Benefits of on-arm robot-mounted 3D machine vision cameras

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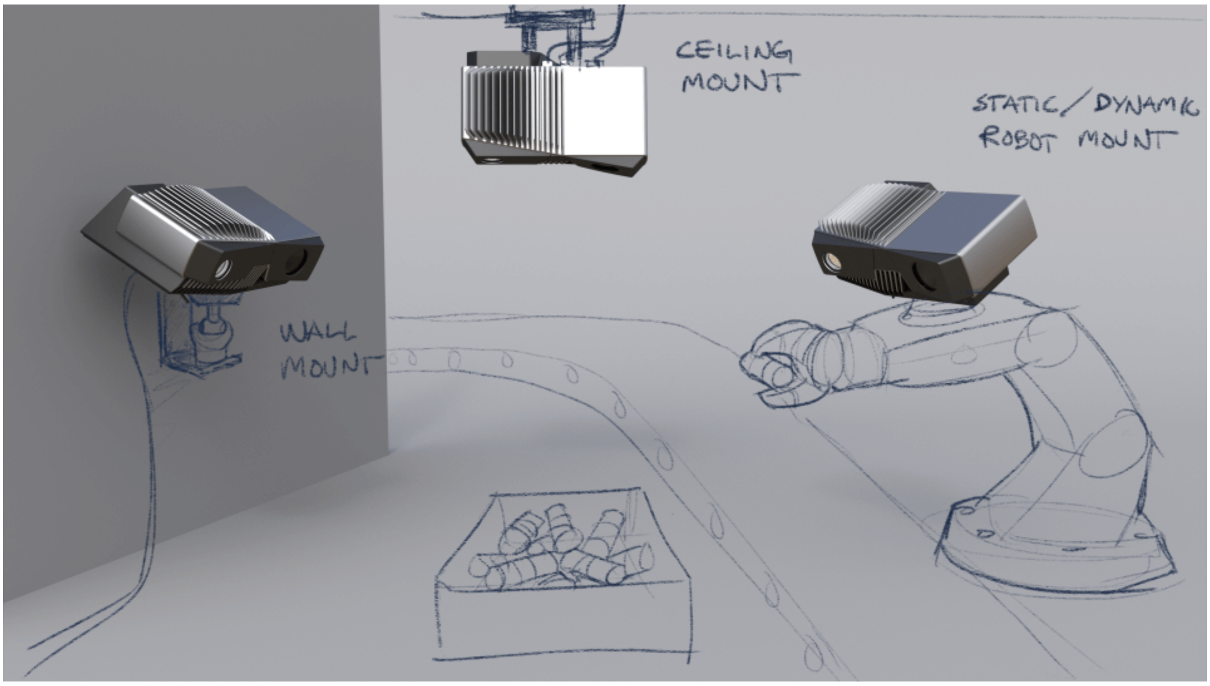


Typical stationary and on-arm robot mounted setups

Most 3D vision sensors today are mounted on a fixed wall, in the ceiling, or on a custom rig to capture point clouds of target objects accurately. The point clouds enable industrial robots to pick and place tasks in piece picking, bin-picking, assembly, and machine tending applications.

Many system integrators use stationary mounting as their go-to solution for vision-guided robotics as it is fairly straightforward to set up. It can be easily installed with any 3D camera regardless of its shape and weight.

On the other hand, attaching the 3D sensor directly to the robot arm is not as common. Because of the benefits, end customers look at how their solution can use a robot-mounted 3D camera.

In late 2020, we introduced a new industrial 3D camera, Zivid Two, to meet the increasing demand for 3D vision solutions with more flexibility, accuracy, and ease of use. One of the main advantages of Zivid Two is that it works for both stationary and on-arm mounting. It enables automation developers to use the camera in dynamic work environments while capturing point clouds of a broad range of products.

Zivid Two 3D industrial color camera

This eBook is written to help you understand the benefits of on-arm mounting and get started with 3D vision-based application development. Throughout the eBook, we will use the Zivid Two 3D camera as an example to describe machine vision techniques and use cases. You will also find links to in-depth resources to learn more about 3D vision best practice guidelines.

- Learn more about on-arm benefits on zivid.com/on-arm
- Learn more about industrial 3D cameras on zivid.com/industrial

Why on-arm robot mounting?

Why does the demand for an on-arm mounting increase in pick and place robotics when you can use the standard stationary mounting setup? Here, we list three unique benefits of on-arm mounting that cannot be solved with stationary mounting.

1. Flexibility

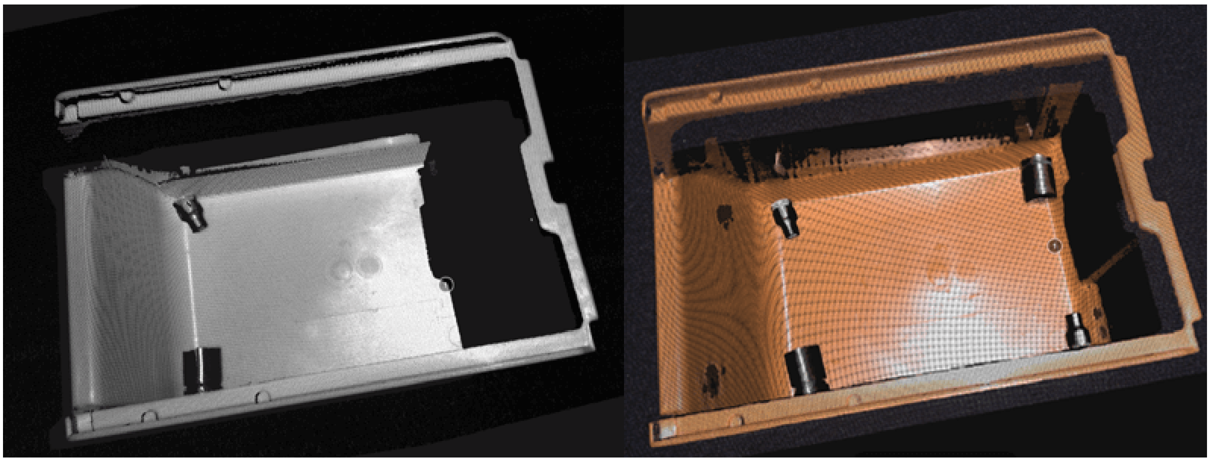
A robot-mounted camera can get close to target objects.

It is not ideal to place a camera at a fixed location in some picking applications due to inconsistent image quality. Keep in mind that many machine vision challenges are caused by distance limitations. A long-distance tends to result in low-quality 3D point clouds, which increases the risk of mispicks and crashes.

For example, in depalletizing applications, it can be challenging to capture a scene with stacked boxes. Ideally, you would like to cover the whole scene with consistently high 3D image quality. However, as your robot keeps removing packages, the initially optimal working distance is not optimal anymore. The result is lower point cloud quality.

On-arm mounting solves this challenge as it allows the 3D camera always to use the optimal working distance. Additionally, your solution can capture point clouds from different angles to view the target objects better. The better data your detection algorithm receives, the more accurate picking can be achieved.

The on-arm movement flexibility has another benefit, as it allows your robot to tackle fundamental 3D vision challenges like occlusion. Occlusion occurs when the placement of your camera creates "blind spots" (shadow areas) in your target scene. It causes a loss of scene details and negatively affects the quality of your point clouds. With on-arm 3D camera mounting, you get an extended field of view. Your system can cover larger bins and partially or hidden products in a bin due to occlusion.

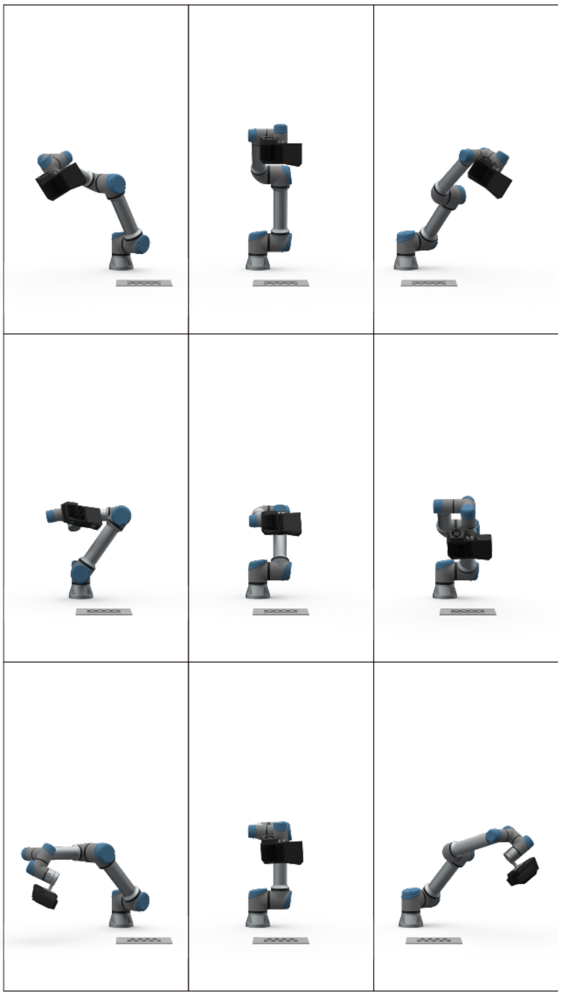


Point Cloud Examples - with occlusion (left) vs. without occlusion (right)

2. Cost-effectiveness

One of the beautiful effects of on-arm robot mounting is that you don't need multiple cameras to capture advanced target scenes. Instead of mounting cameras at different picking and placing locations, you can use a single robot-mounted 3D camera to capture point clouds from different angles and positions. On-arm 3D vision minimizes the total cost of ownership by reducing the number of components that need to be installed, calibrated, maintained, and repaired.

The robot-mounted camera can also be used in various pick and place scenarios. Its unrestricted movement and multiple views allow many automation developers to use the same camera for different applications such as piece picking, bin-picking, inspection, and depalletizing. This is beneficial for manufacturing companies dealing with various objects as they don't have to change vision hardware or its mounting position periodically.



An on-arm 3D camera can capture point clouds from all robot positions

3. Adaptability

It is not always feasible to rely on stationary mounting to get consistent and optimal performance. Some workstations might be space limited, and in SMEs, the workstation might change frequently. With the right on-arm mounted camera approach, it's easier to ensure consistent image quality and reliable pick and place performance. This frees automation developers from restrictions related to 3D image capturing.

An on-arm mounted 3D camera provides great advantages to automation solutions. But is the on-arm option always better than stationary mounting? Are there any circumstances that stationary mounting is sufficient or preferred than on-arm? In the next chapter, we will discuss some considerations for choosing the ideal 3D camera mounting option for your automation application.

Stationary vs. on-arm robot mounting

The industrial Zivid One+ and Zivid Two 3D cameras support both stationary and on-arm robot cell configurations, so we'll consider options and decisions we need to make before we start implementing a 3D vision-based random bin-picking system.

You should perform a 3D hand-eye calibration independently of your final setup to achieve optimal detection, picking, and placing results.

We show you why and how to achieve 3x better translation and 5x better rotational calibration in The practical guide to 3D hand-eye calibration and Understanding the importance of 3D hand-eye calibration.

Stationary mounting (left) vs. on-arm mounting (right) with a Zivid Two 3D camera

Stationary Mounting the 3D Camera

When using 3D and robots to pick randomly placed objects from bins, the most common setup is still to have the depth camera and vision system placed in a fixed position relative to the target. A fixed placement like this is typically above or to the side of the bin or tote housing the various objects we want our robot to pick.

Typical 3D sensors (stereo and laser included) have particular distances and areas they can cover while providing reliable data. Working range limitations mean that you need to consider the flexibility and requirements of your bin-picking solution.

With Zivid's 3D cameras, you benefit from both a flexible field of view (FOV) and a large and functional working distance. The result is that you'll have a platform capable of handling most SKUs, tasks, and working environments.

Compared to a 2D sensor, depth cameras don't need a square or strict top-down view or additional light sources. By mounting your 3D camera at a slight angle, you also help the structured light sensor capture great point clouds without unnecessary reflections from the object and light source.

Stationary mounted Zivid Two 3D cameras in manufacturing

The stationary mounting considerations:

- A fixed 3D camera is in little or no conflict with the bin, gripper, or robot arm.
- Once objects are picked, and the gripper and robot arm is outside the FOV, the system can immediately capture and process new point clouds.
- Robot cycle times can be kept very short and is not so much dependent on waiting for the depth sensor.
- In some settings, the 3D camera can cover both the picking and the placing bins.
- Static camera mounts cover a single area, so unless you can securely place or drop picked objects or parts, it is advised to use 3D cameras in the drop-off or placement area.

- Your vision algorithms still need to wait until the object, gripper, and robot arm is outside the target FOV.
- A stationary mounted camera requires less effort when it comes to system cabling.

On-arm Mounting the 3D Camera

Another mounting option is to attach the 3D camera directly to the robot arm. In this configuration, the vision system moves together with the robot and the end-effector (tool or gripper). Attaching the 3D camera directly onto the robot arm unlocks a more flexible and effective solution since the 3D camera operates in its optimal space regardless of the working volume and robot reach.

Until today, 3D depth sensors have either had insufficient 3D image quality, been too slow, too bulky, or too heavy. Your typical 3D sensor has also not been robust enough to withstand the mechanical impact of on-arm robotics. Finally, these challenges are solved. We designed the industrial Zivid Two 3D color camera explicitly to provide consistent, high-quality point clouds from a robot's arm.

Achieving optimal 3D image quality with on-arm mounting

On-arm mounting allows the Zivid Two 3D camera to operate at its optimal distance for every capture, even as you empty a bin. Object detection algorithms always process the highest quality 3D data, with consistent resolution, color representation, accuracy, and noise performance.

By elevating the robot's flexibility with an on-arm Zivid Two 3D camera, you enable the system to view the scene and objects from multiple angles and positions, avoiding blind spots, occlusion, and point cloud artifacts (e.g. from reflections and highlights). On-arm 3D is the efficient way to reduce system cost and the number of sensors needed to empty bins successfully.

The outcome of your mounting choice dictates if your 3D vision platform is future-proof and usable in different tasks and environments. Applications that benefit from on-arm 3D sensors are machine tending in manufacturing and piece picking order fulfillment in logistics.

A robot mounted Zivid Two 3D camera for bin-picking

The on-arm robot mounting considerations:

- Capture data from multiple positions. 3D cameras mounted on the robot arm give you the option to capture the target area (bins, totes, etc.) from various angles and always get the best point cloud quality and coverage.

- You can stitch multiple 3D captures if you need even higher resolution point clouds.
- You only need a single depth sensor to cover both the pick and place locations.
- Cycle time requirements. Faster 3D sensors make it possible to reduce the time performing stop-capture-move and keep cycle time low.
- Compared to a stationary mounted 3D camera, the on-arm mounting option requires more path planning and robot guiding.
- The size and weight of the 3D sensors can reduce the maneuverability and payload of your robot. If you have a collaborative robot, the weight is much more important to consider than for the more powerful industrial robots.
- Consider the speed and acceleration of your robot arm. You want an industrial depth sensor with IP and shock rating.
- On-arm mounting requires more advanced cabling.

So what is the verdict on on-arm robot vs. stationary 3D camera mounting?

As we have seen, there are pros and cons with both stationary and on-arm robot mounting of your depth sensor. And in some sense, our promise of picking the best 3D camera mounting option is still open.

But, no matter which option you go for, the robust, industrial Zivid 3D camera is designed to be lightweight, small, and fast to minimize the impact on robot maneuverability and payload.

The high-quality and color point cloud data output gives your AI, machine learning, and detection algorithms the best possible view of reality, ensuring that whatever mounting option we choose, our bin-picking solution can cover more SKUs, reduce mispicks, and empty the whole bin.

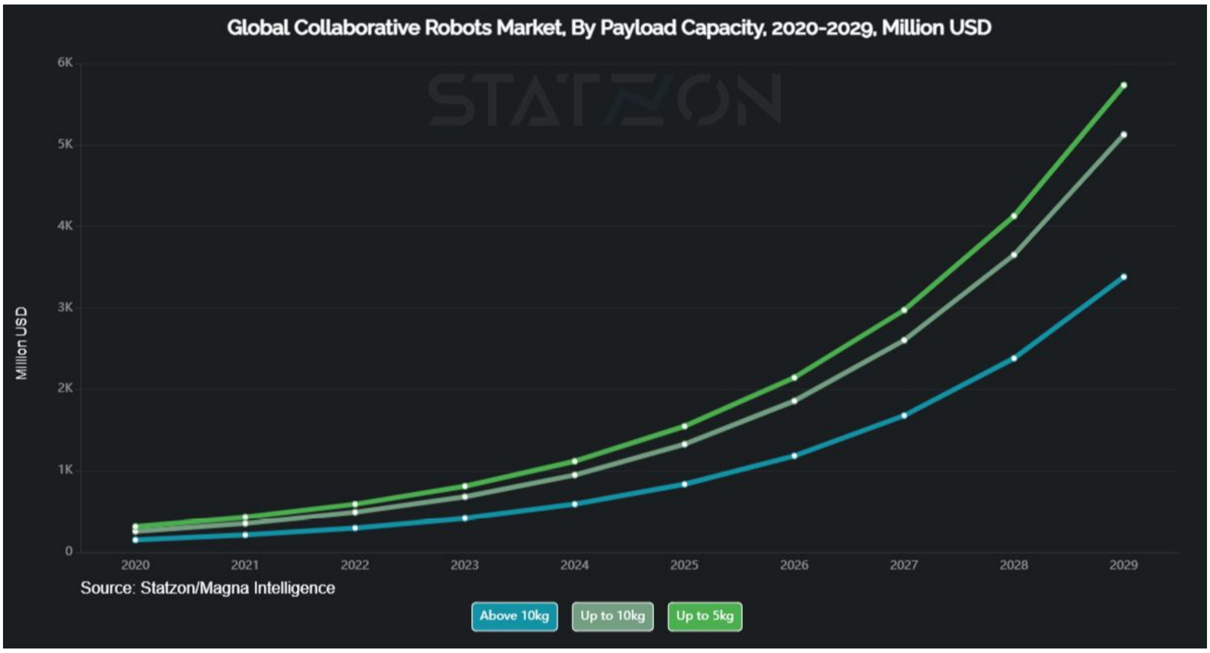
Getting started with on-arm robot mounting

Requirements

You need a 3D vision camera, mounting accessories, and 3D vision software to enable a robot-mounted machine vision solution.

3D vision camera

Your camera should be light enough to minimize the robot's maneuverability, usable payload, and cycle time in on-arm arrangements. The graph below gives an overview of the global collaborative robots market by payload capacity in the future. It indicates that the demand for up to 5kg payload capacity will be higher than larger capacity options. Your on-arm mounted camera should add minimal weight to a robot arm to meet the growing need for faster and smaller robots in the market.



Global cobot market payload capacity

Our Zivid Two 3D camera measures 169 mm x 56 mm x 122 mm and weighs less than 1000 grams to support even small collaborative robots. In addition, the camera provides a flexible working distance of 300 mm to 1200 mm, and 57° horizontal by 35° vertical FOV to support a wide range of on-arm and stationary-mounted robot-guided applications.

Mount accessories

Accessories are essential to simplifying the on-arm and stationary mounting. Like your industrial 3D vision camera, your mount accessories should be robust enough to tackle various temperatures, dust, and humidity. We provide high-quality, industrial-grade, and ready-made mount accessories for Zivid 3D cameras to remove customer's hassle of finding a custom solution.

Example of Zivid's on-arm mount with a 3D camera on Universal Robots.

Zivid provides a camera mount, bracket, and optional extender for robot arm mounting, initially to the ISO 9409-1-50-4-M6 coupling plate standard. Designers paid particular attention to weight, robustness, and flexibility to meet various robot arms and gripper types of requirements. All accessories are machined from black anodized aluminum. Visit our webshop to learn more.

The Zivid stationary mount

The stationary mount is optimized for use with typical structural v-slot profiles. The mount will securely fasten the camera and ensure that its position is kept intact.

The mount can be rotated around two axes for easy targeting. Precise alignment can be achieved with the engraved scale that shows the angular position with 2-degree increments. Only one locking screw will lock the movement of both axes.

A nifty feature is a possibility of switching the rotational axes. The mount can easily be re-configured, giving you either pan-tilt or tilt-roll rotation. This ensures that you can always orient the camera to get the best possible view of your scene.

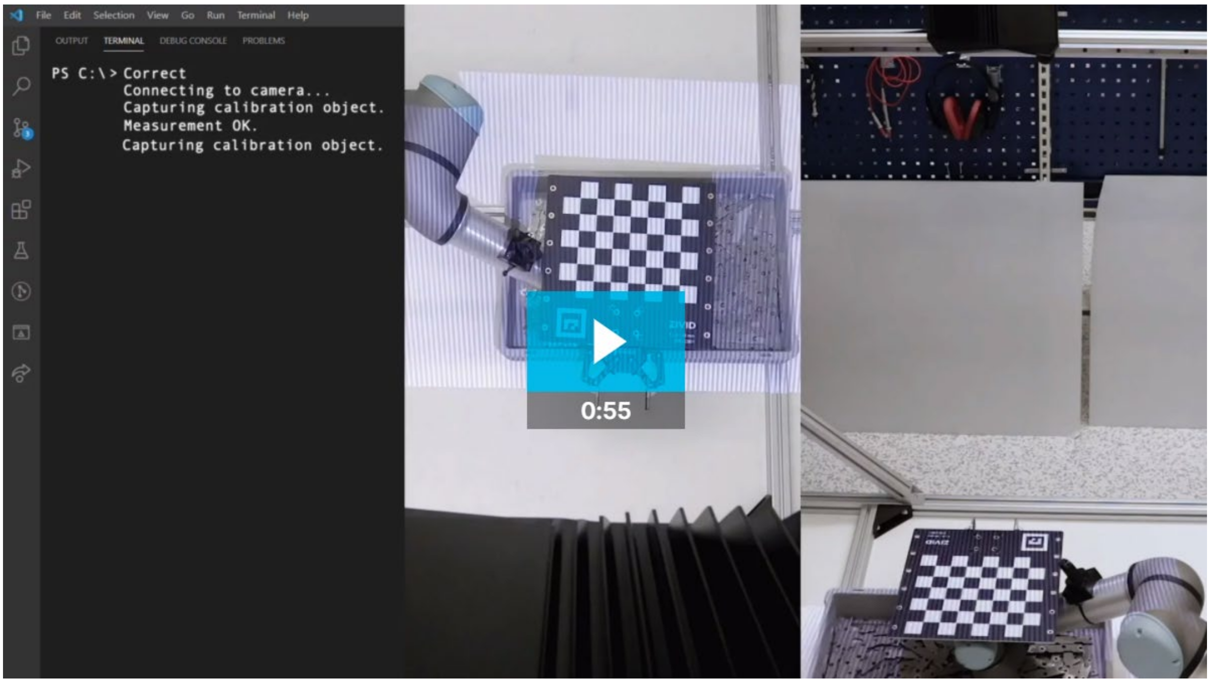
3D vision software

Lastly, your camera needs vision software to capture and improve images. All the Zivid 3D cameras come with a software suite called Zivid Studio. Zivid Studio is an application within the Zivid SDK that provides a graphical user interface (GUI) to explore the functionality of Zivid 3D cameras and capture high-definition 3D point clouds.

Zivid Studio interface

With the Zivid SDK, customers can simplify the 3D hand-eye calibration, the binding process between a camera and a robot, reduce translation and rotational errors and achieve 10x better accuracy in point clouds.

Automation developers can also benefit from our in-field correction feature available in the Zivid SDK. It is useful when your output is changed due to an accident or crash. You can use a stationary or on-arm robot setup to capture the checkerboard and instantly verify camera trueness.



Watch a short in-field correction demo here

Step-by-step instructions

Once you have your Zivid 3D camera, mount accessories, and vision software, you can follow the steps below to run a camera on your robot quickly.

1. Install Zivid Studio

You can download and run the latest Zivid Studio installer here. Check the option to install camera drivers. Once the installation is complete, restart your PC.

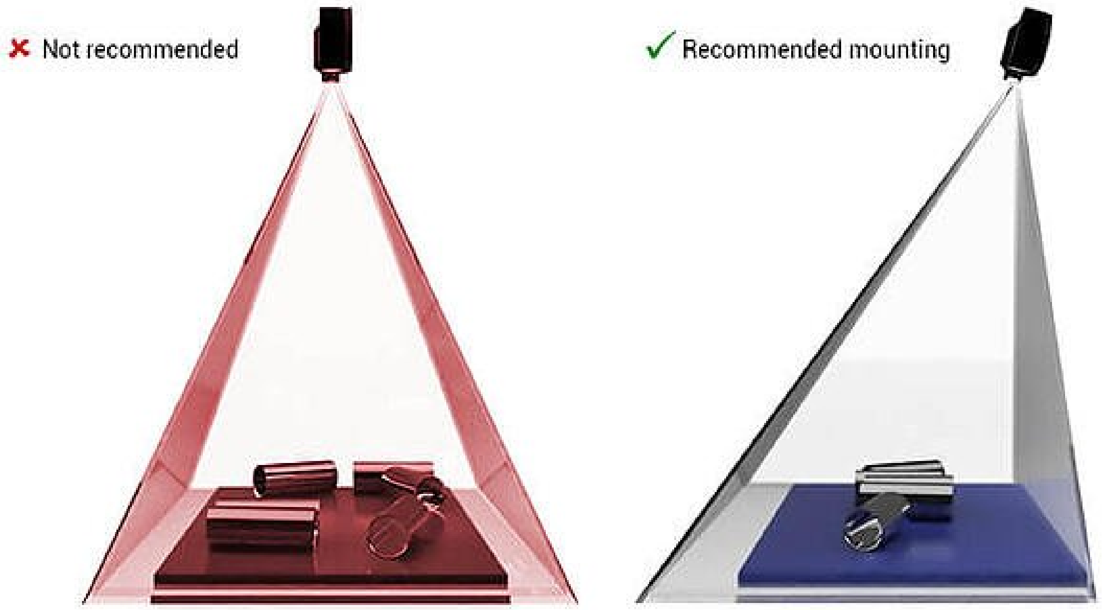
Requirements

- Windows 7 / 8 / 10
- Ubuntu 16.04 / Ubuntu 18.04 / Ubuntu 20.04
- Compatible GPU
- 3 GB RAM or more

2. Mount your camera

Use the threaded holes on the bottom side of the device to mount it to a bracket. We recommend using DIN 912 / ISO 4762 Hexagon or ISO 14579 Hexalobular socket head cap screws in stainless steel (A2 or A4).

3D cameras use active lighting to detect your target objects. To minimize direct reflections from the background and reduce potential artifacts, it is recommended that you mount your camera at a slight angle to get the best results. You can test different positions in Zivid Studio.



3. Connect to your camera

Plug the power supply into the "24V" port and a power outlet. Plug the Ethernet cable into the camera and connect it to your computer. Ensure that all connections are screwed in tightly.

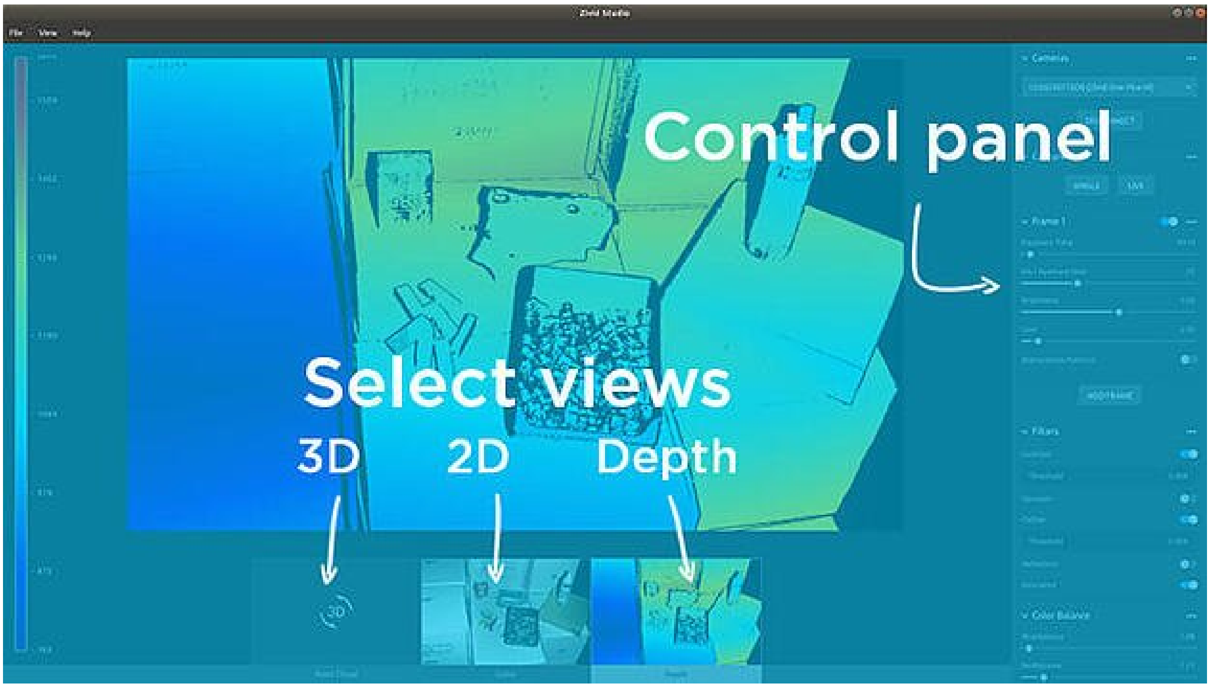
Requirements:

- 24 V power supply
- 10 GigE data cable

4. Launch Zivid Studio

The 3D point cloud of the scene is displayed after capture or in real-time using the live mode. This is a flexible view with zoom, pan, and rotate functionality. Control settings and select from these views:

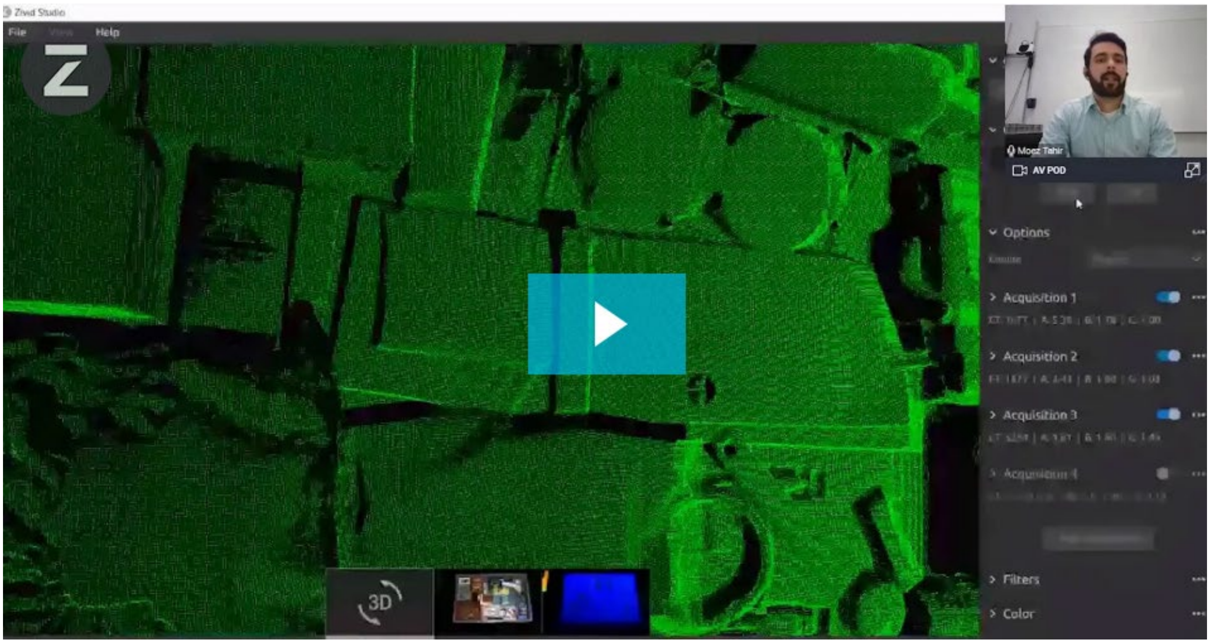
- 3D color/monochrome point cloud
- 2D image
- Depth map



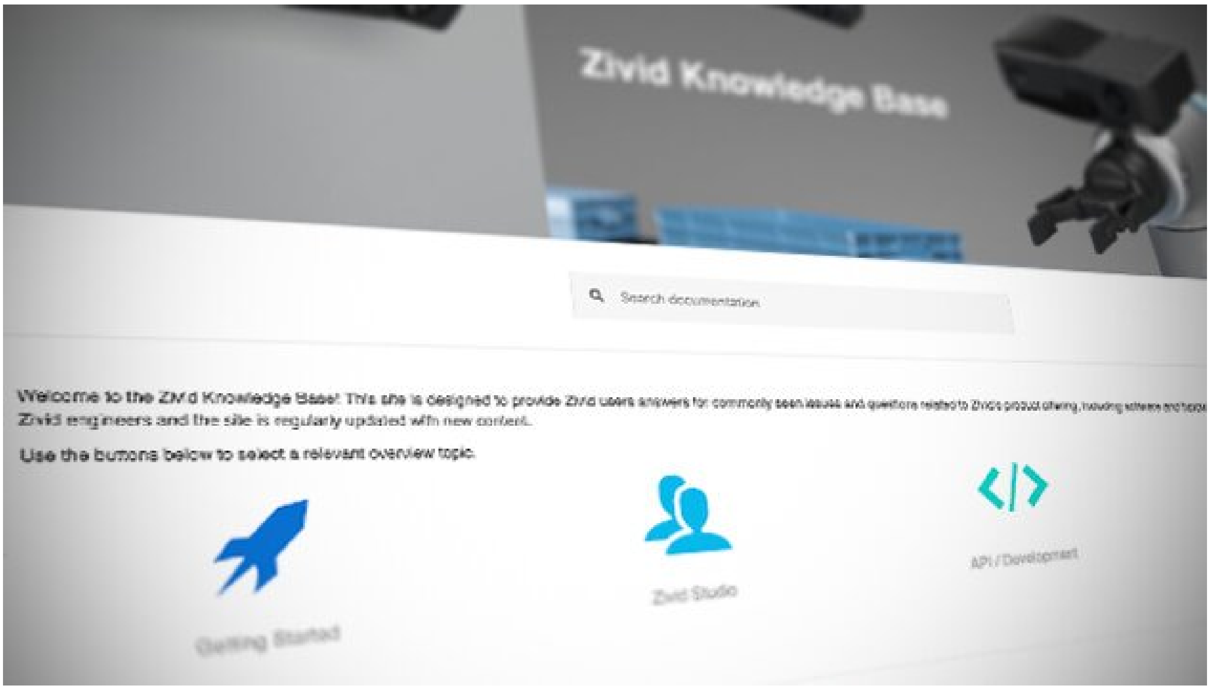
5. Capture high-quality 3D point clouds in 3 steps!

- Enter live mode
- Determine optimal settings to acquire dense points over the entire scene.
- Click Single/HDR to view the resulting point cloud

Watch our [software demo video] to learn more:



6. Visit our Knowledge Base for Q&As



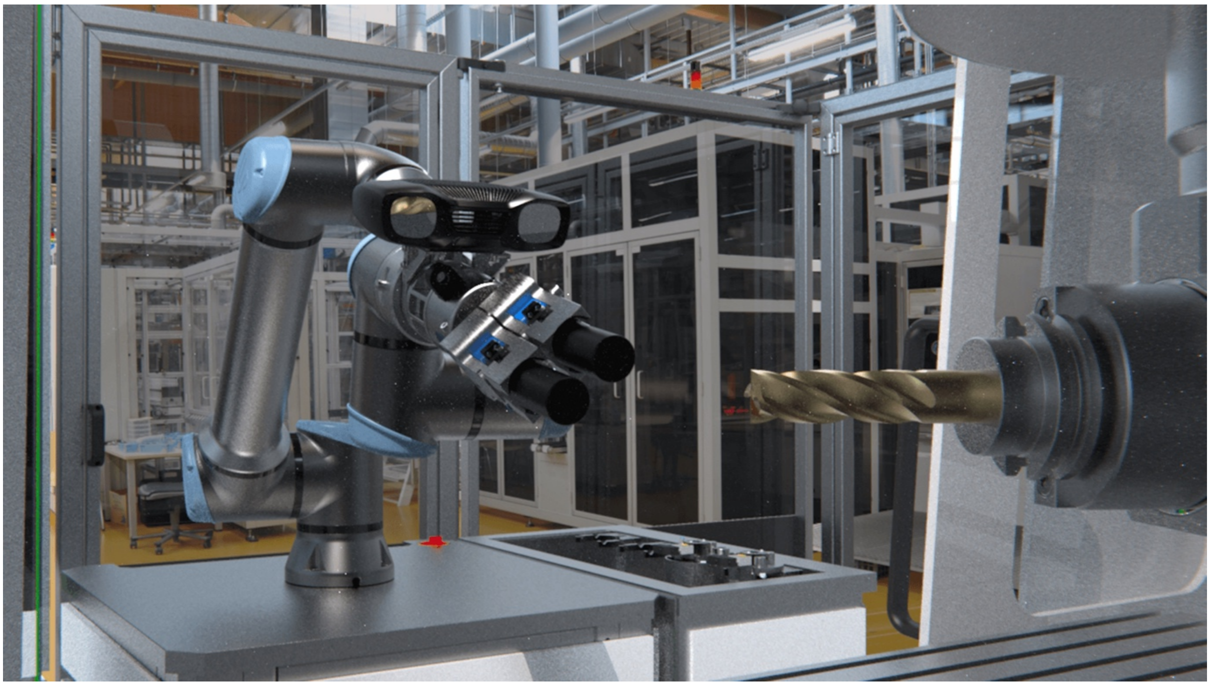
Find information and resources to enhance your 3D camera experience further here.

- In-depth installation guides
- Field of View (FOV) and distance calculators
- Software guides
- Program samples
- Example settings
- Guides for C++, C#, Python, MATLAB, ROS, Halcon
- Hand-eye calibration guidestp://help.zivid.com

Case study

Kolektor Digital's autonomous coworker

Learn how Kolektor enabled flexible machine tending using an on-arm mounted Zivid 3D camera.



A Zivid Two 3D camera mounted on a robot arm for machine tending.

Background

Kolektor boasts tradition in highly specialized industrial production. On its path of half a century, Kolektor evolved into a global company with its seat in Slovenia and a widespread net of companies and subsidiaries in Europe, the USA, and Asia.

KoCo is Kolektor's collaborative robot that enables automated tasks in several work posts. KoCo seamlessly integrates into the manufacturing process without any needed adjustment of the infrastructure.

Machine tending is the process of loading and unloading parts into machines using industrial or collaborative robots. In particular, the choice of the vision system and, in particular, the 3D camera impacts the robot's ability to successfully detect the target objects, pick them accurately, and place them correctly at the desired processing location. The company looked for a smart, flexible, and reliable vision system that collaborates with the KoCo robot.

Challenges

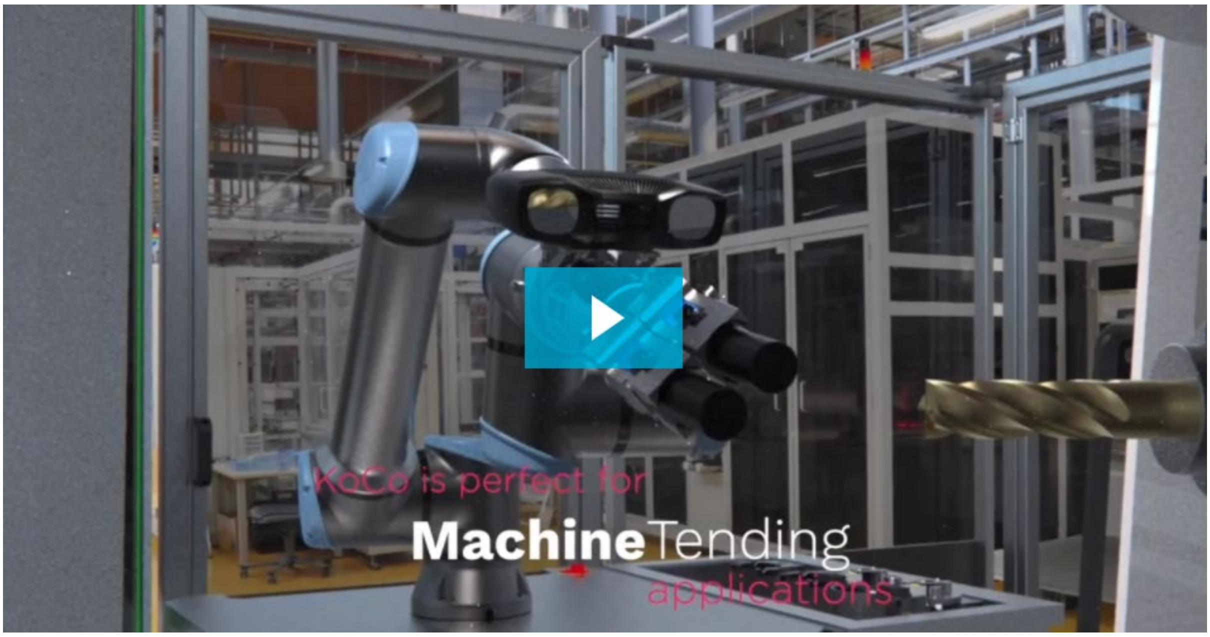
Some machine tending scenarios require inserting or fitting industrial objects like cylinders into a feeding hole or similar or arrange them in a fixture in a uniform way. This can be difficult to achieve without a high accuracy vision system due to tight tolerances and high accuracy required for picking and placing tasks.

Solutions

Zivid Two's high resolution and quality 3D data, combined with true to reality representation of object size, rotation, and absolute position concerning the robot coordinate system, makes it an excellent fit for machine tending scenarios. Achieve reliable detection of object boundaries and orientations for grasp planning, more accurate picking, avoiding mispicks and crashes, and more accurate placing, without colliding or damaging the parts.

Robert Bevec, Ph.D. and Head of Robotics at Kolektor Digital, said;

“Working with Zivid's 3D cameras is a smooth developer experience, so integrating Zivid Two into KoCo – an adaptive robotic worker - was seamless. The point cloud data trueness makes it possible for the robot to perform reliable and highly accurate machine tending operations. The small and lightweight Zivid Two camera helped us advance our platform's capabilities by offering on-arm camera operations with smaller payload robots and applications with tight and limited access.”



Watch the machine tending application demo video featuring Zivid Two here

Conclusion

Customers come to us with many questions about the quality of point clouds, speed, FoV, and robustness of our 3D cameras. Mounting capability is not often on top of their requirement list. However, mounting a camera with a slight angle difference can significantly differentiate point cloud results and the robot's pick and place performance. By choosing the proper mount technique, you can also solve fundamental 3D vision challenges such as point cloud artifacts, FoV limitations, and cost burden.

As a leading 3D vision company, Zivid strives to meet customer's needs and unleash the potential of a 3D vision system in pick and place robotics. Our latest 3D vision camera, Zivid Two, enables flexible, robust, and easy-to-use multi-mount options for automation developers. Unlike traditional 3D sensors, you can use the Zivid camera to solve your unique automation problems for both stationary and on-arm mount.

Zivid Two 3D camera for stationary and on-arm mounting

In this eBook, we looked at some of the benefits of on-arm mounting. More automation companies are using this to their advantage, with industrial 3D cameras now being accessible, easy to use, and cost-effective. We hope that this eBook helped you broaden and deepen your understanding of 3D vision technologies.

Resources

To help automation engineers quickly build their automation solutions, our Zivid team provides free online resources, 1:1 training, and regular SDK releases to evolve our products continuously. If you have any questions about this eBook or other 3D-related topics, please feel free to contact us at customersuccess@zivid.com.

You can find our latest resources in the Zivid knowledge base.

For Zivid 3D camera samples, please visit the Zivid GitHub repo page.

About Zivid

Zivid is a market-leading provider of 3D machine vision cameras and software for next generation robotics and industrial automation systems. Its Zivid One Plus products are regarded as the world's most accurate real-time 3D color cameras and bring human-like vision to the smart factories and warehouses of Industry 4.0.

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