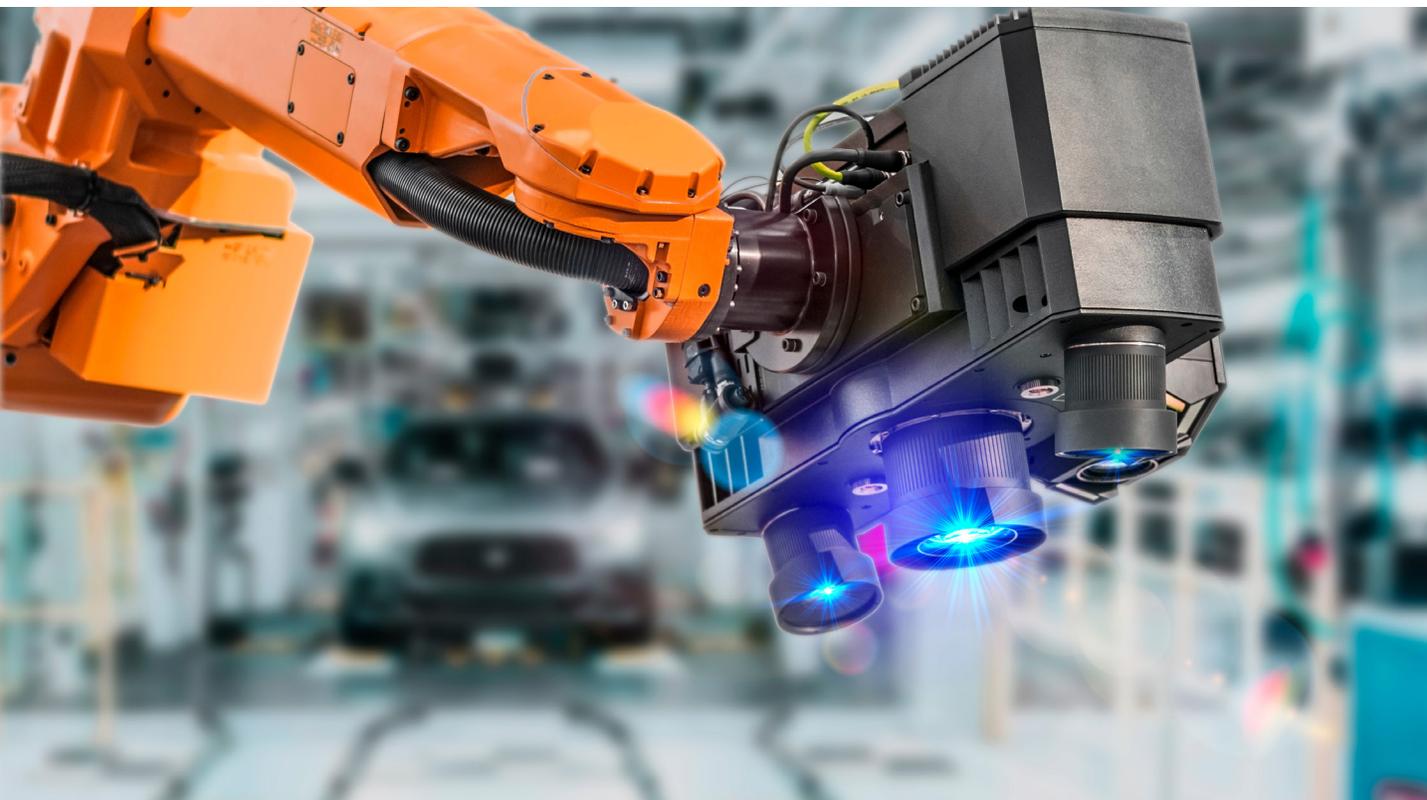# Design and Deployment Advantages for 3D Imaging Devices

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Introduction

One of the fastest-growing segments of the machine vision industry is 3D inspection, driven by software advancements that make it easier to design, deploy and integrate the technology for a wider range of applications.

Previously, 3D vision technology was expensive and complex, limiting its adoption to high-end industrial applications. However, decreasing costs and increasing accessibility have positioned 3D vision solutions as viable for a broader range of industries, including manufacturing, logistics, robotics, and quality control.

By replacing multiple 2D cameras with one or two dedicated 3D cameras, end users can reduce installation complexity, lower system costs, and enhance operational efficiency. Additionally, improvements in plug-and-play software and ease of use are accelerating the transition from 2D to 3D vision systems.

3D vision solutions are delivering the machine vision industry's unparalleled requirement for precision

While the benefits of 3D inspection are clear, some challenges do remain. Device designers face mounting pressure to delicately balance demanding performance, cost, and integration requirements.

This white paper explores the following:

- The technological landscape of 3D machine vision

- Key challenges facing 3D imaging device design and cost

- Pleora's eBUS Edge software as a cost-effective, scalable, and standards-compliant solution that reduces design cost and eases integration for 3D imaging devices

Technology Market Overview

When designing a 3D imaging device, it's important to understand the different types of 3D imaging technologies available. The 3D machine vision market encompasses several competing technologies, each suited for different industrial applications.

3D imaging plays a crucial role in enabling precise object detection, depth measurement, and automated decision-making across various industries. When designing a 3D imaging device, engineers must consider the technology type, operating principles, accuracy, speed, and environmental adaptability to ensure the best fit for a given application.

The following are four primary categories of 3D imaging devices widely used in industrial automation, robotics, logistics, healthcare, and quality inspection. Each technology has its own advantages, challenges, and ideal use cases.

1. Structured Light

Structured light cameras project a known pattern (such as a grid or stripes) onto an object and analyze how the pattern deforms to generate a 3D map.

These cameras offer high-resolution depth information and are widely used in:
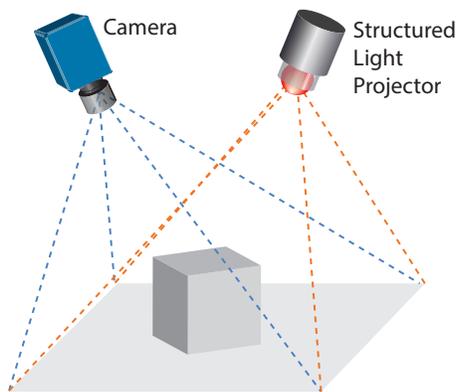
- Quality control
- Automated bin-picking
- Precision measurement
- 3D metrology

Despite their accuracy, structured light cameras tend to be expensive, which has been a barrier to widespread adoption. However, increasing competition, advancements in light sources, and improvements in processing algorithms are driving down costs.

2. Time-of-Flight (ToF) Cameras

ToF cameras measure the time it takes for light to reflect from an object back to the camera, allowing for real-time 3D depth mapping with minimal latency.
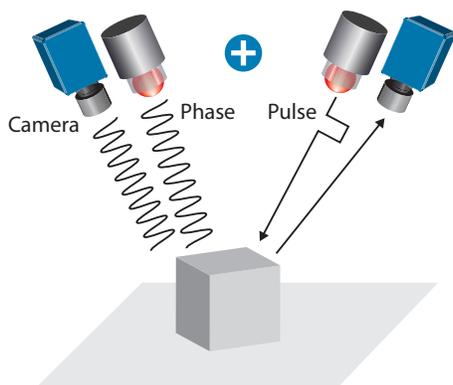

Unlike structured light or stereo vision, ToF technology is ideal for:

- High-speed robotics
- Autonomous vehicles
- Industrial automation
- Gesture recognition

The primary advantage of ToF cameras is their ability to operate in dynamic environments while maintaining accuracy. These cameras eliminate motion blur, making them superior for applications where speed is critical.

3. Stereo Vision

Stereo vision mimics human depth perception by incorporating two or more cameras to capture images from different angles. By comparing disparities between these images, stereo vision systems reconstruct a 3D model of the environment.
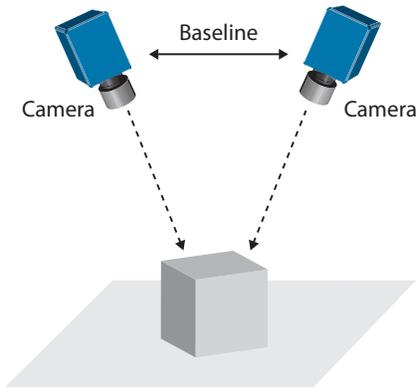

This technique is commonly used in:

• Autonomous mobile robots (AMRs)
• Drones
• Smart surveillance systems

However, stereo vision can be particularly susceptible to lighting variations and texture inconsistencies, requiring advanced post-processing algorithms for accuracy.

4. Laser Triangulation

Laser triangulation employs a laser beam to scan an object's surface, capturing the reflection with a high-resolution camera to calculate precise depth measurements.
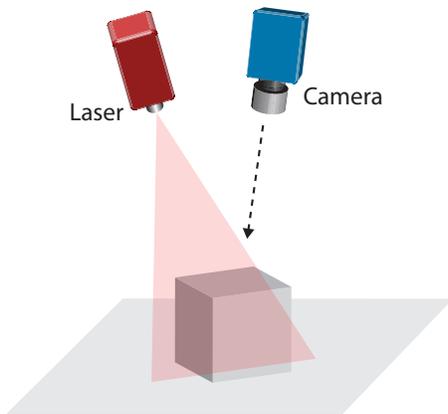
This method is commonly used in:

• High-precision manufacturing
• Surface inspection
• Semiconductor industries

Laser triangulation offers exceptional accuracy but can prove to be complex and expensive to integrate into machine vision systems.

Market Trends and Adoption

The demand for 3D machine vision solutions is quickly increasing, with industries ever more relying upon automated bin-picking, cobots (collaborative robots), autonomous mobile robots (AMRs) and automated guided vehicles (AVGs).

Choosing the Appropriate 3D Imaging Technology

- *Ultra-precise measurements?*
  Structured Light or Laser Triangulation

- *Real-time scanning for fast-moving objects?*
  ToF Cameras

- *Cost-effective depth perception?*
  Stereo Vision Cameras

This includes robotic bin-picking applications requiring precise 3D data to handle objects with random orientations, and navigation and obstacle and object detection for AMRs and AVGs that move goods around factories and warehouses.

Overcoming 3D Design and Cost Challenges

As 3D vision systems shift from high-end to mainstream applications, device designers face several challenges, including cost constraints, system integration, and real-time processing.

1. Cost Optimization

Affordability is a critical factor for the widespread adoption of 3D vision.

Designers must now consider:

- **Hardware costs** - sensors, processing units, and custom optics significantly impact the final price.
- **Development time** - reducing design complexity to accelerate time-to-market.
- **Interface technology** - 3D imaging devices must seamlessly integrate with off-the-shelf processing, which adds costs, complexity and time to proprietary development.

Real-time 3D vision applications demand low-latency, high-speed data transmission. 3D machine vision inspection dramatically improves

processing efficiency by reducing errors, inspection time, and manual interventions while enabling real-time decision-making, automation, and predictive maintenance.

Software-based interface approaches are key to addressing these challenges to enable device manufacturers to build cost-effective 3D vision systems while maintaining high performance.

2. Seamless System Integration

One of the largest hurdles to overcome in 3D vision is ensuring smooth integration between imaging devices and existing machine vision processing. Many traditional 3D cameras rely on proprietary interfaces, adding complexity and limiting interoperability.

Standardized connectivity solutions based on the GigE Vision provide plug-and-play compatibility, simplifying integration with third-party processing software.

Another key challenge is handling multi-part data streams. 3D systems generate multiple data types (depth maps, color images, metadata), requiring efficient synchronization. Software solutions, such as Pleora's eBUS Edge, optimize multi-part data handling, ensuring real-time performance.

GigE Vision and GenICam Integration

Pleora's eBUS Edge is a software-based connectivity platform designed to transform 3D cameras into fully compliant GigE Vision and GenICam devices. Unlike traditional hardware-based approaches, eBUS Edge eliminates the need for additional physical components to reduce footprint while ensuring seamless data transmission over standard Ethernet cabling.

This solution simplifies system integration by offering plug-and-play compatibility with existing machine vision processing software, reducing integration time and lowering development and deployment costs. Device designers can implement high-performance, real-time 3D imaging applications without modifying their existing workflows.

Why Standardization Matters in 3D Machine Vision

GigE Vision and GenICam are widely adopted machine vision standards that ensure interoperability across different camera manufacturers, image processing platforms, and automation systems.

By adhering to these standards, eBUS Edge:

- **Eliminates vendor lock-in** - system designers and integrators can mix and match cameras, sensors, and software from different suppliers

- **Ensures long-term compatibility** - future-proofing investments in machine vision hardware and software for future scalability of device and system design

- **Reduces development complexity** - the off-the-shelf software solution streamlines device design and processing integration, making it easier for integrators to implement 3D vision applications

Without compliance with these standards, system integrators and designers risk compatibility issues, requiring costly custom software development.

Key Benefits of eBUS Edge

Pleora's eBUS Edge is a software-based connectivity platform designed to transform 3D cameras into fully compliant GigE Vision and GenICam devices. Unlike traditional hardware-based approaches, eBUS Edge eliminates the need for additional physical components to reduce footprint while ensuring seamless data transmission over standard Ethernet cabling.

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At the processor, eBUS Receive manages high-speed reception of images or data into buffers for hand-off to the end application for further analysis. With eBUS Receive, developers can write applications that run on a host computer to seamlessly control and configure an unlimited number of GigE Vision, USB3 Vision, and GenICam compliant sensor devices. The eBUS Universal Pro driver reduces CPU usage when receiving 2D images or 3D data, leaving more processing power for analysis and inspection applications while helping to meet latency and throughput requirements for automated real-time inline inspection applications.

These following features showcase eBUS as a proven and robust solution for high-performance image acquisition and processing in diverse machine vision applications.

Eliminating Hardware Dependencies

By providing software-based GigE Vision transmission, eBUS Edge removes the need for specialized hardware components thereby simplifying system architecture and reducing costs.

Cost Efficiency

By eliminating the need for additional hardware and enabling the use of standard Ethernet infrastructure, eBUS Edge reduces both initial setup and ongoing maintenance costs.

Multi-Part Data Handling

eBUS Edge efficiently synchronizes and transmits multiple data streams, including depth maps, 2D images, and metadata, ensuring accurate real-time analysis essential for 3D inspection applications.

Scalability and Flexibility

The software-based nature of eBUS Edge allows for easy updates and scalability, enabling manufacturers to adapt to evolving inspection requirements without significant additional investment.

Standards Compliance

The platform ensures devices are fully compliant with GigE Vision and GenICam standards, facilitating seamless integration and interoperability with existing machine vision processing.

End-to-End Low Latency Performance

With eBUS Receive, designers can implement a transmit-and-receive solution that streamlines the handoff of vision-standard video for processing and analysis while optimizing CPU usage.

Conclusion

While the shift to 3D machine vision is transforming automation, robotics, and industrial inspection, cost and integration challenges continue to pose barriers for device designers and system integrators. As industries move towards Industry 4.0 and smart manufacturing, 3D vision technology will play a critical role in optimizing production speed, quality control, and robotic automation.

Software-only interface options, including Pleora's eBUS Edge, provide a zero-footprint approach that eliminates the time, cost, and complexity of designing proprietary interface solutions.

As a standard-based solution, Pleora's software provides seamless integration with off-the-shelf machine vision processing to make it easier and more cost-effective to deploy 3D inspection.

For more information on eBUS Edge and its applications, visit [Pleora Technologies](#).