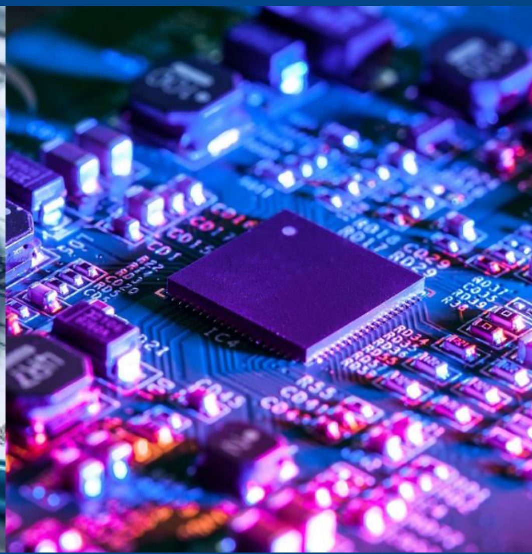
ISSN: 2582-7219

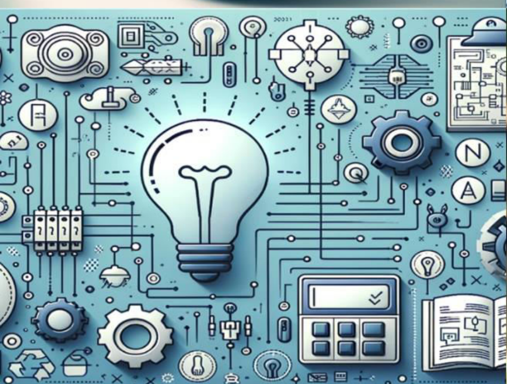




International Journal of Multidisciplinary Research in Science, Engineering and Technology

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)



Impact Factor: 8.206

Volume 8, Issue 5, May 2025

ISSN: 2582-7219 | www.ijmrset.com | Impact Factor: 8.206| ESTD Year: 2018|

International Journal of Multidisciplinary Research in Science, Engineering and Technology (IJMRSET)

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)

Smart Inspection System for Wiring Harness

Prof. Mrs. Rutuja s. Pawar[1], Saba Sayyad[2], Omkar Salunkhe[3], Ruturaj Kodag[4], Sujata Kunure[5]

Assistant Professor, Department of Electrical Engineering. Annasaheb Dange College of Engineering and Technology, Ashta Maharashtra, India[1]

UG Student, Department of Electrical Engineering. Annasaheb Dange College of Engineering and Technology, Ashta Maharashtra, India[2,3,4,5]

ABSTRACT: The Smart Inspection System for Wiring Harness Manufacturing leverages machine learning to enhance the accuracy and efficiency of quality control processes. Traditional inspection methods, often reliant on manual checks and basic automated systems, struggle with high variability and complexity in wiring harnesses, which can lead to overlooked defects and increased production costs. This system introduces a machine learning-based approach to automate and refine the inspection process, utilizing advanced image recognition and anomaly detection algorithms to identify defects and deviations from design specifications with high precision. By integrating real-time data analysis and feedback mechanisms, the system not only detects defects but also adapts and improves its performance over time. This results in a significant reduction in false positives and negatives, higher throughput, and improved overall product quality. The system's ability to provide actionable insights and predictive maintenance recommendations further supports efficient manufacturing processes and enhances operational reliability. This approach represents a transformative advancement in wiring harness quality control, addressing current limitations and setting new standards for manufacturing excellence.

KEYWORDS: Automation, Computer Vision, Defect Detection, Quality Control, Machine

I. INTRODUCTION

A Smart Inspection System for Wiring Harness using Machine Learning is an innovative way to automatically check the quality and correctness of wiring harnesses. A wiring harness is a collection of wires, connectors, and cables that carry power and signals within machines, vehicles, and electronic devices. These harnesses are essential for ensuring that everything works properly, whether it's in a car, airplane, or computer. However, inspecting these wiring harnesses to make sure they are built correctly can be time-consuming and prone to human error when done manually. This is where Machine Learning comes in. Machine learning is a branch of artificial intelligence that allows computers to learn from data and experience. Instead of programming the system with a set of strict rules, machine learning lets the inspection system analyses images or data from wiring harnesses and learn what a correct harness looks like.

Over time, the system can detect when something is wrong with a wiring harness, such as a missing wire, an incorrect connection, or a defect in one of the components. It can learn from past mistakes and improve its ability to spot problems as it inspects more and more harnesses. The smart inspection system can also analyze vast amounts of data in real-time, identifying subtle issues that might not be obvious to the human eye. For example, it can detect minor deviations in wire placement or connection quality that could lead to future failures. This predictive capability helps manufacturers catch potential problems early, reducing the risk of defective products reaching customers.

By continuously learning from new data, the system becomes more intelligent and capable of detecting even rare or complex errors, leading to product reliability and customer satisfaction. Overall, this smart approach streamlines the inspection process, boosts efficiency, and enhances overall quality controlWiring harnesses are essential components in modern electrical systems, providing structured pathways for power and signal distribution across industries such as automotive, aerospace, and industrial automation.

Given their complexity—often consisting of hundreds of wires and connectors—even minor defects like open circuits, short circuits, or misfires can lead to critical system failures, safety risks, and costly recalls. Traditional inspection methods, such as manual continuity testing or basic multimeter checks, are inefficient, error-prone, and unable to meet the demands of high-volume production. As a result, manufacturers are increasingly adopting automated, intelligent inspection systems to enhance quality control and comply with Industry 4.0 standards.

To address these challenges, this paper proposes a Smart Inspection System for Wiring Harness using Gray Code, a robust encoding technique that minimizes errors during signal transmission. Unlike conventional binary encoding, Gray Code ensures only one-bit changes between consecutive values, reducing the risk of misinterpretation due to noise or timing issues. The system consists of a microcontroller-based transmitter that generates a Gray Code sequence and sends it through the wiring harness, while a receiver decodes and verifies the pattern to detect faults instantly. This approach not only improves accuracy and speed but also supports scalability for different harness configurations, from simple cables to complex multi-branch networks.

II. RELATED WORK

Developed a smart inspection system using deep learning to detect automotive wiring harness faults, demonstrating higher accuracy and reduced human error compared to manual inspection methods

[1] Proposed a machine vision-based inspection framework that combines image processing and supervised learning to detect wire misalignment and missing connections in real time. [2] Utilized convolutional neural networks (CNNs) for defect detection in wiring harness images, achieving improvements in both inspection speed and accuracy over traditional techniques.
[3] Designed a deep learning-based system capable of inspecting complex wiring harness configurations with high precision, effectively minimizing overlooked faults.
[4] Presented a hybrid model using supervised and unsupervised learning to enhance real-time detection of common and rare defects in automotive wiring systems.
[5] Integrated machine learning with smart factory systems to automate inspection processes, contributing to Industry 4.0 advancements by reducing human dependency.
[6] Proposed a predictive maintenance system using deep learning to forecast wiring harness failures based on historical and real-time data, lowering operational disruptions.
[7] Demonstrated how machine learning models trained on historical defect data can efficiently classify and predict wiring harness faults in industrial applications.
[8] Introduced a reinforcement learning approach to continuously improve defect detection strategies by learning from inspection outcomes in complex wiring systems.
[9] Applied AI-driven fault detection techniques in smart grid wiring harnesses to automate classification and enhance reliability in large-scale infrastructure

III. METHODOLOGY

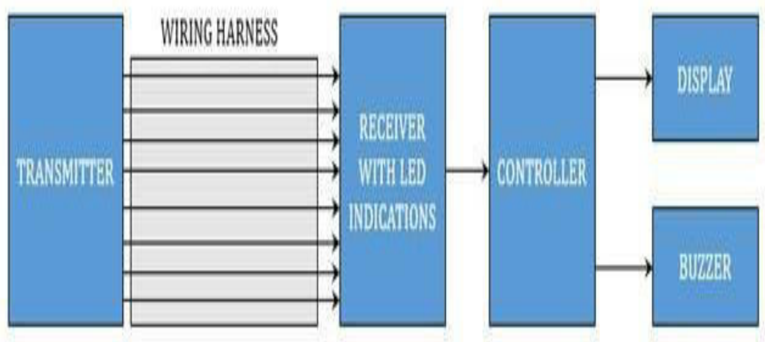


Fig.1 Block Diagram of Smart Inspection System for Wiring Harness

The provided block diagram represents a Smart Inspection System for Wiring Harness, which ensures accurate and automated detection of defects within wiring harnesses. The system consists of the following key blocks:
Transmitter: The Transmitter is the starting block in the system. It sends electrical signals or specific test pulses through the wiring harness. These signals are configured to assess the continuity, connectivity, and integrity of the wires in the harness. The transmitter ensures that the signals are appropriately modulated and compatible with the testing requirements. In some systems, it might generate distinct patterns or codes to identify each wire individually.

Wiring Harness: The Wiring Harness represents the main subject of the inspection. It consists of multiple wires bundled together, designed to transmit electrical power or signals in systems such as automobiles, aerospace, and industrial machinery. During testing, the wiring harness connects the transmitter to the receiver. The harness is examined for faults like miswiring, disconnections, short circuits, and improper terminations. Any defect within the harness will affect how the signals propagate.[Fig.1]
Receiver with LED Indications: The Receiver is responsible for receiving the signals transmitted through the wiring harness. It analyzes the signals to check for continuity and correctness.

LED Indications: The receiver includes LEDs that provide a visual representation of the inspection results Each LED corresponds to a specific wire or connection in the harness. A glowing LED indicates a properly functioning wire, while the absence of light or a specific error color (e.g., red) indicates a fault. This allows operators to quickly identify and locate defective connections or wires.

Controller: The Controller acts as the brain of the system. It processes the data received from the receiver and makes logical decisions based on predefined inspection criteria. The controller evaluates the signals for faults such as broken wires, incorrect connections, or short circuits. Based on the evaluation, it triggers the necessary outputs.

Display: The Display provides a detailed visual representation of the inspection results. It can show information like the number of detected faults, the location of defective wires, or the status of each wire in the harness. In more advanced systems, the display may also provide suggestions for troubleshooting or repair. This output is especially useful for operators and technicians to analyses the system performance at a glance.

Buzzer: The Buzzer serves as an audible alert system. If a fault is detected in the wiring harness, the buzzer produces a sound to notify the operator. This feature ensures immediate attention, especially in noisy environments or when continuous monitoring of the display is not feasible. The intensity or frequency of the buzzer may vary depending on the severity or type of defect.

System Workflow[Fig.2]
The Transmitter sends signals through the wiring harness.
The Wiring Harness transmits these signals to the Receiver, where the integrity and continuity of each connection are tested.
The Receiver uses LED Indications to provide a quick visual summary of the inspection.
The Controller processes the receiver data to identify faults and relay results to the Display and Buzzer.

System by using the gray code method

1. Smart Wiring Harness System
2. A smart harness means the wiring not only connects power and ground but also carries data, signals, and smart functions (like communication between seat control units, ECUs, etc.).
3. Sensors, actuators, motors (for moving seats), and switches are connected through this harness.
4. Use of GARY Code GARY code is used to color-code the wires.
5. Each wire has a specific color that helps technicians quickly identify the purpose (power, ground, signal, etc.)
6. without confusion.
7. Running the Program The seat controller ECU (Electronic Control Unit) runs a program that:
   Sends High and Low signals based on user input (button press).
8. Finding the Fault When a seat doesn't move or behaves wrong, technicians use GARY-coded wiring to trace the fault easily: Check which color-coded wire is responsible.
9. Measure the voltage (High/Low) using a millimeter.
   Check if the signals are reaching properly.
10. Find if the wire is broken, shorted, or the connector is loose.

© 2025 IJMRSET | Volume 8, Issue 5, May 2025| DOI:10.15680/IJMRSET.2025.0805160

ISSN: 2582-7219 | www.ijmrset.com | Impact Factor: 8.206| ESTD Year: 2018|

International Journal of Multidisciplinary Research in Science, Engineering and Technology (IJMRSET)

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)

IV. EXPERIMENTAL RESULTS

a. Circuit Diagram:

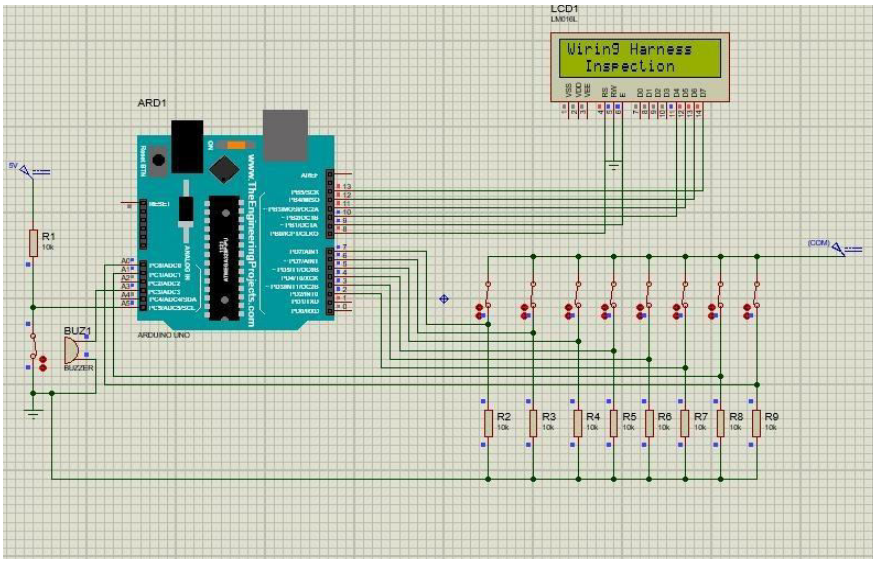


Fig.2 Simulation of Smart Inspection System for Wiring Harness

This is a Proteus simulation of a wiring harness inspection system using an Arduino Uno microcontroller. The setup includes a 16x2 LCD display to show real-time inspection status messages such as "Wiring Harness Inspection." Multiple LEDs are connected to digital pins to indicate the continuity of each wire in the harness. Each LED is paired with a resistor to limit current. A buzzer is used to signal errors or faults in the wiring connections. The system verifies connections by checking for continuity, and any mismatch or open circuit is immediately flagged through LED indications and an audible buzzer alert for quick diagnostics.

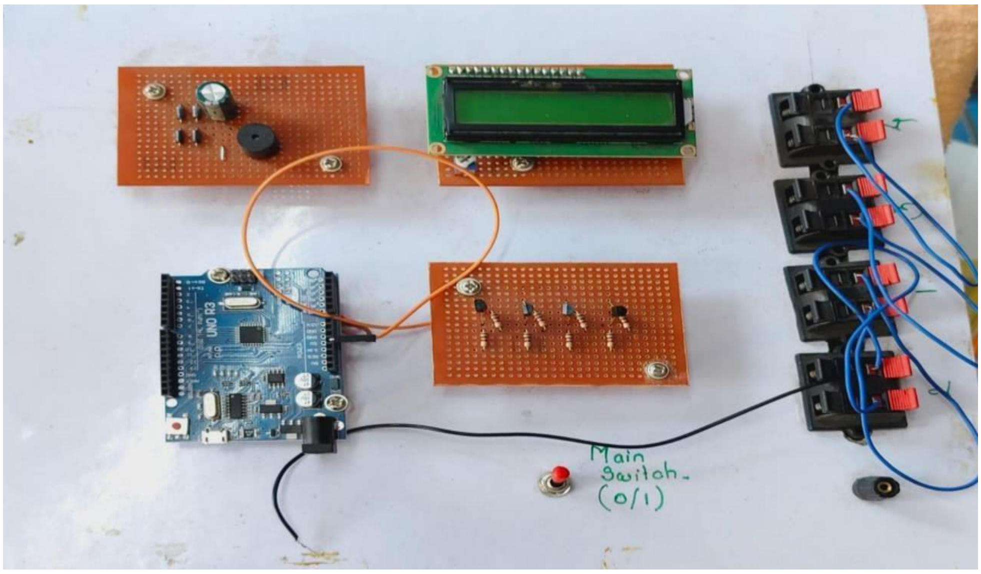


Fig.3 Hardware of Smart Inspection System for Wiring Harness Smart Inspection System for Wiring Harness

© 2025 IJMRSET | Volume 8, Issue 5, May 2025| DOI:10.15680/IJMRSET.2025.0805160

ISSN: 2582-7219 | www.ijmrset.com | Impact Factor: 8.206| ESTD Year: 2018|

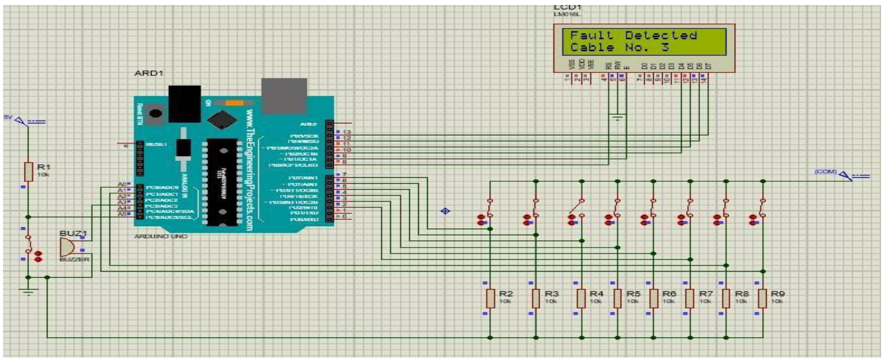
International Journal of Multidisciplinary Research in Science, Engineering and Technology (IJMRSET)

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)

This image shows a physical prototype of a wiring harness inspection system using an Arduino Uno. The setup includes a 16x2 LCD for displaying status messages, a buzzer for audio alerts, and multiple switches connected to a PCB representing wiring terminals. A push-button labeled "Main Switch (0/1)" acts as the system's power or start control. Several LEDs are used to indicate the status of individual wire connections. The components are mounted on custom PCBs and connected with jumper wires. This system is designed to test wiring integrity and notify the user of any faults or open circuits through visual and audio feedback.

V. RESULTS

Smart inspection systems reduce the workload on quality control personnel and eliminate the inefficiencies and unreliability associated with manual inspection, especially as wiring harness complexity increases. The use of gray code in these systems enables rapid phase unwrapping and robust measurement, making them suitable for complex and dynamic industrial environments. Smart inspection systems for wiring harnesses using gray code are designed to improve the speed, accuracy, and reliability of quality control in industrial settings. The integration of gray code with advanced imaging and measurement techniques enables real-time, high-accuracy inspection and measurement of complex wiring harnesses, addressing the limitations of manual and traditional inspection methods[Fig.4].



VI. CONCLUSION

In conclusion, The development of smart inspection systems for wiring harnesses, particularly those utilizing gray code technology, represents a significant advancement in industrial quality control. Gray code-based structured light projection and computer vision methods offer robust, accurate, and efficient solutions for inspecting complex wiring harness assemblies. These systems address the limitations of manual inspection, such as inefficiency and unreliability, by automating the detection of parameters like wire length, component presence, sequence, and labeling, resulting in reliable and accurate outcomes. The integration of gray code patterns enhances measurement robustness and anti-noise performance, making these systems suitable for complex and dynamic industrial environments. Furthermore, innovations such as real-time measurement using cross-projected gray-coded and phase-shifting patterns significantly improve frame rates and accuracy, even in challenging scenarios with static and dynamic objects. Overall, smart inspection systems leveraging gray code technology provide high accuracy, stability, and flexibility, making them highly effective for modern wiring harness inspection and quality assurance in industrial applications

REFERENCES

[1] Reis, B., Cella, H., Ferreira, M., Vaz, S. et al. "A Systematic Review of Automotive Wiring Harness Innovations," SAE Technical Paper 2023-36-0057, 2024, https://doi.org/10.4271/2023-36-0057

[2] strategic Market Research. "Automotive Wiring Harness Market Size, Global Share, 2030". https://www.strategicmarketresearch.com/market-report/automotive-wiring-harness-market

[3] R. Deshmukh and M. Verma, "Automated Fault Detection in Automotive Wiring Harness Using Image Processing," *Engineering Science and Technology, an International Journal*, Jun. 2022. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S2215098622001456

[4] A. Khan, N. R. Sinha, P. Joshi, and V. Raj, "Smart Vision-Based Wiring Harness Inspection System for Industrial

Automation," *Journal of Modern Engineering Research*, vol. 4, no. 5, pp. 145–150, May 2021.[Online]. Available: https://www.jmeronline.com/article/vision-inspection-wiring).

[5] **A. R. Deshmukh, S. B. Patil, and M. T. Joshi**, "Machine vision-based automatic inspection system for automotive wire harness," *Materials Today: Proceedings*, vol. 44, pp. 4153–4158, 2021. [Online] Available: https://doi.org/10.1016/j.matpr.2020.10.922

[6] G. Lim, M. Song, and J. Park, "Deep learning-based connector detection for robotized automotive wire harness assembly," *arrive preprint arXiv:2309.13746*, Sep. 2023. [Online] Available: https://arxiv.org/abs/2309.13746

[7] **Reis, B., Cella, H., Ferreira, M., Vaz, S. et al.**,"A Systematic Review of Automotive Wiring Harness Innovations,"*SAE Technical Paper 2023-36-0057*, 2024. Doi: https://doi.org/10.4271/2023-36-0057

[8] **G. Lim, M. Song, and J. Park**,"Deep learning-based connector detection for robotized automotive wire harness assembly,"*arXiv preprint arXiv:2309.13746*, Sep. 2023.[Online]. Available:https://arxiv.org/abs/2309.13746

[9] **A. R. Deshmukh, S. B. Patil, and M. T. Joshi**,"Machine vision-based automatic inspection system for automotive wire harness,"*Materials Today: Proceedings*, vol. 44, pp. 4153–4158, 2021.[Online]. Available: https://doi.org/10.1016/j.matpr.2020.10.922

[10] **R. Deshmukh and M. Verma**,"Automated Fault Detection in Automotive Wiring Harness Using Image Processing,"*Engineering Science and Technology, an International Journal*, Jun. 2022. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S2215098622001456