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Utilization of Camera Vision to Monitor Production Line Operator Learning Curve

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Abstract

The increasing demand for efficiency in modern manufacturing requires advanced methods for monitoring and optimizing production line performance. Traditional approaches often fail to provide real-time insights into operator proficiency, resulting in delayed responses and suboptimal training interventions. This research addresses these challenges by leveraging camera vision technology to enhance the assessment and improvement of operator learning curves. The primary objective is to develop and implement a real-time monitoring system that captures and analyzes production line operator activities using camera vision, providing timely and accurate assessments to design targeted training programs. The system employs high-resolution cameras and computer vision techniques to monitor and evaluate operator movements, improving the accuracy and timeliness of proficiency assessments. Results indicate significant improvements in operator learning curves and smoother motion patterns, demonstrating the system's effectiveness. Real-time feedback enabled immediate adjustments and targeted training, enhancing overall production line efficiency. The successful implementation of this technology promises increased efficiency and productivity in manufacturing, showcasing its transformative impact on operator performance assessment.

1. Introduction

In modern manufacturing and production environments, the efficiency and effectiveness of production operators are critical for maintaining high productivity and quality standards. Monitoring and analyzing this learning curve can provide valuable insights into training effectiveness, operator proficiency, and potential areas for improvement [1]. However, manually collecting data about machine downtime, cycle times, or the number of parts produced is time consuming and often inaccurate. To address these challenges, this project explores the utilization of camera vision technology to monitor production operator learning curves in a more automated, objective, and real-time manner. This project specifically focuses on the detection and analysis of shoulder movements of production operators using a camera vision system. Shoulder movement is a significant indicator of an operator’s activity and ergonomics, and deviations from optimal movements can suggest issues such as improper technique or fatigue. By implementing a camera system that can detect and quantify shoulder movements, this project aims to provide a continuous, real-time assessment of operator performance.

1.1 Literature Review

Typical image processing module consists of four main parts, image acquisition, im-age segmentation, image understanding, and application specific feature extraction as shown in Fig 1. The vision module consists of four parts. Image segmentation aside main image segmentation algorithm has image pre-processing and post-processing of segmented image. Image understanding is done in order to detect human in the scene and human coordinates can be extracted [2]. The core of the image understanding is neural network classifier that detects human based on extracted features from segmented objects.

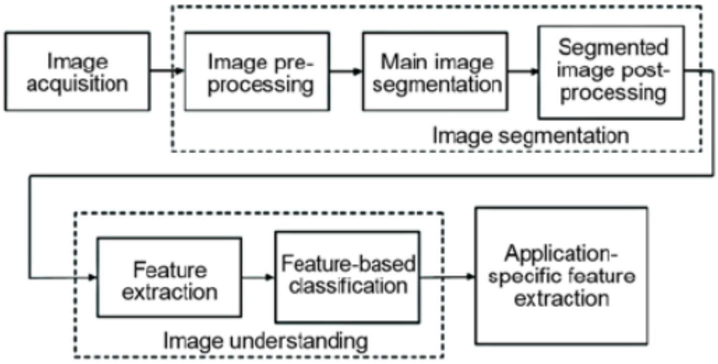

Fig. 1 *Computer vision block-diagram [3]*

2. Materials and Method

The primary objective of this project is to implement a sophisticated camera vision system designed to capture and analyze operator activities on the production line. This system aims to monitor the operators in real-time, focusing on key movements to provide a detailed assessment of their performance. By leveraging advanced image processing techniques, the system will gather precise data on the operators' actions, which will then be analyzed to evaluate their performance and learning curves. The analysis will highlight areas of improvement and track the progression of skill acquisition over time.

Furthermore, the project seeks to develop comprehensive real-time monitoring and reporting tools that translate raw data into actionable insights. These tools will be integrated into a user-friendly graphical user interface (GUI) that displays real-time feedback, performance metrics, and detailed logs of operator activities. The ultimate goal is to enable immediate intervention and support, facilitating continuous improvement and enhanced efficiency on the production line. By achieving these objectives, the project aims to contribute significantly to optimizing operator training and production line management through the use of advanced camera vision technology. The methodology part demonstrates a comprehensive explanation of the method used to complete this project. It includes the workflow, block diagram, flow diagram, and project design.

2.1 Operational Block Diagram

The mechanism design use in this project is webcam serves as the primary sensor, capturing the video feed for shoulder detection, while a stable structure, including a tripod and USB extension, ensures optimal positioning during the assembly process. The software is written in Python, with OpenCV for face detection, Tkinter for the graphical user interface and buttons, multithreading for simultaneous shoulder detection and GUI updates. For modularity and clarity, the code employs an object-oriented programming style.

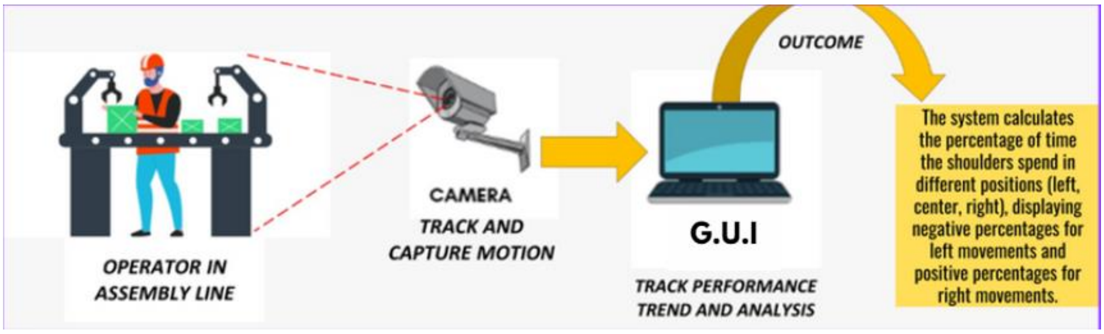

Fig. 2 *System General Block Diagram*

Fig. 2 illustrate that, these movements are captured in real-time by the process using tools like MediaPipe to tracks the shoulder positions and calculates the movement percentages. Movements to the left are displayed as negative percentages, while movements to the right are shown as positive percentages. The output is the graphical user interface (GUI), which records and displays the trends and analysis of the operator's movements. This real-time feedback helps in monitoring the learning curve of the operator and provides insights for targeted training and performance optimization.

2.2 System Flowchart

Fig. 3 illustrates the system flowchart for this project. Initially, the webcam will be securely positioned on the tripod, and the webcam will connect to the laptop and digital user interface (GUI) display will be generated data.

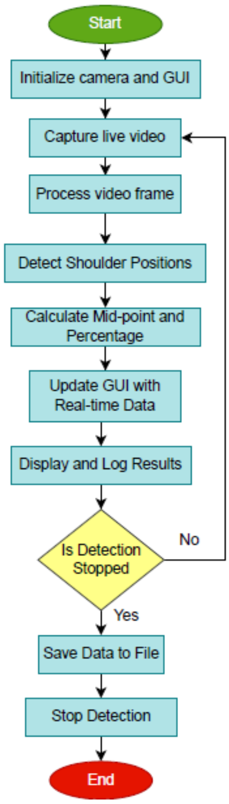

Fig.3 *System Flowchart*

The flowchart system for the "Utilization of Camera Vision to Monitor Production Operator Learning Curve" begins with initializing and configuring the system, followed by setting up and calibrating cameras to accurately capture operator movements. Images and videos are continuously captured and preprocessed, then analyzed using MediaPipe for pose estimation and key point extraction [4]. The system specifically detects the center position of the shoulders and tracks their movements to the left and right. Data analysis involves calculating the percentages of time the operator's shoulders spend in each position (left, center, right). If the shoulders move to the left, the system displays a negative percentage, and if they move to the right, a positive percentage is shown.

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These percentages are displayed in real-time on a graphical user interface (GUI) for immediate feedback, helping operators adjust their movements dynamically. The system stores and backs up this data for periodic performance review and report generation. Insights from the data help identify improvement areas, leading to the development and implementation of targeted training programs. Regular calibration and software updates maintain the system's accuracy and efficiency, ensuring ongoing optimization of operator performance. This includes calculations to find the average of the x and y coordinates of the left and right shoulders to determine the mid-point between them which calculated as follows:

1. **Mid-point X-coordinate:**

$$\text{mid\_point\_x} = \frac{\text{left\_shoulder.x} + \text{right\_shoulder.x}}{2}$$

2. **Mid-point Y-coordinate:**

$$\text{mid\_point\_y} = \frac{\text{left\_shoulder.y} + \text{right\_shoulder.y}}{2}$$

It then calculated the percentage based on the horizontal distance of the mid-point from the center of the frame using the equation of:

1. **Distance from Center Calculation:**

$$\text{center} = \frac{\text{frame\_width}}{2}$$

$$\text{distance\_from\_center} = \text{mid\_point} - \text{center}$$

2. **Percentage Calculation:**

$$\text{percentage} = \left(\frac{\text{distance\_from\_center}}{\text{max\_distance}}\right) \times 100$$

where $\text{max\_distance} = \text{center}$.

2.3 Camera Setup

In the camera setup as shown in Fig. 4 for the "Utilization of Camera Vision to Monitor Production Operator Learning Curve" project, a single camera is mounted on a tripod stand positioned directly in front of the operator who is performing the assembly task. This positioning ensures that the camera has a clear and unobstructed view of the operator's shoulder movements. The camera is connected to a laptop, which runs the graphical user interface (GUI) and the necessary software for tracking and analyzing the operator's movements. The laptop processes the video feed from the camera in real-time, using MediaPipe for pose estimation and key point extraction. The GUI displays the calculated percentages of shoulder movements, providing immediate visual feedback to the operator and facilitating the monitoring of the learning curve. This setup ensures that the system captures accurate data and provides real-time analysis, essential for evaluating and improving operator proficiency.

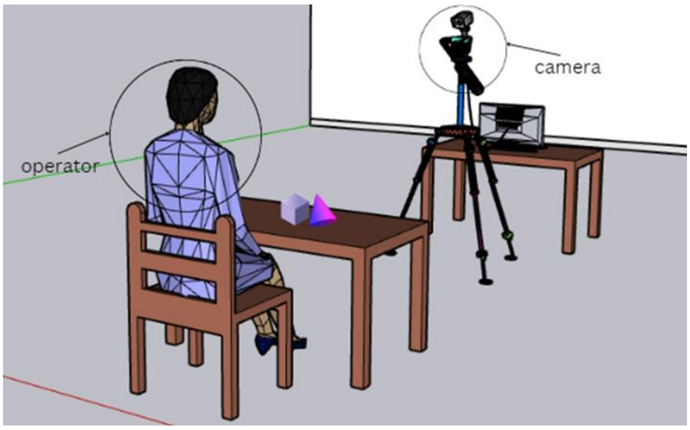

Fig. 4 *Camera setup for operator monitoring system*

2.4 Software Design

Fig. 5 shows the software design of this project that have been developed by using Python coding and generate using PyCharm. The Graphical User Interface (GUI) for this project is designed to provide an intuitive and user-friendly experience. Built using Tkinter, the GUI layout is organized to facilitate ease of use and real-time interaction.

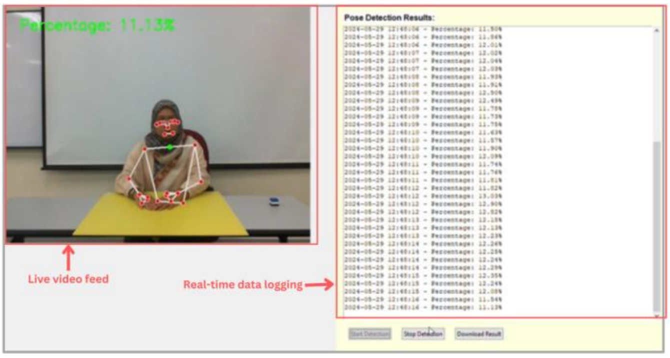

Fig. 5 *GUI Design*

The main window is divided into two primary sections: the video display area and the control panel. The video display area occupies the left side of the window, where live video feed from the camera is shown with annotations indicating the operator's shoulder movements and the calculated percentage. The right side contains the control panel, includes a section for displaying results and buttons for starting and stopping the detection.

3. Results and Discussion

The results of this project provide an in-depth look at the effectiveness of utilizing camera vision technology to monitor the learning curves of production line operators. By tracking and analyzing shoulder movements, the system aims to deliver real-time insights into operator performance, identifying areas for improvement and optimizing overall efficiency. The Fig. 6 illustrates the graph of trend analysis for the three respondents, showing the changes in their performance percentages over time during the assembly tasks.

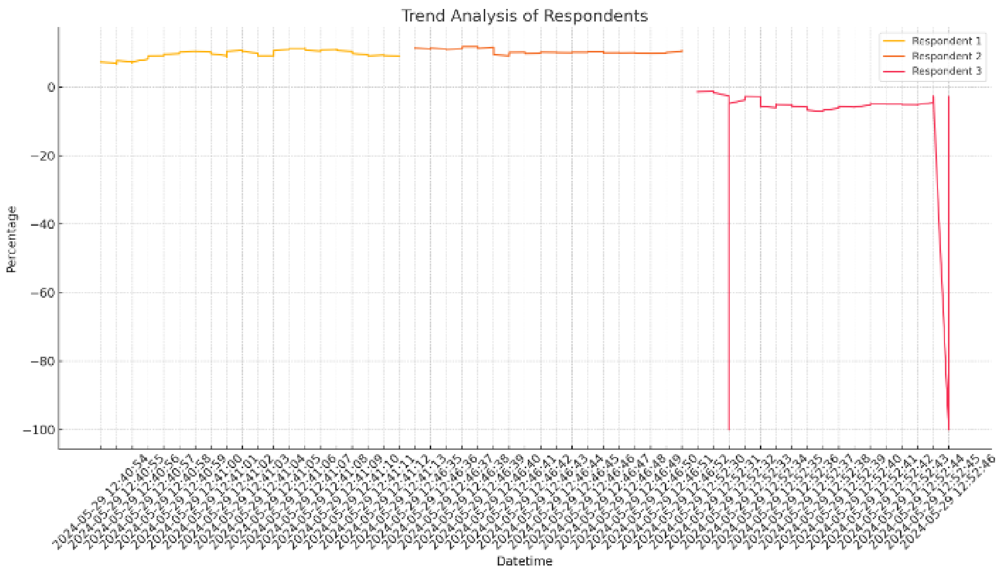

Fig. 6 *Graph of trend analysis*

Analysis of the results:

i. Respondent 1: This respondent's performance exhibits a relatively stable trend with slight fluctuations. The percentage values start around 7% and show small variations throughout the observation period.

ii. Respondent 2: This respondent demonstrates a generally increasing trend, starting from about 11% and showing noticeable improvement over time, with peaks and troughs indicating variability in performance.

iii. Respondent 3: This respondent has the most varied performance, with negative percentages at the start, indicating movement to the left, and gradually moving towards positive percentages. This suggests an initial struggle followed by a recovery and improvement phase.

A critical component of comprehending operator performance in production line tasks is the analysis of variances in individual learning curves and efficiency improvements. With the aim of improving overall productivity, the visualization assists in identifying patterns and areas that may require targeted interventions.

4. Conclusion

In conclusion, this project successfully demonstrated the implementation of a camera vision system to monitor and analyze operator activities on the production line. Utilizing advanced tools like MediaPipe for real-time pose estimation and a custom-built GUI for immediate data visualization, the system proved effective in capturing precise operator movements and providing actionable insights. The analysis of collected data allowed for a detailed assessment of operator performance and learning curves, highlighting areas for improvement and tracking skill development over time. Despite its current limitation of monitoring a single angle, the project laid a strong foundation for future enhancements, such as multi-angle monitoring and multi-operator tracking. Overall, the project achieved its objectives of enhancing operator training and production line efficiency through innovative camera vision technology.

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Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

Author Contribution

The authors confirm contribution to the paper as follow: study concept and design: Sabania; data collection: Sabania; analysis and interpretation of results: Sabania, Shahidah, Amirul; draft manuscript preparation: Sabania, Shahidah, Amirul. All authors reviewed the results and approved the final version of the manuscript.

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