components of personal protective equipment (PPE). PPE is an acronym for personal protective equipment. Rotation, rotating, and random cropping are examples of the types of methods that are included in these categories. The potential to enhance the model's performance and accuracy in identifying objects under a diverse range of conditions is present through the implementation of data augmentation, which entails subjecting the model to a diverse array of settings during the training process. This is due to the model's exposure to a variety of scenarios. This objective can be accomplished by subjecting the model to a wide range of diverse circumstances. The detector is capable of identifying and distinguishing personal protective equipment (PPE) worn by workers in real time while continuously monitoring the industrial environment. This enables the detector to accomplish its task. In general, the design and implementation of the ACF detector for training photos in the project is a rigorous and iterative process that employs complex algorithms and approaches to enhance the capabilities of object recognition and to ensure the safety of workers in industrial settings. This is implemented to guarantee the project's accomplishment. Additionally, in order to accomplish its objectives, the initiative aims to improve the efficacy of employees in industrial environments. The ACF detector is a substantial contributor to the AI-based safety system's success, which ultimately leads to a more secure and safe work environment for all employees. This is the ultimate objective. By optimizing performance, customizing parameters, and incorporating data augmentation, this objective may be accomplished. These are the methods that can be employed to accomplish this objective.

D. Wearable Health Monitoring System

The Wearable Health Monitoring System is primarily concerned with integrating sensor data from wearable devices in order to monitor the vital health indicators of workers in industrial settings. This is because the system is designed to monitor the health of workers. This system has the power to collect data in real time on factors such as heart rate, SpO2 levels, and body temperature. The objective of this system is to monitor the health of employees on a regular basis. Through the use of this method, any anomalies or potential threats to one's health will be recognized in a timely way.

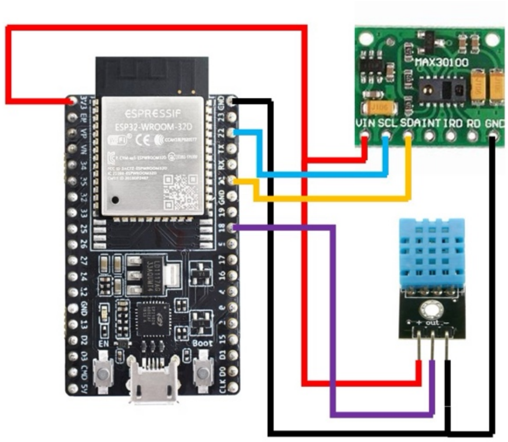

Fig. 5. Design of the circuit

The implementation of this monitoring system makes it possible to carry out preventative measures that may be done to address potential health hazards and to make it easier to keep a safe working environment where all employees can perform their jobs.

E. Power BI and Data Visualization

Collecting information from five different channels that are specifically designed to meet our objectives is the procedure that we go through to obtain data when we use Power BI. To locate the information that we require, this is done. These channels include the sensor data that was obtained by Employee 1, in addition to the data that was gathered from three more sources that are present inside MATLAB at the same time. There are many different types of personal protective equipment (PPE) that personnel use. Some examples are earmuffs, helmets, and jackets. Furthermore, gloves and face shields are examples of such items. The information that is provided by the MATLAB sources is important about the current state of these different objects. The status of the earmuff, which includes whether it is worn, is an example of the one-of-a-kind insights that may be gleaned from every MATLAB source. In addition to that, the reader is also provided with the percentage of confidence that is associated with the detection. Once these data sources have been selected, the 'Get Data' function in Power BI is the one that is responsible for initiating the process of data collection from those sources. As can be seen in Fig. 6 and Fig. 7, this function makes it possible to execute searches for sensor data and to choose files from defined directories for MATLAB sources. After the data has been acquired, it is put into Power BI for the goal of conducting in-depth analysis and making modifications to guarantee that the data correctly provides a representation of the scenario. The 'Edit Queries' option presented by Power BI, which can be found inside the data part of the application, makes it possible to finish this essential phase, which is an essential step. The construction of the different datasets is performed by utilizing the relationships function that is available within Power BI, as can be seen in Fig. 8. This feature is accessible inside Power BI. When this activity is carried out, it is done with the intention of improving the quality of the data and acquiring important insights. Using the 'Edit Queries' tool, it is now possible to perform the construction of conditional columns, the inclusion of new data, and the enhancement of datasets. All of these tasks may be accomplished. One other advantage is that this makes it feasible to incorporate fresh data, which is a significant advantage. The final stage is the generation of reports by selecting the 'Report' option, which offers a blank canvas for the construction of comprehensive reports based on the data that has been modified. When the processing of the data is finished, it is immediately visualized by making use of the different visuals that are available inside Power BI. This follows immediately after the conclusion of the processing. The displays that are included in these displays include stacked bar charts and stacked column charts, among other types of displays. These visualizations, which provide a full picture of the data, make it possible for the managers to comprehend and assess the information in a manner that is satisfactory to them. After the processes of data analysis and report creation have been successfully completed, it is possible to send the reports to Power BI Services by selecting the 'submit' option from the menu. This is done once the procedures have been completely carried out. Additionally, users are provided with the opportunity to make extra modifications in the case that it is essential for them to do so. This is because users are required to log in before they are able to utilize Power BI Services. Alternatively, reports may be converted into interactive dashboards by utilizing the 'Publish on the Web' option, which will result in the creation of an embedded link. This option is available to users. As an alternative to the conventional approach to the presenting of data, this is an alternative. This link can be easily included in websites so that end users can access it, or it may be provided to certain persons so that they can read it. Both options are possibilities. Any one of these two arrangements is a viable option. Consequently, this ensures that the crucial insights and information that are acquired from the data sources that are being utilized in our project are effectively disseminated to the stakeholders who are responsible for receiving them.

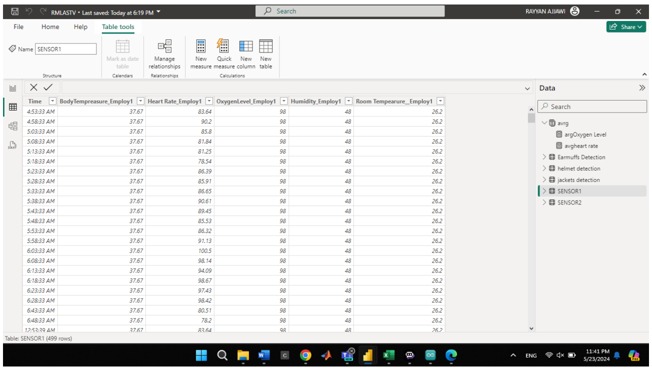

Fig. 6. Sensor data from an employee

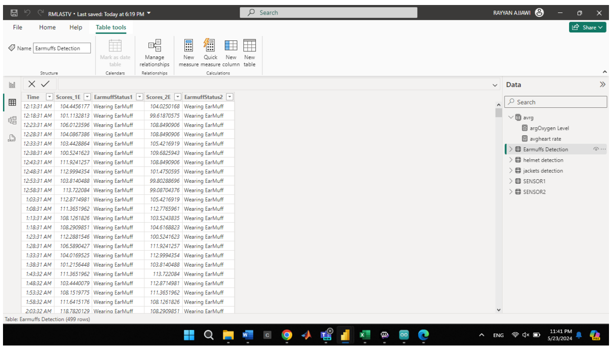

Fig. 7. Earmuff detection for an employee

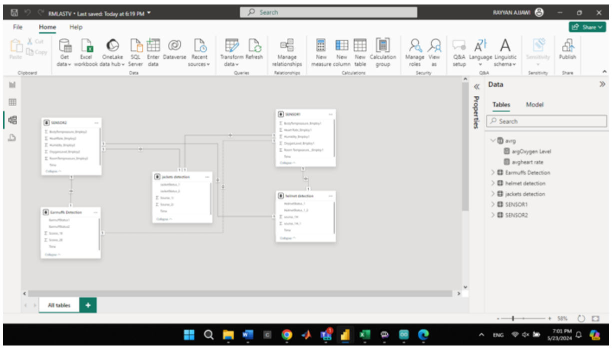

Fig. 8. Power BI relationship

F. *Integrated Design Artificial Intelligence Safety System and Wearable Health Monitoring System*

Integrating these sensors into the design of earmuffs for industrial workers has markedly progressed the industry. We ensure the precision and dependability of essential health indicator measurements by strategically positioning the MAX30100 sensor on the earmuff cushion located behind the ear, as seen in the image. The DHT11 sensor is optimally located to protrude from the earmuff, allowing efficient monitoring of ambient environmental variables. This distinctive method guarantees employee comfort and convenience while enhancing the precision and efficacy of health monitoring in industrial settings. Additionally, to improve the user experience and aid in the understanding of our project, we have utilized 3D images created using Microsoft 3D Paint to visually convey our design concept. The earmuff shell and padding design was sourced from Simon Innsmade, available on GitHub. These graphics clarify the incorporation of sensors into the earmuff design, demonstrating the use and effectiveness of our novel technique in a manner that is both clear and captivating. The project we are doing demonstrates a thorough approach to workplace safety and health surveillance. It incorporates cutting-edge technology, innovative design, and user-centric solutions to provide a comprehensive system that prioritizes the health and safety of industrial workers. We want to revolutionize safety practices in industrial environments by merging personal protective equipment (PPE) detection with health monitoring sensors in a wearable and user-friendly format, therefore fostering a safer and healthier workplace.

Fig. 9. Earmuff Shell Side View of the 3D Design

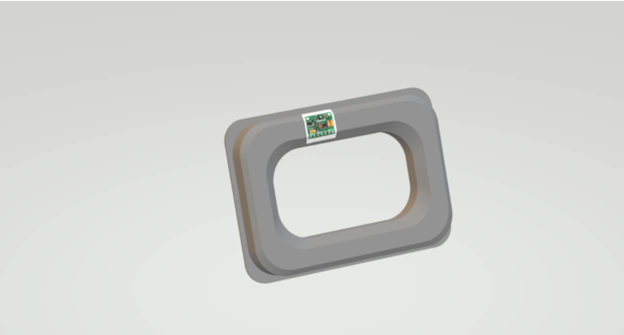

Fig. 10. Earmuff Shell Side View of the 3D Design

V. Results and Discussions

The initial stage of the project is dedicated to the utilization of the Image Labeler utility in MATLAB. Images were annotated, regions of interest were defined, and objects such as headgear, safety vests, and earmuffs were labelled using the Image Labeler. In a comprehensive dataset of images, the Image Labeler generates ground truth data for the purpose of training machine learning models by precisely delineating bounding boxes around these PPE items. Training images are subjected to data augmentation techniques in order to improve the trained model's reliability and robustness. These methods, including random cropping, flipping, and rotation, introduce variation in the appearance of the PPE items, thereby artificially expanding the training dataset. During the training process, data augmentation enhances the model's capacity to generalize and maintain high accuracy in the presence of variations in object appearance, position, and orientation by exposing it to a broader range of scenarios. Annotated images are utilized to train the Aggregate Channel Features (ACF) object detector. After the images are trained, a mat file is produced and utilized by the primary detection program during its execution. The Aggregate Channel Features (ACF) algorithm checks trained images to determine if they match the features of the inserted images by extracting channel information such as color, gradient magnitude, and gradient orientation during the training phase, using a sliding window approach to scan the input image at different scales and positions during the detection phase and computing similar features at each window position, evaluating the extracted features using a classifier based on machine learning techniques like AdaBoost to determine if they match those of the trained images, applying a threshold to the classifier's output to distinguish between positive and negative detections, and generating a bounding box around the detected object to outline its location in the image, enabling accurate and reliable object detection by comparing the features extracted from the trained images with those computed from the input image and identifying objects based on the learned patterns and characteristics. The bounding boxes' confidence percentages then indicated whether or not the individual was wearing personal protective equipment (PPE). The second segment of the project is dedicated to the development of a wearable health monitoring system that will enable the real-time surveillance of the health of employees. This system includes an ESP32 Wi-Fi module, DHT11, and MAX30100 sensors that are used to monitor critical health parameters, including body temperature, ambient temperature, humidity, heart rate, and oxygen levels. The data that has been collected is subsequently transferred to Power BI, a robust business intelligence and data visualization platform, for analysis and presentation. The data in Power BI is presented in comprehensive tables that include humidity, room temperature, and timestamps. The overall health trends of the employees are given insight into by displaying the oxygen levels and pulse rates for each time period. In addition, the interface includes dynamic displays of current health metrics, which enable real-time monitoring of vital signs. To offer a comprehensive perspective on employee health and safety, the Power BI dashboard integrates a variety of visualizations. Fig. 11 illustrates the percentage of time employees wear specific PPE items, as demonstrated by pie charts. This enables the simple identification of compliance trends. Any anomalies or prospective health concerns are highlighted by the display of body temperature trends. A stacked area chart illustrates the fluctuation of body temperature and pulse rate over time, enabling the identification of potential health hazards and the identification of patterns. Displayed in Fig. 11 and Fig. 12 are the dashboards of the Power BI desktop app and the phone app, respectively. Power BI's integration of data visualization, wearable health monitoring, and computer vision techniques illustrates the AI-based safety system's efficacy in improving employee well-being and workplace safety.

Fig. 11. Desktop Dashboard showing good vitals

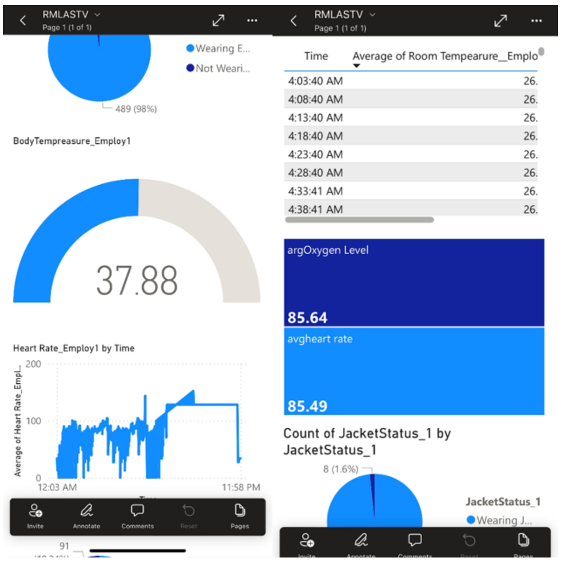

Fig. 12. Phone Dashboard

VI. Conclusions

The artificial intelligence-driven safety system being developed for this project employs advanced technologies to improve workplace safety and monitor employee welfare across diverse industrial environments. The system can precisely identify critical personal protection equipment (PPE) such as helmets, safety vests, and earmuffs by employing the ACF object detector and the Image Labeler available in MATLAB. This guarantees the frequent monitoring of personal protective equipment (PPE) utilization to confirm adherence to certain safety procedures. The omnipresent health monitoring system incorporates sensors such as the DHT11 and MAX30100, together with ESP32 Wi-Fi modules, to gather vital health information. This assessment encompasses heart rate, oxygen saturation, body temperature, ambient temperature, and humidity levels. This information is subsequently relayed to Power BI for comprehensive analysis, providing administrators with insights into employee health trends and facilitating preventative measures. The real-time data is subsequently transferred to Power BI. The Power BI interface offers several visual representations, like pie charts and stacked area charts, alongside comprehensive tables. This is executed to facilitate real-time monitoring and decision-making. Data visualization, pervasive sensors, and computer vision exemplify their effective integration to establish a complete safety monitoring system. This software shows how this may be achieved. This strategy, emphasizing data-driven insights and modern technologies, cultivates a workplace culture that prioritizes employee well-being and safety. This technique ensures that all safety standards are adequately fulfilled. The system's flexibility and utility will be enhanced across many industrial contexts due to several planned enhancements. These improvements encompass predictive analytics, alert systems, and more sensors. This endeavor has resulted in the establishment of a standard for improving health and safety monitoring systems. This program demonstrates the transformative potential of technology in creating workplaces that are more productive, healthier, and safer than in previous eras.

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