# 3D Vision-Guided Robotics for Industrial Applications

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## Background

As modern industrial manufacturing shifts from traditional mass production to customization, the need for advanced robot-based object detection, recognition, and gripping technologies has increased significantly. Traditional industrial robots depend on consistent part location. If a part is even slightly out of place, the picking operation will fail. Modern advanced vision systems are used to adjust the coordinates of the robot to the actual location of the object. This allows the robot to recognize a changing environment and adapt to it.

Advanced vision applications such as bin picking, object tracking, and product profiling demand a system that is capable of generating three-dimensional image data. Figure 1 presents representative industrial 3D vision systems including (1) ifm O3D, (2) Canon RV, (3) Faro Cobalt, and (4) Keyence XR-HT. The ifm O3D303 has low resolution and a large workspace, making it well-suited to the handling of large objects. Canon's RV system is designed for random bin-picking applications, while both Faro's Cobalt system and Keyence's XR-HT system are well-suited to precise surface metrology applications.

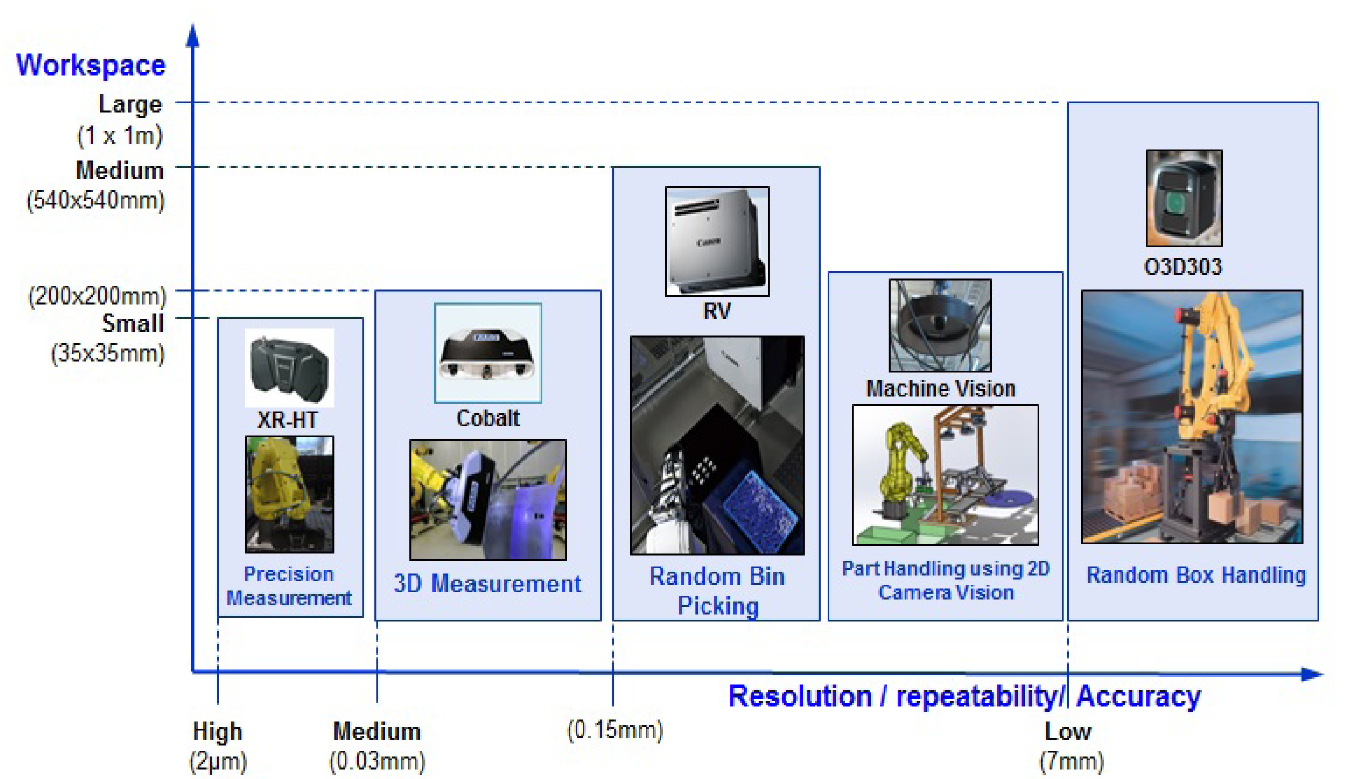


Figure 1: Specifications and representative applications of industrial 3D vision systems

## 3D Vision Technologies

3D imaging systems are categorized as either passive or active, depending on the type of lighting used. A stereo camera using ambient lighting is considered to be passive, while the Canon RV, Faro Cobalt and Keyence XR-HT sensors use structured laser lighting and are considered to be active systems. In most cases, a 3D imaging system generates a point cloud that represents the external surface of the object and each point represents the measured X, Y, and Z coordinates. 3D vision system selection is highly dependent on the parts to be measured and the tasks which must be performed by the automated manipulator. While a number of different 3D imaging techniques are available, this paper focusses on those which are most commonly used in industrial automation: (1) time-of-flight, (2) structured light, and (3) stereo cameras.

Time-of-flight cameras such as the ifm O3D303 project photons toward an object and measure those that are reflected, calculating the distance of the respective pixels which carry the desired 3D information (Figure 2). The Canon RV, Faro Cobalt, and Keyence XR-HT systems produce point-cloud data of external surfaces using structured light 3D scanning. These structured light systems project narrow bands of light and this pattern of parallel strips is geometrically distorted due to the shape of the surface. This distortion is captured by stereo camera, allowing the 3D coordinate of the surface to be calculated (Figure 3).

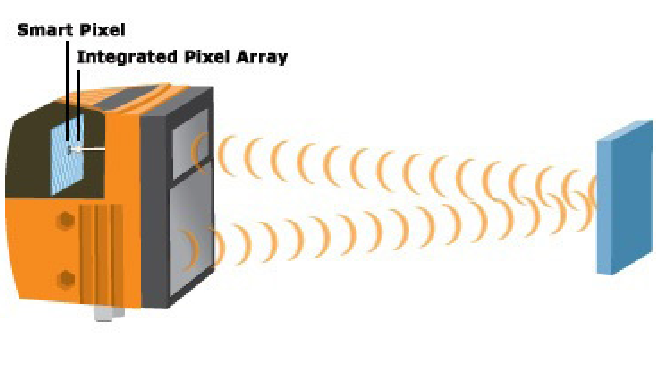

Figure 2: Time of flight (courtesy of ifm)

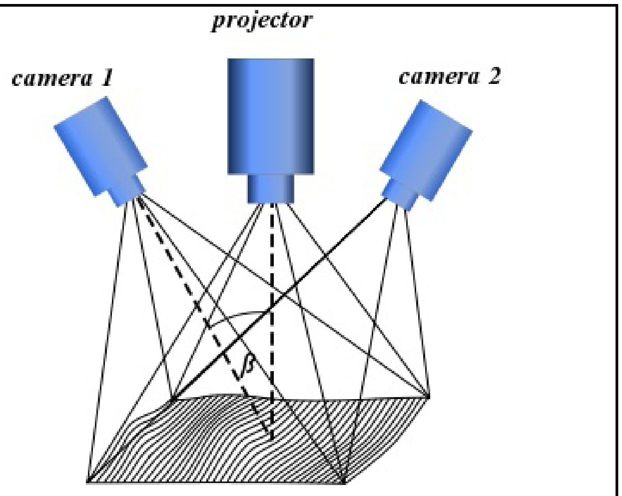

Figure 3: Structured light (courtesy of Wikipedia)

By mapping common pixels from two images taken with different cameras, a stereo camera can calculate the depth map of a surface.

## Industrial Applications

Using a 3D imaging sensor, a wide range of industrial applications are possible including surface quality control, dimensional measurements, reverse engineering, and spatial robot guidance. The objective of surface quality control is to quantify the shape and roughness of a surface at resolutions from a few microns to thirty microns, as shown in Figure 1. A typical application of surface quality control is the geometric dimensioning and tolerancing (GD&T) of a machined part.

3D vision systems can effectively be used to take dimensional measurements of complex surfaces, facilitating inspection of large areas in a fraction of the time and with higher consistency compared to human operators. Coordinate measuring machines (CMMs) are widely used for the creation of surface geometries for reverse engineering applications; however, this technique is time-consuming. Figure 4 shows an “eye-in-hand” setup of a Keyence XR-HT 3D area sensor and an articulated industrial robot capable of measuring surface geometry with a resolution of 2 microns. Figure 5 shows point cloud data measured by using setup.

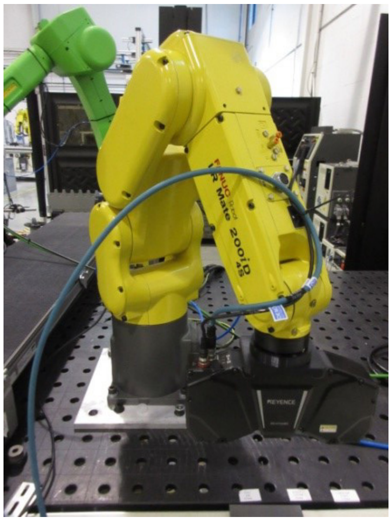

Figure 4: Automated 3D area scanner setup

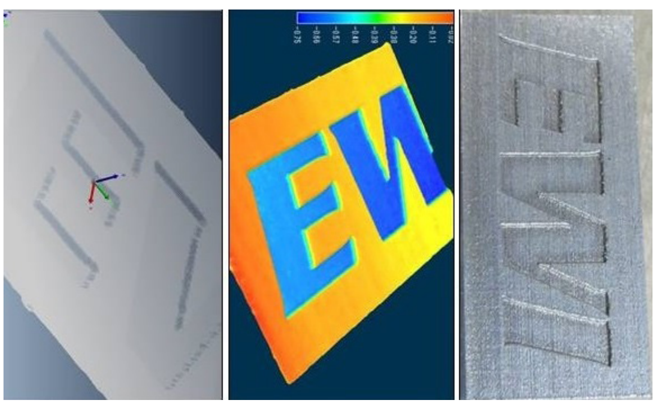

Figure 5: 3D vision point-cloud data

The variation of shapes and sizes for parts in high-variation/low-volume manufacturing is challenging for 2D machine vision systems. Because of product variability, competitive manufacturers must be able to efficiently produce a variety of different parts. 3D vision provides spatial geometric information in varying environments to guide robots in a variety of adaptive tasks.

For assembly lines, 3D vision measures the shape and size of each model, allowing robots to adaptively select the correct corresponding parts. 3D vision can also measure part variations and calibrate robot coordinates. Bin picking, the task of picking parts randomly piled in bins, pushes the limits of even the most advanced 2D machine vision systems. 3D vision systems are able to generate point-cloud data and stream them to the vision controller. The vision controller can then calculate the best path to pick a component with a gripper while avoiding collisions by 3D shape matching between the point-cloud data and the CAD model. In a warehouse and distribution center, 3D vision assists robots in handling a wide variety of boxes for palletizing. In addition to the applications discussed here, 3D vision technologies have the potential to solve many difficult industrial challenges.

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