# Vision Technology in Smart Factories

## Executive Summary

Vision technology is rapidly transforming the manufacturing industry, enabling smart factories to achieve unprecedented levels of efficiency, quality, and safety. Once an expensive and exclusive luxury, this technology is now more affordable and accessible than ever before. From smart cameras to autonomous robotics, vision solutions are being used by manufacturers of all sizes to automate inspection tasks, improve product quality, and reduce costs.

The global computer vision market is expected to grow at a remarkable compound annual growth rate of 19.6% between 2023 and 2030, reaching a value of [$58.29 billion by 2030](https://www.grandviewresearch.com/industry-analysis/computer-vision-market). In recent years, there have been significant advances in the accuracy of computer vision systems. Contemporary systems can achieve an accuracy of up to [99%](https://towardsdatascience.com/everything-you-ever-wanted-to-know-about-computer-vision-heres-a-look-why-it-s-so-awesome-e8a58dfb641e), surpassing the capabilities of human inspectors. This makes them ideal for tasks that require rapid response to visual stimuli, such as defect detection and quality control.

Such capabilities hold significant importance in the context of smart factories. This paper elucidates the pivotal role of vision technology in orchestrating the smart factory transition. By automating inspection tasks, improving product quality, and reducing costs, vision technology can help manufacturers achieve their goals and compete in the global marketplace. Through an in-depth exploration of its applications, the challenges in adoption, and strategic steps for successful implementation, this paper aims to furnish a blueprint for the right use of vision technology in smart factories.

## Computer Vision's Evolution Over the Years

Computer vision, a fascinating field that endows machines with the gift of sight, has evolved significantly over the decades. Over the years, various inventions and implementations have reflected upon a transformative evolution of the technology — from early endeavours in object recognition to ground-breaking achievements in autonomous vehicles and deep learning applications.

### **How It All Started?**

**1960s:**The roots of computer vision can be traced back to this era when Lawrence "Larry" Roberts, known for his pivotal contributions to the internet, delved into the possibilities of extracting [three-dimensional geometrical information](https://dspace.mit.edu/bitstream/handle/1721.1/11589/33959125-MIT.pdf) from two-dimensional perspective views of objects.

**1970s:** Researchers began investigating the use of neural networks to enhance the precision of computer vision algorithms, setting the stage for more sophisticated developments in the field.

**1980s:** The introduction of the[Hough Transform](https://www.sciencedirect.com/topics/computer-science/hough-transforms#:~:text=The%20Hough%20transform%20(HT)%20%5B,the%20Radon%20transform%20%5BDeans81%5D) in this decade marked a significant milestone. It enabled the detection of complex shapes in images, a crucial advancement for computer vision.

**1990s:**Notably, in 1996, the DARPA Grand Challenge was launched, sparking the development of autonomous vehicles designed to navigate a gruelling 200-mile desert course.

**2000s:**Facebook started harnessing facial recognition, and Google introduced TensorFlow, a prominent machine-learning framework. In 2001, Carnegie Mellon University demonstrated the first self-driving car. Google joined the autonomous vehicle race in 2009 by announcing its self-driving car project.

### **Where Is It Today?**

Today, computer vision systems are capable of performing complex tasks such as object detection, image segmentation, and facial recognition with high levels of accuracy and efficiency. This has led to their widespread adoption in a wide range of industries, including transportation, healthcare, agriculture, retail, and manufacturing.

One of the most notable trends in computer vision is its increasing ubiquity in our daily lives. For example, computer vision is used in self-driving cars to identify objects on the road, in smartphones to unlock devices and take photos, and in social media platforms to tag friends and identify objects in images. Apple's Face ID, Google Lens, and more are real-life examples of computer vision's omnipresence. These applications have an exceptionally low usage entry barrier.

Another important trend is the shift towards edge computing for computer vision applications. Edge computing allows computer vision systems to run directly on devices, such as smartphones and cameras, without the need to send data to the cloud for processing. This improves performance and reduces latency, which is essential for many real-time applications.

In the context of smart factories, in particular, computer vision systems are scaling from proof of concepts (POC) to full-fledged implementations for a variety of applications — predictive maintenance, inspection, safety standard adherence, defect reduction, perimeter security, object dimensioning, and more. Jason Bergstrom of [Deloitte Consulting](https://www.industryweek.com/technology-and-iiot/article/21256878/where-manufacturing-technology-goes-in-2023-part-1) says that implementing the AI/ML-backed technologies on the "factory floor will be key to providing insights and capabilities needed to make their factories more predictive, adaptable, efficient, and competitive."

## How Vision Technology is the Foundational Element of "Smart" in Factories?

Computer vision technology serves as the bedrock of "smart" in factories, underpinning automation, productivity enhancements, and optimised supply chains. In the Industry 4.0 smart factories, [machine vision](https://www.qodenext.com/blog/what-is-machine-vision-and-applications/) plays a pivotal role by providing a diverse array of critical data.

Edge computing acts as a vital cog in gathering pertinent information about products, processes, and personnel, facilitating highly automated manufacturing. In the end, operators are equipped with the tools to effectively monitor machinery and factory workers and conduct quality checks and dimensional inspections with unparalleled speed and precision.

### **The Case for Process Efficiency**

Every minute counts, and inefficient processes can have significant financial implications. These inefficiencies impact not only the bottom line but also the customer experience. The precious time wasted on inefficient processes or systems is time that could be better spent delivering value to customers. This is where computer vision technology becomes vital to enhance process efficiency within smart factories.

* **Cycle Time Control**: Computer vision systems are capable of measuring the time of every production cycle, enabling the deduction of the best practice time for each cycle. This helps in reducing target time and meeting takt time, resulting in a more efficient assembly process.
* **Efficiency Optimisation:** Vision technology monitors and analyses the performance, utilisation, and condition of equipment, leading to downtime reduction and enhanced production line efficiency.
* **Equipment Monitoring and Predictive Maintenance:** Real-time monitoring of machinery and equipment for signs of wear and damage is made possible through computer vision. The proactive approach helps prevent breakdowns and, again, helps reduce production line downtime.
* **Data-Driven Decision-Making:** Vision technology provides invaluable data on product quality, machine performance, and production efficiency. This data-driven approach empowers manufacturers to make informed decisions and tone down the high costs associated with the usual post-mortem analysis.

### **The Case for Assembly Process Automation**

Automating the assembly process is the cornerstone of smart factories, and computer vision plays a pivotal role in achieving this. Here are key aspects of how vision technology revolutionises assembly automation:

* **3D Modelling for Precision Assembly:** Computer vision extends its capabilities into three-dimensional modelling, providing precise product models for assembly guidance. By utilising volumetric data from sources like LIDAR and multiple 2D images, the vision technology enables the creation of detailed 3D models. These models serve as a foundation for monitoring and guiding assembly processes, even by robotic arms. This results in unparalleled assembly precision, with applications spanning augmented reality/virtual reality (AR/VR), robotics, design, self-driving cars, and drones. The major tasks here include classification, object detection, and segmentation (semantic, instance, part pose).
* **Enhancing Product Quality through Defect Detection:** Computer vision excels in detecting defects in products, leading to a substantial improvement in product quality and waste reduction. Combining machine learning-powered anomaly detection with computer vision enables automated visual inspections that can identify a wide range of anomalies, ensuring that only flawless products move forward in the assembly process.
* **Increasing Picker Efficiency with Pick to Light (PTL) Technology:** [Pick to light (PTL)](https://www.qodenext.com/blog/pick-to-light-system-everything-you-need-to-know/) technologies enhance picker productivity. Enabled by computer vision, these technologies can guide operators and streamline the order-picking process. The idea is to enable high-speed order fulfilment and ensure top-notch picking rates.

### **The Case for Safety and Security**

Safety and security are of paramount importance in smart factories, where operational risks and cybersecurity threats are significant concerns. In fact, cyberattacks pose a substantial threat to manufacturing firms, with their costs averaging nearly [$4.5 million](https://shardsecure.com/blog/data-security-landscape-manufacturing). Favourably, computer vision technology contributes to safety and security in multiple ways.

* **Worksite Safety:** Computer vision systems intelligently monitor visual data, such as CCTV footage, to ensure worksite safety. They detect safety hazards in real time, preventing accidents and enhancing human-machine safety.
* **Productivity:** The vision technology facilitates early detection of machinery degradation. Combined with the Internet of Things (IoT) and deep learning, the technology provides consistent and accurate monitoring. Engineers can receive maintenance alerts before issues occur.
* **Improved Quality:** Computer vision identifies production issues, segregates faulty products, and improves process efficiency, contributing to higher product quality. Such capabilities can also help in toning down the leaks on the digital side that can otherwise be exploited by hackers.

## Adoption Use Cases for Vision Technology in Smart Factories

The adoption of vision technology within the smart factory framework can revolutionise various aspects of manufacturing and production. Let's delve into the diverse applications of this technology:

### **Quality Inspection**

Quality inspection is critical to the successful functioning of modern smart manufacturing systems. Its prominence arises from the multifaceted objectives that manufacturing companies strive to achieve. These objectives encompass:

* The delivery of high-quality products
* Fostering brand loyalty
* Ensuring regulatory compliance
* Optimising resource utilisation to minimise waste and maximise profits

Quality inspection is a pivotal component in attaining these goals, and it entails various interventions, ranging from human operators to sophisticated sensor systems. It's here that cutting-edge image-based quality inspection systems gain prominence.

Leveraging vision technology for quality inspection helps scrutinise items for defects, inconsistencies, and imperfections that may be imperceptible to the human eye. This meticulous inspection process ensures that only products meeting stringent quality standards advance to the next production stage.

### **Lean Manufacturing**

To remain competitive in today's global marketplace, manufacturers strive for leaner, more efficient processes. Vision technology plays a pivotal role in this endeavour by identifying inefficiencies, bottlenecks, and opportunities for process optimisation. By collecting and analysing real-time data, as discussed above, these systems help factories become more agile and responsive, reducing waste and enhancing productivity.

### **Compliance Monitoring**

Adhering to industry regulations and standards is a fundamental requirement in manufacturing. Vision systems enable real-time compliance monitoring, allowing factories to proactively address non-compliance issues. Through continuous surveillance and data analysis, these systems ensure that processes align with the necessary standards, thereby reducing the risk of regulatory violations and associated penalties. Adherence to worker safety regulations is also facilitated.

### **Equipment Monitoring**

Minimising downtime and unplanned maintenance is a top priority in smart factories. Vision technology continuously monitors the health and performance of machines and equipment. It employs predictive analytics and condition monitoring to detect anomalies and signs of wear and tear. By sending alerts when maintenance is needed, these systems help factories schedule repairs during planned downtime, optimising equipment lifespan and production efficiency.

### **Establishment's Security**

The security of a smart factory is paramount, as it houses valuable assets, sensitive information, and critical infrastructure. Vision technology enhances security by offering advanced access control and surveillance. These systems use facial recognition, access cards, and real-time video feeds to restrict unauthorised access to secure areas. Additionally, surveillance cameras with intelligent analytics can identify and respond to security threats promptly.

### **Supply Chain Optimisation**

Smart factories are embedded in a complex web of supply chains that span the globe. Vision systems streamline the tracking of products at each stage of the [supply chain](https://www.qodenext.com/blog/logistics-and-supply-chain-management/), from manufacturing to distribution. This optimisation enhances transparency, allowing manufacturers to monitor the status and location of products in real-time. This not only improves operational efficiency but also reduces errors, ensuring that products reach their destinations efficiently and in line with production schedules.

### **Workers’ Safety Enhancement**

Worker safety is a growing concern in the age of computer vision. As computer vision technology becomes more prevalent in industries such as manufacturing, healthcare, and transportation, there is a need to ensure that workers are protected from potential hazards. This includes ensuring that computer vision systems are designed and implemented with safety features such as collision avoidance, obstacle detection, and worker tracking.

Besides, vision technology can improve workplace safety in several ways, including:

* **Monitoring high-risk areas:** Computer vision systems can continuously monitor high-risk areas, such as those laden with machinery and equipment. This can help identify potential hazards and alert employees.
* **Detecting PPE violations:**Visual analytics can detect when a worker is not wearing the appropriate personal protective equipment (PPE) and alert them to put it on.
* **Recognising appropriate form:**Vision models can also be trained to recognise appropriate forms for tasks like lifting heavy objects.
* **Monitoring risky processes:**Computer vision models can further monitor employees as they engage in risky processes, like working at heights.

## Challenges of Implementing Computer Vision in Smart Factories

Having a full-fledged visual analytics implementation across the factory floor is not without its challenges. For manufacturers, it becomes critical to comprehend these and create strategies that could proactively address and alleviate them.

### **Data Quality and Security Concerns**

For visual analytics systems to perform optimally, they must have substantial data at their disposal. The visual data collected needs to be managed and annotated to prevent any imperfections or biases from creeping up. Plus, organisations need to ensure that the processing of sensitive data, such as facial or biometric data, is not compromised. They have to have proper security frameworks in place to ensure data security across all touchpoints.

### **Idea to POC to Scalability**

It's one thing to have an idea and test it across a specific use case in a constrained environment. But it's an entirely different game altogether when it comes to implementing that on the factory floor. Businesses have to account for the:

* The upfront cost involved in making the full-fledged implementation an instant hit
* The hardware installation requirements in terms of their use and strategic placement
* The software requirements that can help create a centralised platform for holistic visibility and action
* The integration requirements with existing systems and how can such integration play out

### **Technical Support**

Implementation is just one step. Organisations need to ensure that their vision technology is constantly performing at its best to prevent downtime and reactive maintenance. For that, they have to have technical support in place. Favourably, manufacturers can look at two options in such a scenario. They can either invest in training their in-house staff or have external vision technology experts take care of the system.

### **Regulatory Compliance**

The accuracy of a computer vision platform will be immensely critical when it comes to ensuring that workers are safe, operations are streamlined, and everything proceeds as per the state or national-level regulations. Ensuring such accuracy, however, would again require constant upkeep of the entire ecosystem, from hardware (like sensors) to centralised inspection software.

## Setting Up the Vision Technology for Success

By following these steps, you can set up a vision technology system that helps drive your business forward.

### **Identifying the Requisite Use Cases**

The success of vision technology in smart factories is dependent on its appropriate usage. This encompasses understanding and defining the specific use cases, identifying the required criteria to select the most suitable option, and implementing a well-defined integration strategy.

### **Creating a Proof of Concept (POC)**

Setting up a proof of concept (POC) is a critical step for obtaining business confidence. A POC enables companies to demonstrate the efficacy and benefits of vision technology. This leads to buy-in from stakeholders, helps champion project adoption, and helps establish vision technology as the core driver for future smart factory solutions.

### **Laying Out a Concrete Roadmap to Scale POC**

Building and implementing a roadmap is crucial to optimising the impact of vision technology in smart factories. This roadmap should be defined in consultation with stakeholders to ensure sector-specific requirements – such as logistical, metrology, and human capital, for instance. Additionally, the roadmap must outline clear KPIs, timelines, cost and investment estimates, and relevant milestones across the entire project lifecycle.

### **Setting Up the Infrastructure (Hardware & Software Considerations)**

Laying out the infrastructure and integrating it with other factory systems requires expertise, as it involves various technologies and disciplines, including embedded systems, computer vision, real-time operating systems, remote-sensing devices, data analytics software, and networking technologies. This effort should be spearheaded by a technical lead who has extensive experience in implementing similar solutions.

### **Testing and Validating the Setup**

Test modes, automated testing platforms, and other software development tools ensure that vision technology in smart factories is ready for use. These tools enable companies to run simulation models to test and validate the entire setup before adopting it.

### **Ensuring the Integration of Vision Technology with Other Systems**

Due to their inherent nature of integrating a myriad of different technologies, vision systems are often integrated with other factory systems – such as ERP, PLCs, HMI/SCADA, robotics/CAD/CAE, etc. A concrete business strategy must define these integrations to prevent any unnecessary disruptions.

### **Investing in Training and Maintenance**

Vision technology in smart factories requires a skilled workforce to ensure all stakeholders thoroughly understand its various functions and use cases. Additionally, it requires regular maintenance and upgrades to ensure that it continues to deliver the desired benefits. So, all in all, computer vision's introduction in factories needs a holistic approach that encompasses expertise on both the engineering and manufacturing end.

## Conclusion

As we stand on the cusp of the fourth industrial revolution, computer vision technology is a driving force propelling industries toward efficient, secure, and intelligent smart factories. It underscores the idea that the path to a smarter and more efficient future begins with vision technology. However, the successful adoption of vision technologies requires manufacturers to keep aware of the various implementation and scaling challenges. They must invest in laying out a concrete roadmap and seek technical help to set up visual analytics across their factory for success.

## About QodeNext

[Qodenext,](https://www.qodenext.com/) a leading solutions provider in the vision technology space, is helping smart factories achieve unprecedented levels of efficiency, quality, and safety through its advanced machine vision and industrial vision solutions.

We help organisations improve product quality, reduce errors, lower operational costs, amplify productivity, tone down wastage, improve establishment safety, and ensure traceability. From picking technologies to advanced machine vision, our solutions are highly configurable and reliable, serving a wide range of industries. [Book a call](https://www.qodenext.com/contact-us.php)with us today to learn more.