

# Computer Vision Based Quality Control In Manufacturing

## **Aim:**

The aim of a computer vision-based quality control project in manufacturing is to leverage advanced visual processing techniques to inspect and ensure the quality of products during the manufacturing process. This involves using computer vision algorithms and technologies to analyse images or videos of the manufacturing line, identifying defects, anomalies, or deviations from the desired product specifications

## **Purpose:**

The purpose of this computer vision-based quality control project in manufacturing is to enhance product quality and reduce costs by automating the inspection process. By employing advanced visual processing, the project aims to identify defects, anomalies, and deviations in real-time, ensuring compliance with industry standards. The system strives to improve efficiency, minimize human error, and provide data-driven insights for continuous process optimization. Ultimately, this project seeks to increase customer satisfaction, establish a competitive advantage, and adapt seamlessly to changes in production requirements, contributing to overall excellence and reliability in manufacturing operations.

## **Task:**

- Clearly outline the goals and specifications for the computer vision-based quality control system in manufacturing.
- Plan the overall structure of the system, considering hardware, software, and integration requirements.
- Gather a diverse dataset of images or videos depicting both normal and defective products in the manufacturing environment.
- Clean and enhance the dataset, addressing issues such as noise, lighting

variations, and image quality.

- Develop computer vision algorithms for defect detection and classification, considering the specific characteristics of the manufacturing process.
- Train the algorithms using the preprocessed dataset to ensure accurate identification of defects.
- Integrate the computer vision system into the production line, ensuring compatibility with existing machinery and processes.
- Optimize algorithms and system components to achieve real-time defect detection during manufacturing.
- Define and establish clear criteria for defect classification and adherence to quality standards.
- Conduct extensive testing to validate the accuracy, reliability, and real-time performance of the system.
- Fine-tune algorithms based on testing results to minimize false positives and negatives.
- Design the system to scale seamlessly with changes in production volume and manufacturing requirements.
- Ensure smooth integration with existing manufacturing control systems and automation infrastructure.
- Implement automated processes for defect detection and quality control to reduce manual intervention.
- Establish a monitoring system to track system performance, and conduct regular maintenance to address any issues promptly.
- Implement data analytics to extract insights from the quality control process, identifying patterns and areas for improvement.
- Document the entire system, including algorithms, configurations, and

maintenance procedures for future reference.

- Train manufacturing personnel on the operation, maintenance, and troubleshooting of the computer vision system.
- Ensure that the system complies with industry regulations and quality standards.
- Establish a framework for ongoing improvements, incorporating feedback, data analytics, and evolving manufacturing needs to enhance the system's effectiveness over time.

### **Steps involved in Computer Vision –Based Quality Control In Manufacturing:**

Computer Vision-Based Quality Control in Manufacturing involves using computer vision technology to inspect and assess the quality of products during the manufacturing process. Here are the general steps involved in implementing such a system:

- **Define Quality Standards:**

Clearly define the quality standards and criteria for the manufactured products. This involves specifying the acceptable parameters and characteristics that the products must possess.

- **Select and Install Cameras:**

Choose appropriate cameras and sensors based on the specific requirements of the manufacturing process. Install them in strategic locations to capture images or videos of the products during different stages of production.

- **Lighting Setup:**

Design and set up proper lighting conditions to ensure optimal image quality. Adequate lighting helps in highlighting important features and details of the products, making it easier for the computer vision system to analyze them.

- Image Acquisition:

Capture images or videos of the products as they move through the production line. Ensure that the images are clear and representative of the entire product.

- Pre-processing:

Apply pre-processing techniques to enhance the quality of the captured images. This may include tasks such as noise reduction, contrast adjustment, and image normalization.

- Feature Extraction:

Identify and extract relevant features from the images that are crucial for quality assessment. This may involve detecting specific shapes, colours, textures, or other characteristics that are indicative of product quality.

- Training the Model:

Train a computer vision model using machine learning algorithms. This involves using a labelled dataset that includes examples of both acceptable and defective products. The model learns to recognize patterns and features associated with product quality.

- Integration with Manufacturing Equipment:

Integrate the computer vision system with the manufacturing equipment or production line. This may involve connecting the cameras to a central processing unit or control system.

- Real-time Analysis:

Implement real-time analysis of the captured images. The computer vision system should quickly assess whether each product meets the defined quality standards.

- Decision Making:

Implement a decision-making mechanism based on the analysis results. If a

product is identified as defective, appropriate actions can be taken, such as triggering an alert, diverting the product for rework, or stopping the production line.

- **Continuous Monitoring and Feedback:**

Continuously monitor the performance of the computer vision system and provide feedback to improve its accuracy over time. This may involve updating the model with new data or adjusting parameters based on the evolving manufacturing process.

- **Maintenance and Optimization:**

Regularly maintain and optimize the computer vision system to ensure its continued effectiveness. This includes updating software, calibrating cameras, and addressing any issues that may arise during operation.

**Goal:**

The goals of implementing computer vision-based quality control in manufacturing typically include:

**Enhanced Product Quality:**

By leveraging computer vision technology, manufacturers aim to elevate the overall quality of their products. By detecting defects, imperfections, or deviations early in the manufacturing process, they can ensure that only high-quality items are delivered to customers.

**Reduced Downtime and Rework Costs:**

Computer vision-based quality control minimizes downtime and rework costs associated with defective products. By identifying issues promptly, manufacturers can address them before they escalate, thereby avoiding production interruptions and the need for costly rework or recalls.

**Optimized Resource Utilization:**

Efficient allocation of resources is critical in manufacturing. With computer vision, manufacturers can optimize resource utilization by identifying and addressing inefficiencies in the production process, such as material wastage or equipment downtime.

#### Improved Speed and Efficiency:

Automating quality control through computer vision accelerates the inspection process, leading to faster production cycles. Real-time detection of defects allows for swift intervention, preventing bottlenecks and ensuring smooth operations.

#### Data-Driven Decision Making:

Computer vision systems generate vast amounts of data regarding product quality and production performance. By analyzing this data, manufacturers can gain valuable insights into trends, patterns, and root causes of defects, enabling data-driven decision-making and continuous process improvement.

#### Enhanced Compliance and Risk Mitigation:

Compliance with industry regulations and standards is crucial for manufacturers. Computer vision-based quality control ensures adherence to quality standards and regulatory requirements, reducing the risk of non-compliance and associated penalties or reputational damage.

#### Scalability and Adaptability:

Computer vision systems are scalable and adaptable, making them suitable for various manufacturing environments and product types. Manufacturers can easily deploy and customize these systems to meet evolving production needs and accommodate changes in product specifications.

#### Integration with Industry 4.0 Technologies:

Computer vision complements other Industry 4.0 technologies, such as IoT devices and machine learning algorithms, enabling seamless integration within smart manufacturing ecosystems. This integration enhances overall operational

efficiency and competitiveness.

#### Empowerment of Workforce:

Implementing computer vision-based quality control empowers the workforce by freeing them from mundane, repetitive tasks and allowing them to focus on more value-added activities, such as problem-solving and process optimization.

#### Competitive Advantage and Customer Satisfaction:

By consistently delivering high-quality products, manufacturers gain a competitive edge in the market and enhance customer satisfaction. Reliable quality control fosters trust and loyalty among customers, driving long-term business success.



### 1.Product Quality Assurance

- Product Quality Assurance (PQA) is a comprehensive set of systematic activities and processes designed to ensure that products meet or exceed predefined quality standards throughout their entire lifecycle.

- It encompasses measures taken to prevent, detect, and correct defects or deviations in a product, ensuring that it adheres to specified requirements and customer expectations.
- The goal of Product Quality Assurance is to establish and maintain processes that consistently produce high-quality products, fostering customer satisfaction, and building a reputation for reliability and excellence.
- PQA involves various stages, from design and manufacturing to distribution and post-sales support, with a focus on continuous improvement to enhance overall product quality.

## 2. Role of Computer Vision in Product Inspection

- Computer vision has revolutionized the field of manufacturing and quality assurance through its use in product inspection. A branch of artificial intelligence called computer vision has become a potent instrument for improving and automating inspection procedures so that goods fulfill exacting quality requirements.
- Here, we explore the essential elements that characterize computer vision's vital role in product inspection.

**manufacturing**





### 1. Precision and Accuracy :

- Computer vision systems excel in precision and accuracy, surpassing human capabilities in detecting subtle defects or variations in product
- This heightened accuracy ensures that even the smallest deviations from quality standards are identified, contributing to the overall improvement of product quality.

### 2. Speed and Efficiency :

- Automated product inspection powered by computer vision operates at remarkable speeds, surpassing the pace of manual inspections.
- This speed is essential for high-volume production lines, where quick and efficient inspections are imperative without compromising accuracy.

### 3. Consistency in Inspections :

- Computer vision systems provide a consistent and unbiased approach to inspections.
- Unlike human inspectors, they do not experience fatigue or variations in attention, leading to a more reliable and uniform assessment of products across different batches.

#### 4. Multi-faceted Inspections :

- Computer vision can be programmed to inspect products for various characteristics simultaneously.
- Whether it's detecting defects, checking dimensions, or verifying labels, computer vision systems can perform multi-faceted inspections with versatility, contributing to comprehensive quality control.

#### 5. Adaptability to Varied Products :

- One of the remarkable features of computer vision is its adaptability to diverse products and manufacturing processes.
- The same system can be trained to inspect different types of products, making it a flexible solution for industries with varying production lines.

#### 6. Reduction of Human Error :

- Automated inspections with computer vision significantly reduce the chances of human error. By eliminating the subjective elements of manual inspections
- computer vision ensures a more objective and reliable assessment of product quality.

#### 7. Real-time Monitoring :

- Computer vision allows for real-time monitoring of the production line, enabling instant identification and rectification of defects. This real-time feedback loop contributes to minimizing production downtime and potential losses.

#### 8. Data-driven Decision Making :

- The data generated by computer vision inspections can be leveraged for data-driven decision-making. Analytics derived from inspection results provide valuable insights into production trends, defect patterns, and areas for continuous improvement.

#### 9. Cost Reduction and Resource Optimization :

- Automated inspections contribute to cost reduction by minimizing the need for extensive manual labor.
- The deployment of automated systems reduces labor costs, and the efficiency gains lead to optimized resource utilization, making production processes more economically viable.

#### 3. Brief Steps Involved in Product Quality Assurance System

- To effectively integrate computer vision into PQA, a series of key steps must be followed. Data collection and preprocessing lay the groundwork, ensuring a reliable dataset for model training.
- Subsequent stages involve data annotation, model selection, and training, where algorithms learn to recognize defects and components.
- Augmentation techniques enhance model robustness, and validation and testing phases validate its performance on diverse data sets.

##### 3.1 Data Collection and Preprocessing:

- The foundation of any successful computer vision system lies in the quality and diversity of the data it is trained on.
- The initial step involves collecting a comprehensive dataset representative of the production environment.
- Preprocessing techniques are then applied to clean and enhance the data, ensuring that the model is trained on reliable information.

##### 3.2 Data Annotation:

- To train a computer vision model for PQA, a labeled dataset is essential.
- This involves annotating images with bounding boxes or segmentation masks, indicating the location and extent of defects or components.
- Tools like Labelerr facilitate this process, ensuring accurate annotations for effective model training.

## **Data Annotation**

### 3.3 Model Selection and Architecture:

Choosing the right model architecture is crucial for the success of a PQA system. Models like Convolutional Neural Networks (CNNs) have proven effective in image recognition tasks. The selection of the architecture depends on the specific requirements of the quality assurance task.

### 3.4 Model Training:

The annotated dataset is used to train the chosen model. During this phase, the model learns to recognize patterns and features that distinguish between acceptable and defective products. The training process involves adjusting the model's parameters to minimize errors and enhance accuracy.

### 3.5 Augmentation Techniques:

To enhance the model's robustness, data augmentation techniques are applied. This involves artificially expanding the dataset by introducing variations such as rotation, flipping, or changes in lighting conditions. Augmentation ensures that the model generalizes well to different scenarios.

### 3.6 Validation and Testing:

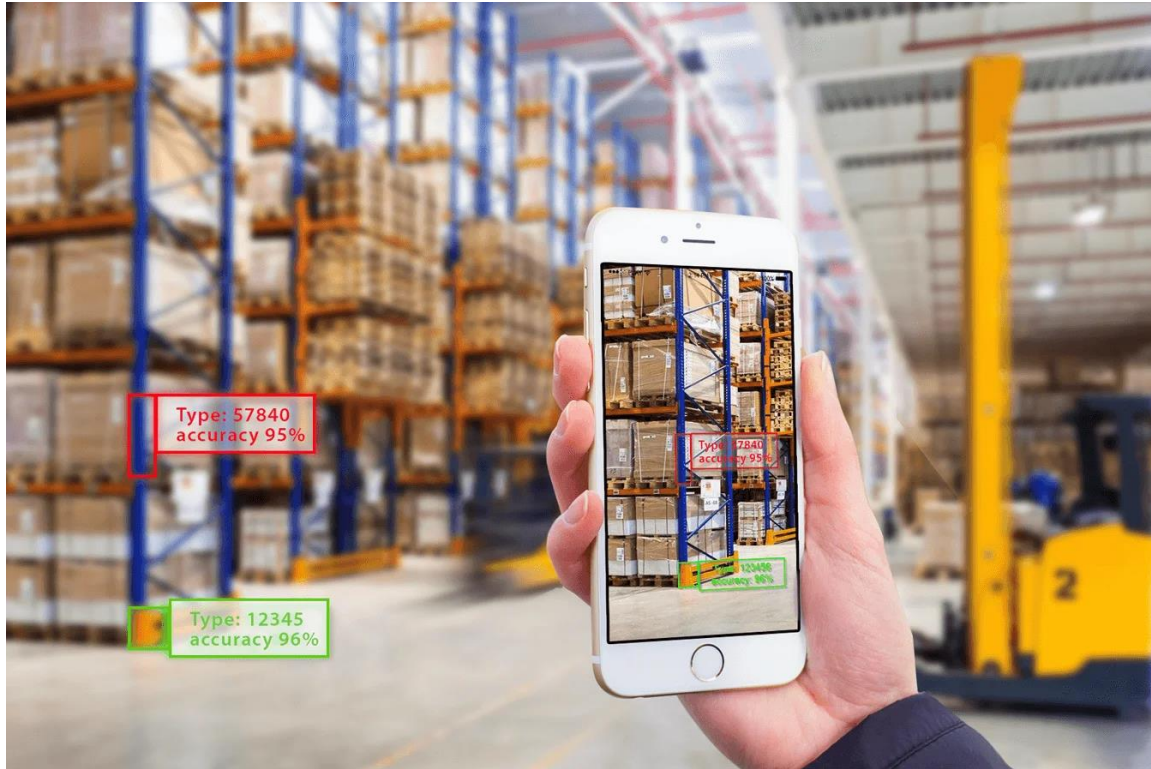
Once the model is trained, it undergoes validation and testing phases. Validation helps fine-tune parameters and prevent overfitting, while testing evaluates the model's performance on new, unseen data. Rigorous testing is crucial to ensure the reliability of the PQA system.

### 3.7 Integration and Deployment:

After successful testing, the model is integrated into the production line for real-time inspection. Seamless integration ensures minimal disruption to the manufacturing process. Deployment involves adapting the model to the production environment, accounting for variations in lighting and product positioning.

### 3.8 Real-time Processing and Optimization:

For effective PQA, real-time processing is essential. The computer vision system continuously analyzes incoming data, making instant decisions on product quality. Optimization techniques are employed to enhance the system's speed and efficiency.



#### 4. Monitoring and Continuous Improvement:

- The implementation of a PQA system doesn't end with deployment. Continuous monitoring is necessary to identify any issues or drift in performance.
- Regular updates and retraining of the model with new data contribute to continuous improvement, ensuring the system adapts to changes in the production environment.
- Monitoring and continuous improvement constitute integral components of an effective Product Quality Assurance (PQA) system. Monitoring involves the systematic observation and evaluation of the quality assurance processes and their outcomes.
- This ongoing scrutiny ensures that the established standards are consistently met and deviations are promptly identified.

- Continuous improvement, on the other hand, is a proactive approach aimed at enhancing the effectiveness of quality assurance processes over time.
- By analyzing performance metrics, feedback, and data from ongoing operations, organizations can identify areas for refinement, implement corrective actions, and optimize their PQA systems.
- This iterative cycle of monitoring and improvement is essential to adapt to evolving production dynamics and uphold or elevate product quality standards.

## 5.Applications and Real-world Impact

Computer vision has emerged as a transformative force in enhancing quality assurance across diverse industries. The applications of computer vision in quality assurance are far-reaching, revolutionizing traditional inspection processes and offering real-world impacts that significantly elevate overall product quality.

Here, we explore the specific applications and the tangible effects of implementing computer vision in quality assurance.

### **Defect**

#### 1. Automated Defect Detection :

- Computer vision excels in detecting defects with unparalleled precision. From manufacturing lines to product assembly
- automated systems equipped with computer vision algorithms can swiftly identify and classify defects, ensuring that only products meeting stringent quality standards proceed further in the production process.

#### 2. Product Classification and Sorting :

- Computer vision enables the automated classification of products based on predefined criteria. This is particularly valuable in industries where products have varying specifications.
- Automated sorting based on visual characteristics ensures that each product is directed to the appropriate category, optimizing the overall production workflow.

### 3. Dimensional Accuracy Checks :

- Quality assurance often involves ensuring products meet specific dimensional criteria. Computer vision systems are adept at performing accurate dimensional checks, verifying product dimensions against predefined standards.
- This ensures that products conform to precise specifications, minimizing variations in size and shape.



### 4. Label and Packaging Verification :



- Computer vision is employed for verifying labels, barcodes, and packaging integrity. Automated inspections ensure that the correct labels are applied, barcodes are readable, and packaging is intact.
- This not only guarantees compliance with regulatory requirements but also enhances overall product presentation.

5. Real-time Process Monitoring : Computer vision systems provide real-time monitoring of production processes. This instantaneous feedback allows for immediate corrective actions in case of deviations or defects, preventing the production of substandard products and minimizing potential waste.

6. Quality Control in Food and Pharmaceuticals :

- In industries such as food and pharmaceuticals, where product safety is paramount, computer vision ensures stringent quality control.
- Automated inspections identify contaminants, irregularities, or deviations from quality standards, contributing to the delivery of safe and high-quality products to consumers.

7. Improving Manufacturing Efficiency :

- By automating quality assurance processes, computer vision enhances manufacturing efficiency. The speed and accuracy of automated inspections contribute to streamlined production workflows, reducing the time required for manual inspections and increasing overall throughput.

8. Supply Chain Traceability :

- Computer vision aids in supply chain traceability by capturing and analyzing visual

data throughout the production and distribution processes.

- This not only enhances transparency but also facilitates tracking and identifying the source of any quality issues that may arise.

## 6.Challenges and Considerations

- The integration of computer vision into product inspection, while promising transformative benefits, comes with its set of challenges and considerations.
- Understanding and addressing these factors is crucial for successful implementation.

Here, we explore the key challenges and considerations associated with leveraging computer vision for product inspection.

### 1. Complexity of Product Variations :

Products within a manufacturing line often exhibit diverse shapes, sizes, and features. The complexity of handling these variations poses a challenge for computer vision systems, necessitating robust algorithms capable of adapting to diverse product characteristics.

### 2. Ambient Conditions and Lighting :

The quality of visual data captured by computer vision systems is highly dependent on ambient conditions and lighting. Variations in lighting conditions across different shifts or production environments can impact the accuracy of inspections, requiring adaptive algorithms and sophisticated image processing techniques.

### 3. Data Quality and Annotation :

The quality of the dataset used for training computer vision models is paramount. Insufficient or inaccurately annotated data can lead to sub-optimal model performance.

Ensuring a high-quality, diverse dataset is crucial for the successful deployment of computer vision in product inspection.

#### 4. Integration with Existing Systems :

Integrating computer vision into existing production systems can be a complex process. Compatibility issues, the need for additional hardware, and potential disruptions to ongoing operations should be carefully considered during the integration phase.

#### 5. Scalability and Performance :

As production volumes scale, the performance of computer vision systems must keep pace. Ensuring that the system remains efficient and responsive, even under increased workloads, is a consideration to prevent bottlenecks in the production line.

#### 6. Ethical and Regulatory Compliance :

Adhering to ethical standards and regulatory compliance is imperative when implementing computer vision in product inspection. Ensuring the responsible use of technology, addressing privacy concerns, and complying with industry-specific regulations are essential considerations.

#### 7. Human-AI Collaboration :

While computer vision automates many aspects of product inspection, there is a need for effective collaboration between automated systems and human inspectors. Establishing clear protocols for human-AI collaboration ensures that the strengths of both are leveraged to achieve optimal inspection outcomes.

#### 7.Future Trends in Computer Vision for Product Inspection

Looking ahead, several trends are poised to shape the future landscape of computer vision for product inspection, further enhancing its capabilities and applicability.



#### 1. Advancements in Deep Learning Architectures :

- Ongoing developments in deep learning architectures, including novel neural network structures and algorithms
- will continue to enhance the ability of computer vision systems to learn and adapt to complex inspection tasks.

#### 2. Edge Computing for Real-time Processing :

- The adoption of edge computing enables computer vision systems to process data closer to the source, facilitating real-time inspections without the need for extensive data transfer.
- This trend contributes to increased speed and efficiency in product inspection.

### 3. Explainable AI for Enhanced Transparency :

- As the importance of transparency in AI systems grows, the integration of explainable AI techniques allows for clearer understanding of how computer vision models arrive at specific inspection decisions
- addressing concerns related to the "black box" nature of some deep learning models.

### 4. Multi-modal Sensing Integration :

- Combining visual data with data from other sensor modalities, such as infrared or hyperspectral imaging, enhances the richness of information available for inspections.
- Multi-modal sensing integration provides a more comprehensive view of product characteristics.

### 5. Continuous Learning and Adaptability :

- Future computer vision systems for product inspection will likely incorporate continuous learning capabilities
- allowing them to adapt to evolving production environments and variations in product specifications over time.

### 6. AI-driven Automated Annotation :

- Addressing the challenge of data annotation, the future may see the rise of AI-driven tools that automate the annotation process
- reducing the manual effort required to prepare high-quality datasets for training.

### 7. Increased Collaboration Across Industries :

- Collaboration and knowledge-sharing across industries will become more prevalent, allowing insights and best practices from one sector to benefit others.
- This cross-industry collaboration accelerates the development and adoption of

effective computer vision solutions for product inspection.

- Modern technologies are being integrated into manufacturing processes as a result of the constant search for product quality.
- A subset of artificial intelligence called computer vision is one such revolutionary force that is changing the landscape of product quality assurance (PQA).
- It is becoming more and more important to comprehend the fundamentals of applying computer vision as enterprises move towards automated quality control.
- With the goal of offering a useful manual for companies looking to improve their quality assurance procedures, this blog provides a succinct analysis of the mutually beneficial link between computer vision and PQA.

#### Signal processing

- Yet another field related to computer vision is signal processing. Many methods for processing one-variable signals, typically temporal signals, can be extended in a natural way to the processing of two-variable signals or multi-variable signals in computer vision. However, because of the specific nature of images, there are many methods developed within computer vision that have no counterpart in the processing of one-variable signals. Together with the multi-dimensionality of the signal, this defines a subfield in signal processing as a part of computer vision.

#### Robotic navigation

- Robot navigation sometimes deals with autonomous path planning or deliberation for robotic systems to navigate through an environment.[22] A detailed understanding of these environments is required to navigate through them. Information about the environment could be provided by a computer vision system, acting as a vision sensor and providing high-level information about the environment and the robot.



### Visual computing:

- This section is an excerpt from Visual computing.
- Visual computing is a generic term for all computer science disciplines dealing with images and 3D models, such as computer graphics, image processing, visualization, computer vision, virtual and augmented reality and video processing. Visual computing also includes aspects of pattern recognition, human computer interaction, machine learning and digital libraries. The core challenges are the acquisition, processing, analysis and rendering of visual information (mainly images and video). Application areas include industrial quality control, medical image processing and visualization, surveying, robotics, multimedia systems, virtual heritage, special effects in movies and television, and computer games.

### Other fields

- Besides the above-mentioned views on computer vision, many of the related research topics can also be studied from a purely mathematical point of view. For example, many methods in computer vision are based on statistics, optimization or

geometry. Finally, a significant part of the field is devoted to the implementation aspect of computer vision; how existing methods can be realized in various combinations of software and hardware, or how these methods can be modified in order to gain processing speed without losing too much performance. Computer vision is also used in fashion eCommerce, inventory management, patent search, furniture, and the beauty industry.

## Distinctions

- The fields most closely related to computer vision are image processing, image analysis and machine vision. There is a significant overlap in the range of techniques and applications that these cover. This implies that the basic techniques that are used and developed in these fields are similar, something which can be interpreted as there is only one field with different names.
- On the other hand, it appears to be necessary for research groups, scientific journals, conferences, and companies to present or market themselves as belonging specifically to one of these fields and, hence, various characterizations which distinguish each of the fields from the others have been presented.
- In image processing, the input is an image and the output is an image as well, whereas in computer vision, an image or a video is taken as an input and the output could be an enhanced image, an understanding of the content of an image or even behavior of a computer system based on such understanding.
- Computer graphics produces image data from 3D models, and computer vision often produces 3D models from image data.[24] There is also a trend towards a combination of the two disciplines, e.g., as explored in augmented reality.

The following characterizations appear relevant but should not be taken as universally accepted:

- Image processing and image analysis tend to focus on 2D images, how to transform one image to another, e.g., by pixel-wise operations such as contrast enhancement, local operations such as edge extraction or noise removal, or geometrical



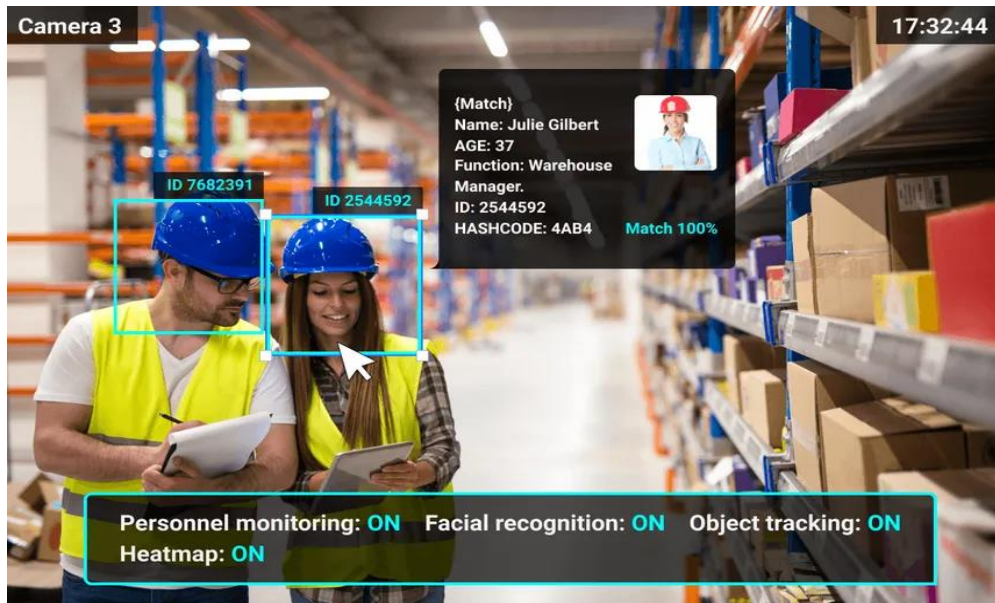
transformations such as rotating the image. This characterization implies that image processing/analysis neither requires assumptions nor produces interpretations about the image content.

- Computer vision includes 3D analysis from 2D images. This analyzes the 3D scene projected onto one or several images, e.g., how to reconstruct structure or other information about the 3D scene from one or several images. Computer vision often relies on more or less complex assumptions about the scene depicted in an image.
- Machine vision is the process of applying a range of technologies and methods to provide imaging-based automatic inspection, process control, and robot guidance in industrial applications. Machine vision tends to focus on applications, mainly in manufacturing, e.g., vision-based robots and systems for vision-based inspection, measurement, or picking (such as bin picking).
- This implies that image sensor technologies and control theory often are integrated with the processing of image data to control a robot and that real-time processing is emphasized by means of efficient implementations in hardware and software. It also implies that external conditions such as lighting can be and are often more controlled in machine vision than they are in general computer vision, which can enable the use of different algorithms.

propose of Quality check in manufacturing.

- There is also a field called imaging which primarily focuses on the process of producing images, but sometimes also deals with the processing and analysis of images. For example, medical imaging includes substantial work on the analysis of image data in medical applications.
- Finally, pattern recognition is a field that uses various methods to extract information from signals in general, mainly based on statistical approaches and artificial neural networks.[27] A significant part of this field is devoted to applying these methods to image data.
- Photogrammetry also overlaps with computer vision, e.g., stereophotogrammetry

vs. computer stereo vision.



## Applications

- Applications range from tasks such as industrial machine vision systems which, say, inspect bottles speeding by on a production line, to research into artificial intelligence and computers or robots that can comprehend the world around them. The computer vision and machine vision fields have significant overlap.
- Computer vision covers the core technology of automated image analysis which is used in many fields. Machine vision usually refers to a process of combining automated image analysis with other methods and technologies to provide automated inspection and robot guidance in industrial applications. In many computer-vision applications, computers are pre-programmed to solve a particular task, but methods based on learning are now becoming increasingly common. Examples of applications of computer vision include systems for varification

**overall quality manufacturing:**

- There are many kinds of computer vision systems; however, all of them contain these basic elements: a power source, at least one image acquisition device (camera, ccd, etc.), a processor, and control and communication cables or some kind of wireless interconnection mechanism.
- In addition, a practical vision system contains software, as well as a display in order to monitor the system.
- Vision systems for inner spaces, as most industrial ones, contain an illumination system and may be placed in a controlled environment. Furthermore, a completed system includes many accessories, such as camera supports, cables, and connectors.

Most computer vision systems use visible-light cameras passively viewing a scene at frame rates of at most 60 frames per second (usually far slower).

- A few computer vision systems use image-acquisition hardware with active illumination or something other than visible light or both, such as structured-light 3D scanners, thermographic cameras, hyperspectral imagers, radar imaging, lidar scanners, magnetic resonance images, side-scan sonar, synthetic aperture sonar, etc. Such hardware captures "images" that are then processed often using the same computer vision algorithms used to process visible-light images.
- While traditional broadcast and consumer video systems operate at a rate of 30 frames per second, advances in digital signal processing and consumer graphics hardware has made high-speed image acquisition, processing, and display possible for real-time systems on the order of hundreds to thousands of frames per second.
- For applications in robotics, fast, real-time video systems are critically important and often can simplify the processing needed for certain algorithms. When combined with a high-speed projector, fast image acquisition allows 3D measurement and feature tracking to be realized.

Egocentric vision systems are composed of a wearable camera that automatically take pictures from a first-person perspective.

- As of 2016, vision processing units are emerging as a new class of processors to

complement CPUs and graphics processing units (GPUs) in this role.

### **Conclusion**

Incorporating computer vision into Product Quality Assurance is a transformative step towards achieving higher levels of precision and efficiency in manufacturing. By following the outlined steps and leveraging proven methodologies, businesses can enhance their quality control processes, ultimately delivering superior products to consumers.

The ongoing advancements in computer vision technology promise even greater potential for the future of PQA, making it an integral component in the pursuit of excellence in manufacturing.