OPTICS

2 KEY TOOLS

Why You Need to Consider Sunex DXM™ and SXM™ in Your Next **HUMANOID ROBOT SYSTEM.**

SHOW EDITION

Sunex

36° Dual Lens

Dual Channel
Single Sensor Module

Sunex DXM™ - Stereo Vision in a Smaller Package

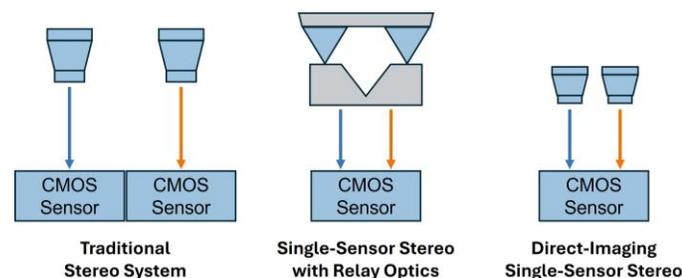## Single-Sensor Stereo Imaging in Robotics and Beyond

As robotics and automation systems grow increasingly compact, intelligent, and power-efficient, the supporting vision technologies must evolve in parallel. One area undergoing rapid growth and innovation is **single-sensor stereo imaging**, where two optical channels converge onto a single CMOS sensor.

This architectural shift offers a powerful blend of reduced physical footprint, lower power consumption, improved synchronization, color-matching, and overall cost efficiency. Originally explored for space-constrained applications, the concept is now gaining momentum across a diverse set of platforms, including **Autonomous Mobile Robots (AMRs)**, **Automated Guided Vehicles (AGVs)**, **humanoid robots**, **manufacturing automation**, and even **multi-modal vision systems**.

The Architecture: Two Optical Channels, One CMOS Sensor

A single-sensor stereo imaging system consists of two independent optical channels, based on two different base architectures. The result in either case is a stereo image pair captured simultaneously, pixel-aligned, and temporally consistent, without the need for a second sensor.

- **Relay-prism or mirror systems**, which allow a longer baseline (distance between the optical channels), enabling better depth perception at mid-to-long ranges.
- **Direct-imaging optics**, where two small lenses with a shorter baseline directly image adjacent scenes onto the same CMOS sensor.

Comparison of stereo imaging architectures

Compact Design and Space Efficiency

The compactness of single-sensor stereo systems is obviously one compelling feature. This opens the door to new designs for **low-profile AGVs**, **slim robotic arms**, or **humanoid head units**, where stereo vision must be integrated without adding bulk or weight. Building on experiences in designing and manufacturing miniaturized optics for automotive and medical systems, the DXM™ direct imaging solution enables tighter baselines without sacrificing image quality or manufacturability.

Sunex DXM™ Direct Imaging camera leveraging SXM™ pre-aligned and interchangeable dual-optics heads.

Power Efficiency in Battery-Operated Systems

In battery-powered robots, energy is often the most limited resource. A conventional two-sensor stereo setup not only doubles sensor power draw but also adds thermal and processing load for synchronizing and handling dual video streams. With a single-sensor system, all duplicate overhead is eliminated.

Perfect Synchronization and Simplified Calibration

Another major advantage of single-sensor stereo imaging is **zero latency synchronization**, paramount for fast-moving robotic systems or dynamic environments. Both images are captured on the same sensor die in the same exposure cycle. This eliminates the need for complex software-level synchronization, color matching, dual-sensor calibration routines, or even sensor-to-sensor alignment.

Cost Efficiency: Fewer Components, Lower BOM

Reducing component count directly translates to lower costs, not just in materials, but also in assembly, calibration, and quality control. A single-sensor stereo system uses:

- One sensor (instead of two)
- A shared image processing pipeline
- Fewer connectors, cables, and serializers
- Simplified housing and optical alignment

Sunex DXM™ for wide baseline requirements

Performance Considerations

While compelling, single-sensor stereo systems are not without trade-offs.

- **Baseline Constraints** - In direct imaging configurations, the baseline is inherently limited by the physical size of the optics and sensor. This constrains the depth resolution and range, making such systems better suited for near-field applications (e.g., 0.2 – 2 meters). Relay optics can increase baseline distance, but at the cost of added optical complexity and potential alignment drift if not properly designed.
- **Reduced Per-Channel Resolution** - Because the sensor area is split between two optical channels, each stereo view occupies only half (or less) of the total pixel array. While sufficient for many tasks, such as obstacle detection or object segmentation, this may be inadequate for high-precision metrology or long-distance depth mapping and would likely require a switch to a higher-resolution sensor.

Application-Specific Opportunities

AGVs and AMRs - Warehouse robots and last-mile delivery bots require compact, cost-effective depth perception for obstacle avoidance and autonomous navigation. Since the operating environment is structured and typically well-lit, the reduced baseline of a direct imaging and resolution of a single-sensor dual-channel system are acceptable trade-offs for gains in size, weight, and battery life.

Humanoid and Consumer Robots - For robots that interact with people or operate in tight spaces—such as service robots, assistants, or educational bots—single-sensor stereo vision provides reliable depth awareness for facial tracking, gesture detection, and object manipulation. The compact form factor enables the embedding of vision systems in aesthetically pleasing designs.

Manufacturing Automation - In high-speed production lines, stereo vision is used for bin picking, height profiling, presence detection, and assembly inspection. Single-sensor stereo cameras provide an efficient way to deliver these functions in a durable, factory-ready package. Their simplified calibration and reduced cabling also translate to easier deployment and less downtime.

Expanded Use Cases Beyond Traditional Stereo Imaging

The same architecture used for stereo vision can also be adapted for multi-modal or dual-purpose imaging by varying the optical paths or filters on each channel. This unlocks several compelling new applications:

Dual Field of View (FOV) Imaging - One optical channel can be designed for wide-angle situational awareness (e.g., 120° FOV), while the other is optimized for narrow-angle detail (e.g., 30° FOV). This is particularly useful in Security robots (surveillance + facial identification), Agricultural drones (large field + individual plant monitoring), and Logistics (Box detection + barcode reading).

Simultaneous Visible and Infrared (RGB/IR) Imaging - Another configuration utilizes one lens and an optical filter stack optimized for RGB, while the other is tuned for near-IR or thermal infrared. This enables day/night (RGBIR) vision in Medical robotics (visual navigation + vein mapping), Food processing (surface color + sub-surface bruising or spoilage), and Smart agriculture (Visible plant monitoring + chlorophyll/NIR reflection analysis).

Extended Exposure HDR - Imagine using two otherwise identical lenses, but one is optimized for a low F/#, while the other is optimized for high F/# enabling capturing a wider dynamic range in the same exposure time and simultaneously allowing more deterministic control over depth of field in Robotics, Machine Vision, Security, and Autonomy.

Stereo Content Capture - The human eye is very sensitive to differences in color and relative illumination when presented with two images side-by-side. Single-sensor stereo content capture eliminates these discrepancies and the need to calibrate two different sensors for use in AR/VR, content capture, and video conferencing.

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Scan the QR code to download the in-depth case study (incl. a Guideline for System Designers).