Standard CMOS sensors applied to 3D vision, detection, and measurement

3D sensors are now adopted widely by both consumer markets and the machine vision industry.

3D imaging technology has been around for several decades, but the first products were only commercialized in the 2000s when major film studios released movies in 3D using the latest HD video cameras.

3D vision increases the autonomy and effectiveness of robots/machine systems in the factory automation market, proving essential for higher accuracy quality inspection, reverse engineering, and object dimensioning where 2D vision is limited. In addition, the use of vision system-guided robotics is growing and requires 3D vision for better remote guidance, obstacle recognition, and accurate moving.

The 3D vision sensors also protect workers in factories from intensive human/machine interactions, with systems preventing and resolving dangerous situations, including surveillance systems that are able to count and differentiate people from robots or objects.

The technology is influencing society with its ability to make safer, better performing, and more effective assistance systems for end-users. For instance, 3D vision is an enabler for advanced automotive assistance driver systems in autonomous vehicles and collaborative robots.

For scanning barcodes and OCR applications, however, 2D imaging is here to stay. It plays an integral role in factories and warehouses, where its deployment is rising through block chain adoption, as well as the e-commerce boom, which is driving spectacular growth in fulfillment centers and transportation.

Several techniques and technologies exist to get a 3D image. The main ones are:

- Stereo vision – two cameras are used, mounted with different perspectives of an object, and calibration techniques are used to align pixel information between the cameras and extract depth information. Imitating how our brains work to visually measure distance
- Structured light – a known light pattern is projected onto an object and depth information is calculated by the way the pattern is distorted around the object
- Laser triangulation – laser triangulation systems enable 3-dimensional measurements to be captured by pairing a camera with a laser source. Due to a known angular offset between the laser and the camera, the system measures the geometrical offset of a laser line using trigonometry. This technique is based on the scanning of the object
- Time-of-Flight (ToF) – A light source is synchronized with an image sensor to calculate distance based on the time between the pulse of light and the reflected light back onto the sensor.

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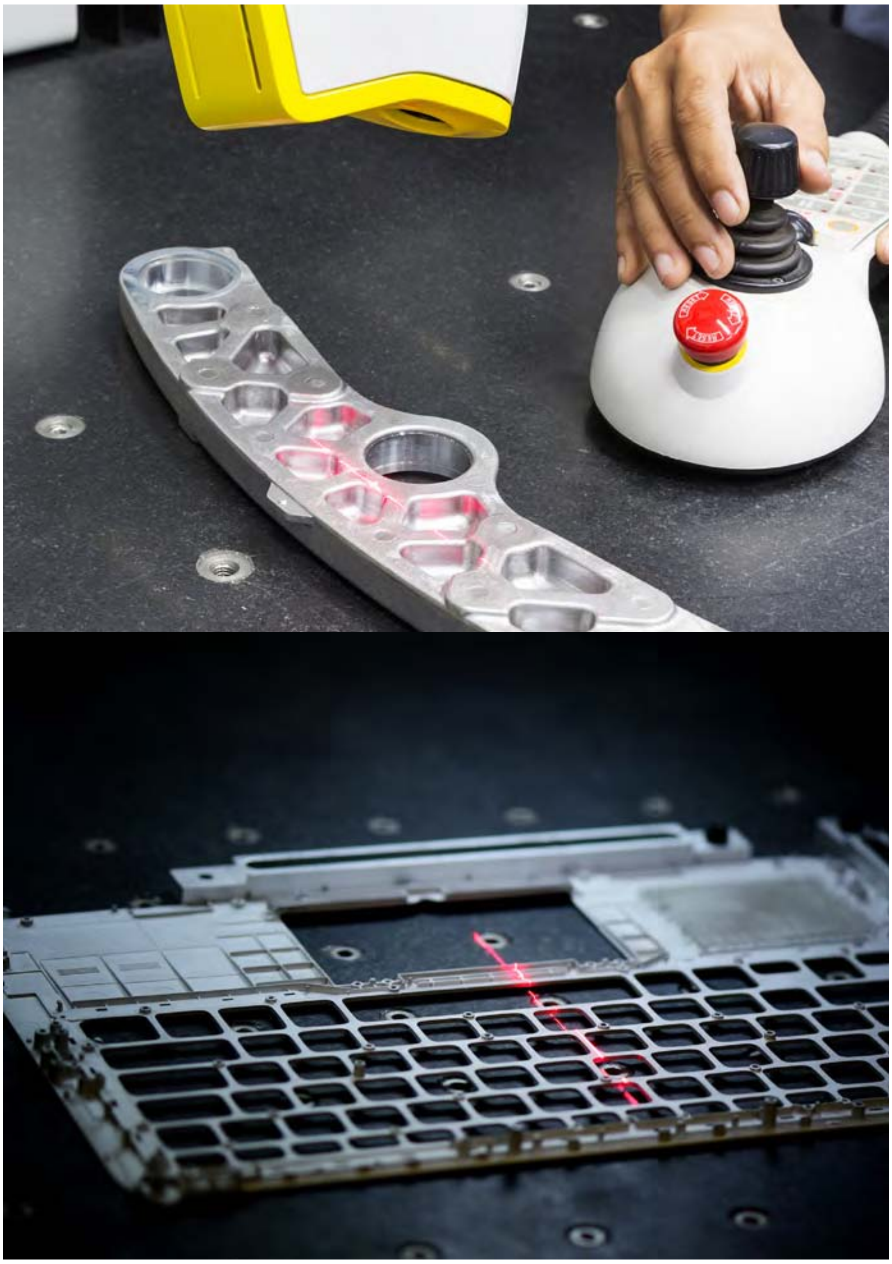

Credit: iStock Photos / Teledyne e2v.

Figure 1. Laser triangulation application examples.

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Boosting productivity

Factories are automated to increase productivity and gain time and money in all the cycles of product inspection and inventory. To optimize these factors, machines with vision systems need to operate at higher speeds and with better performance.

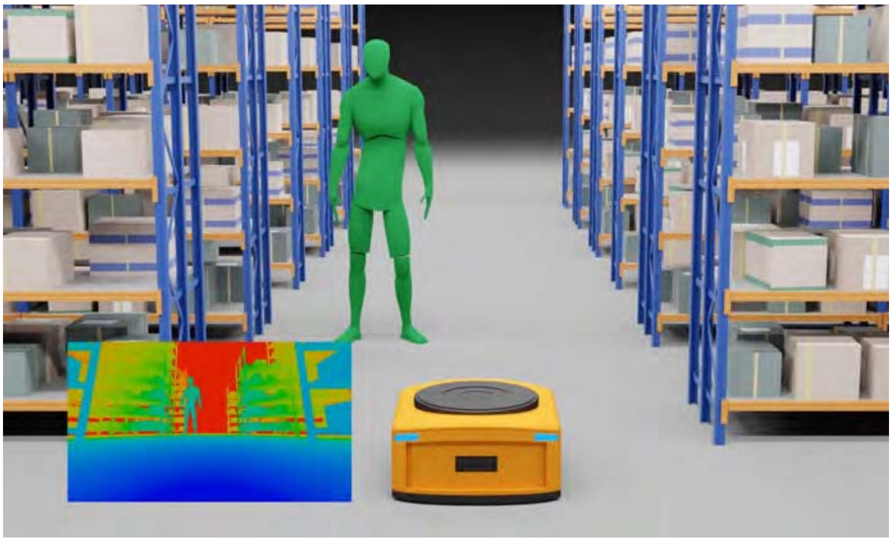
With 2D vision's inherent limitations, 3D vision is extensively deployed for higher accuracy quality inspection, reverse engineering, or object dimensioning. The laser triangulation technique is commonly used in these types of applications because of the high resolution required on the three axes, therefore demanding very high-speed sensors.

Designed to enable easy and cost-effective integration for camera makers, the new sensors available include a range of application-based features enabling high flexibility, such as:

- High Dynamic Range modes with up to 100 dB that enables the measurement and inspection of both highly reflective surfaces and dark areas in the same image through an HDR mode up to 100 dB.
- Multiple Region of Interest mode that allows a perfect trade-off between profiling rate and range/resolution in the height measurement.
- Frame-to-frame 'hot' changes the mode of some parameters that enables flexibility and real-time adaptation to the environment conditions.
- Different trigger modes that allow a perfect adaptation to the speed of production.

Rise of the robots

In order to improve the autonomy and effectiveness of factory automation, the use of autonomous guided robots is growing. As factories and warehouses



Credit: Teledyne e2v.

Robot navigation application example.

become increasingly automated, working stations are intensively collaborative between humans and machines making prevention and safety even more essential.

In such unpredictable working environments, ToF systems are ideal due to their real-time 3D information and decision capability and the ability to detect objects or people within fast scenes. There are two methods when talking about the Time-of-Flight technique: direct Time-of-Flight and indirect Time-of-Flight:

- Direct ToF - the system measures the distance by directly calculating the time it takes for the light to bounce off an object
- Indirect ToF - the system measures the distance by calculating the phase differences of the light waves when they are emitted to the object and when they bounce back. This allows the system to build a 3D map.

Both techniques have pros and cons. However, Indirect ToF (iToF) is in Teledyne's view a more flexible technology to tackle the challenges in factory automation and warehouse environments. In iToF, in order to estimate the phase of the reflected light, multiple images (or phases) are required.

Complex environments

A ToF system is highly flexible, so a system could be mounted in a moving robot as it doesn't need to be calibrated depending on the setup (e.g., factory calibration). ToF can provide accurate measurements for indoor applications. It can handle short distance range, small reflectivity range, and small field-of view suitable pick and place robot applications, and in the meantime handle medium distance range, wide reflectivity range, and wide

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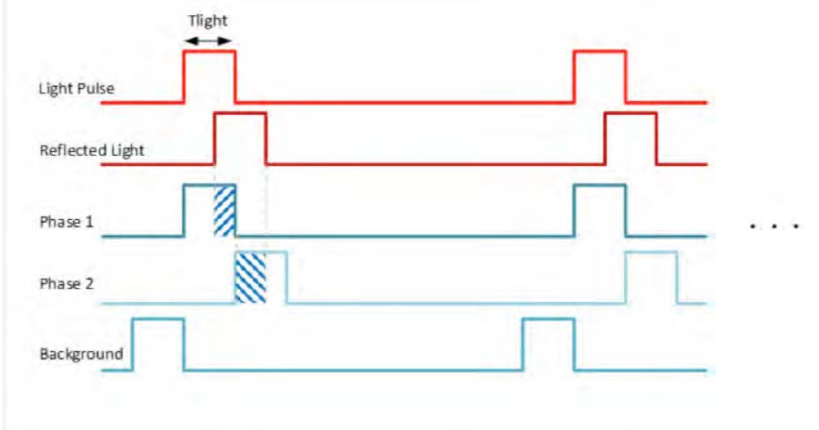

$$Distance = \frac{c\,Tlight}{2}\left(\frac{Phase2 - Background}{Phase1 + Phase2\ - 2Background}\right)$$

Credit: Teledyne e2v.

Indirect ToF principle: Compared to other 3D techniques, the ToF system is fast, simple, inexpensive, and has excellent 3D performances at mid and long-range applications.

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field-of-view such needed for warehouse/ logistics management or handle medium distance range and narrow field-of-view such as robot navigation. Following are some examples of factory and warehouse applications where ToF is the best candidate.

Navigation

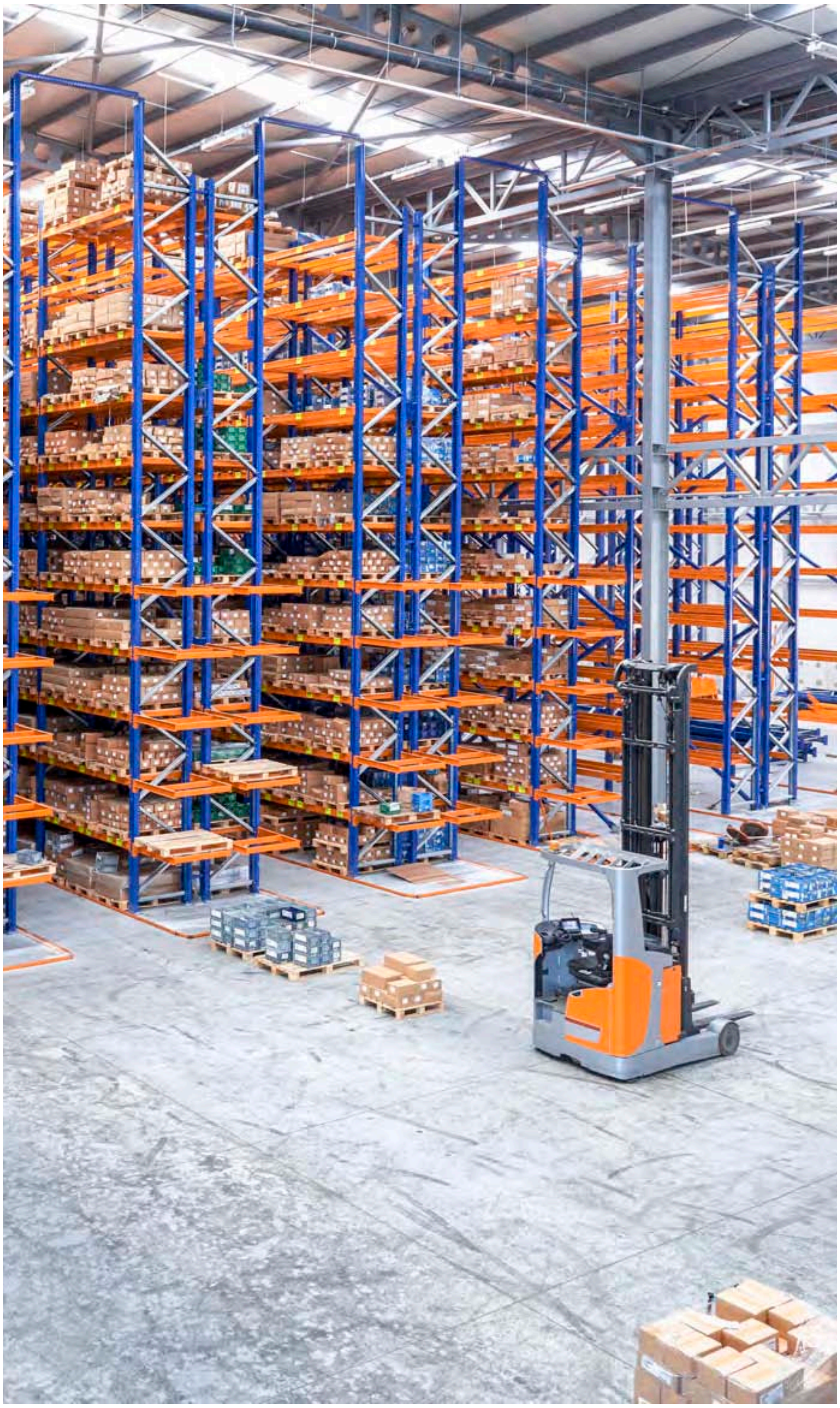
Another application where ToF systems are beneficial compared to other 3D techniques Helping robots to navigate autonomously and safely in a factory environment in.

Nowadays, most navigation systems employ a lidar scanner to detect objects, but there are some cons, and more and more solutions are emerging with alternative technologies such as indirect ToF. Compared to the traditional lidar scanner, indirect ToF systems can provide real-time image information with fast response times and no motion artefacts. They are also more robust and compact as no mechanical part is involved and cheaper since it's a solid-state design using less power and less computation.

In the aforementioned applications, a ToF system tackles many challenges. The system needs to handle both short and mid-, long-range distances starting from 10 meters, as well as needing to be fast without any motion artefacts (today, most ToF solutions on the market are focused on short ranges up to 5-6 meters). In addition, the system could be exposed to several changing lighting conditions as the robot is moving throughout the factory/ warehouse and needs to operate without any interference from other robots in the same area.

Dynamic range

Another consideration in ToF is dynamic range: ToF is, intrinsically, a very-high dynamic range application, due to the combined contribution of the reflectivity of the objects and the distance range required by the application.



Credit: Teledyne e2v.

ToF application example for factory automation; goods identification for intelligent and efficient warehouse management.

To illustrate this point, assume you have one application one, targeting the detection of objects with reflectivity between 15% and 85% from 0.5m to 6m; and a second application, where you need to inspect black rubber, with reflectivity of 1.8%, up to 95% and increasing maximum distance to 10m.

In these conditions, Application 2 requires more than 25 times more dynamic range than Application 1. This huge dynamic range could be managed with specific techniques at sensor level as such non-destructive readouts based on multiple captures combined with high frame rates.

About the Author:

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