

2D or 3D Camera? Which 3D Camera Technology Fits Your Application?

The third dimension is playing an increasingly important role in image processing applications. Our White Paper describes the most popular 3D technologies on the market and notes their respective strengths and weaknesses. You will also get criteria to answer the question of whether the third dimension is even worthwhile for your application.

Contents

1. 2D Camera Technology	1
1.1 Application Areas	1
2. 3D Camera Technology	2
2.1 Application Areas	2
3. 2D or 3D – Will the Third Dimension Even Help Me Solve My Task?	2
4. Overview of the Most Popular 3D Technologies	2
4.1 Stereovision and Structured Light	3
4.1.1 Strengths and Weaknesses of Stereovision	3
4.1.2 Strengths and Weaknesses of Structured Light	3
4.1.3 Typical Application Areas of Stereovision and Structured Light	3
4.2 Laser Triangulation	3
4.2.1 Strengths and Weaknesses of Laser Triangulation	4
4.2.2 Application Areas of Laser Scanners	4
4.3 Time-of-Flight Method	4
4.3.1 Strengths and Weaknesses of Time-of-Flight	4
4.3.2 Typical Application Areas for Time-of-Flight	5
5. Comparison of the Listed 3D Technologies	5
6. Which Is the Right 3D Technology for My Application?	6
7. Summary	6

1.1 Application Areas

2D image processing is suitable whenever the application offers high contrast or if the structure and color of the object are decisive for the end result. At the moment, 2D is the dominant technology when it comes to image processing tasks.

Applications for 2D cameras can generally be found in all areas of image processing, such as positioning, detection, measuring and reading. Typical application areas for a 2D camera include the following:

- Assembly inspection of objects with contrasting components
- Detection of the form and dimensions of very flat objects with almost no height value
- Detection of contamination on an object, especially in an integrated test directly in the production line
- Evaluation of color and/or print quality e.g. of barcodes on packages
- Sorting of products that are clearly differentiated from each other in terms of their color or imprint
- Solder inspection of circuit boards

1. 2D Camera Technology

Area scan and line scan cameras are available as 2D camera technologies. Area scan cameras capture the scene to be analyzed with a single image, while the line scan camera uses a scanning process where the image is recorded line by line. Depending on the selected camera model, the scene is represented either in a monochrome or color image, i.e. in RGB values.



2. 3D Camera Technology

Several technologies, which will be explained in more detail in section 4, are available for capturing the third dimension of objects and scenes. A distinguishing characteristic of 2D and 3D technologies is that in addition to making the X- and Y-values visible in an object, the depth values of the recorded scene or object are also provided. This opens up entirely new possibilities to solve complex tasks, particularly in robotics, factory automation and the medical sector. By now it is hardly possible to imagine the entertainment sector without 3D solutions and there is an increasing range of new applications driven by the trend towards virtual reality and the use of 3D data in film production.

2.1 Application Areas

3D image processing is used in particular whenever volumes, shapes or the 3D position of objects will be analyzed. Depth information can also be used to handle tasks in the examination of objects and images of defects that do not have enough contrast for 2D but do show a recognizable difference in heights. Typical application areas for a 3D camera include the following:

- Detection of obstacles and “human” navigation of autonomously driving vehicles in an industrial environment, such as fork lifts
- Robot-controlled gripping jobs on conveyor belts or bin picking
- Presence detection, checking and counting objects in a bin / box, even if they exhibit no contrast at all against the background
- Examination of position and presence of components on a circuit board
- Volume measurements of a wide range of objects
- Portioning of food, such as meat separation

Even if 2D technology has played a greater role in the image processing market so far, the trend towards 3D solutions is constantly growing. In the coming years, 3D image processing will become increasingly significant particularly due to the trend towards Industry 4.0 and the growth of automation.



3. 2D or 3D – Will the Third Dimension Even Help Me Solve My Task?

The decision of whether 2D or 3D camera technology should be used to handle a respective inspection task has to be made at the very beginning, with a good deal of consideration. With some applications, this question can be answered easily, since the demands are very clear. However, 2D as well as 3D technologies could be used for some other applications, although they offer very different advantages and disadvantages. These have to be understood so that they can be used appropriately and before the best solution can be chosen.

To check whether a 2D or 3D solution is suitable for the intended task, it helps to proceed according to a list of criteria, and consider the following items in respect to the application:

Requirements for the task:	2D	3D
Analysis of volumes and / or shapes	-	✓
Structure and color must be recognized	✓	-
Good contrast information available	✓	-
Contrast information is bad or missing	-	✓
Differences in height must be recognized	-	✓
Positioning task / detection in the third dimension	-	✓

4. Overview of the Most Popular 3D Technologies

Just as it is possible in 2D image processing to use area scan and line scan cameras that complement each other to satisfy the needs of the different applications, 3D image processing also offers various technologies. Those that are used most frequently right now are:

- Stereovision and structured light
- Laser triangulation
- Time-of-Flight

Each of the technologies is based on a different principle to record the third dimension and they each have various advantages and disadvantages. The technologies complement each other here as well, and the most suitable one will depend on the requirements of the respective application. This will be addressed in more detail in the following section.

4.1 Stereovision and Structured Light

Stereovision works according to the principle of a human pair of eyes. Two cameras are used to record two 2D images of one object. The same scene is recorded from two different positions and the depth information is assembled into a three-dimensional image with the aid of the triangulation principle.

Stereovision uses image data from two regular 2D area scan cameras to provide depth values for the scene. The images are rectified based on the camera positions and knowledge about the geometry of the application. After the rectification, a matching algorithm is used to search for corresponding points in the right and left image and a depth image of the scene is created.

The working distance at which this process functions depends on the baseline – the distance between the cameras – and therefore varies.

One option for improving the performance of a stereo system is to add structured light to the stereo solution. With a light source that projects the geometric brightness patterns on the scene, the measurement results become more precise and the disadvantages of the stereoscopy due to homogeneous surfaces and low light are significantly reduced. Calibrating the projector with the camera even makes it possible to dispense with the use of a second camera.

4.1.1 Strengths and Weaknesses of Stereovision

- + Possibility to achieve high accuracy at short range
- + 2D area scan cameras can be used
- + Exposure to sunlight is not a problem
- + No problems with highly reflective, so-called uncooperative surfaces
- Will not work on homogeneous surfaces
- Will not work in low light
- High computing load makes real-time capability difficult

4.1.2 Strengths and Weaknesses of Structured Light

- + Possibility to achieve high accuracy at short range
- + 2D area scan cameras can be used
- + Exposure to sunlight is not a problem
- + No problems with highly reflective, so-called uncooperative surfaces
- High computing load makes real-time capability difficult
- High overall system costs due to complex setup and high installation cost

4.1.3 Typical Application Areas of Stereovision and Structured Light

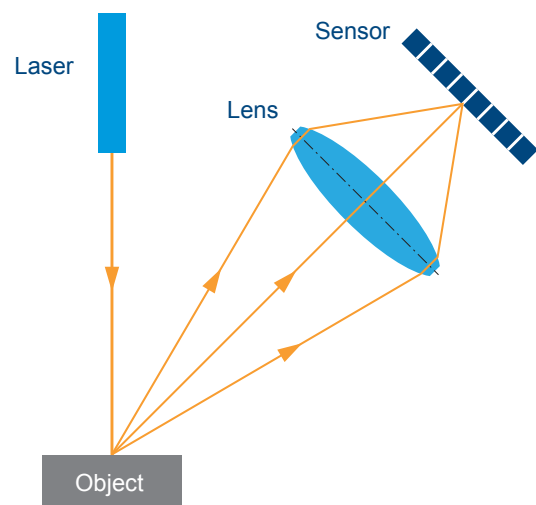
Fairly high accuracy can be achieved with stereovision. Uncooperative surfaces do not pose major problems for stereovision, but a few reference marks or random patterns on the object are always required. This means that this technology is generally not very well-suited for use in a production environment. Stereovision can often be found in coordinate measurement technology, the 3D measuring of objects and workspaces for applications with industrial, service or robot systems, as well as in the 3D visualization of work areas that are dangerous or inaccessible to humans. Stereo systems are also very suitable for use in measurement systems for outdoor areas, such as in a sawmill to measure and inspect tree trunks.

However, when structured light is added, stereovision is also interesting for such industrial applications as measuring objects if the high processing load, complex installation effort and higher costs are tolerable.

4.2 Laser Triangulation

The process of laser triangulation uses a combination of a 2D camera and a laser light source. In this procedure, the laser projects lines or dots onto the scene in front of the camera.

The laser lines or dots appear on the objects in front of the camera and are recorded by a 2D camera. If the distance of the measured object to the sensor changes due to camera movement across the object or to movement by the object, e.g. through a conveyor belt, the angle at which the laser lines or dots are observed will change along with their position in the camera image. The distance of the object from the light source is calculated from the position coordinates in the image with the aid of mathematics.



Functional principle of laser triangulation

4.2.1 Strengths and Weaknesses of Laser Triangulation

- + Very high accuracy
- + Difficult lighting conditions are not a problem
- + No problems with mirroring or highly reflective (uncooperative) surfaces
- Slow due to the required laser scanning of the object
- Small working distance
- High accuracy requires the use of very expensive individual components
- High overall system costs due to complex setup and high installation cost
- Eye safety is not guaranteed without safety precautions

4.2.2 Application Areas of Laser Scanners

Laser triangulation is always the means of choice in applications where extreme accuracy is required. It is also recommended to choose laser triangulation for uncooperative surfaces with strong reflections combined with difficult lighting conditions. The measurement of highly reflective metal pieces in a sub-millimeter range, for example, would be a typical application for laser triangulation. Another example is the sorting of glass bottles where little contrast is provided.

4.3 Time-of-Flight Method

The Time-of-Flight method is a very efficient technology to get depth data and measure distances. A Time-of-Flight camera provides two kinds of information for each pixel: the intensity value, stated as the grey value, and the distance of the object to the camera, namely the depth value.

There are two different methods to use the Time-of-Flight technology: the continuous wave and the pulsed Time-of-Flight method.

The continuous wave Time-of-Flight method is based on measurements of the phase length for a brightness-modulated light source. The method is mature and works with standard electronics. The sensors used in this method are relatively large and work only at low resolutions.

Pulsed Time-of-Flight measures distances based on the travel time for many individual pulses of light. This requires very fast and precise electronics to reach accuracy in the +/- 1cm range. By now, technological progress allows for the creation of precise light pulses and their exact measurement at high resolution at justifiable costs. That is why the pulsed Time-of-Flight method will continue to develop rapidly, since the trend towards high resolutions is significant here as well.

A Time-of-Flight camera is a compact system without movable parts and consists of the following components:

- an integrated light source
- an integrated lens and
- a Time-of-Flight sensor

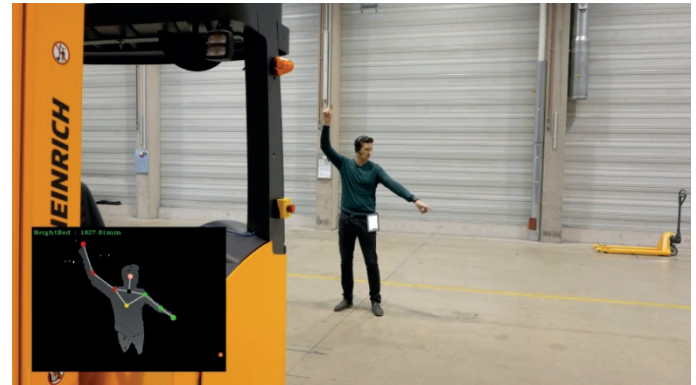
The light source sends out pulses of light or continuous light. This light strikes an object and is reflected back towards the camera. The integrated lens ensures that the reflected light reaches the sensor. In a simplified explanation, the distance and thus the depth value of each individual pixel is calculated on the basis of the time traveled by the light until it reaches the sensor again. This process enables a simple and real-time-capable depiction of scatter diagrams / depth maps and also provides an image of intensity and confidence, recorded at the same time.

4.3.1 Strengths and Weaknesses of Time-of-Flight

- + The scene is recorded all at once and doesn't have to be scanned
- + High speed
- + 2D and 3D information in a multi-part image
- + High X/Y resolution
- + Compact system without moving components
- + Works very well at low light
- + Eye safety is provided
- + No structure or contrast required
- + Large working distances are possible with a sufficiently strong light source
- + Low overall system costs
- + High real-time capability
- Problems with mirroring and highly reflective (uncooperative) surfaces
- Sensitive to scattered light
- Difficulties with sunlight

4.3.2 Typical Application Areas for Time-of-Flight

Time-of-Flight cameras are suitable for applications that require a large working distance, high speed and low complexity. If these properties are desired and a low budget is more important than accuracy down to the millimeter, the pulsed Time-of-Flight technology is the right choice. Volume measurements in logistics, palletizing and de-palletizing tasks as well as autonomously driving vehicles in a logistics environment are suitable for Time-of-Flight cameras. There are also new and exciting tasks for Time-of-Flight cameras in the medical field, namely for the positioning and monitoring of patients. In the industrial field, due to their relatively low depth precision, systems with Time-of-Flight cameras are more suitable for generalized tasks such as pick and place applications of larger objects. They can also be used for robot control systems or the measuring and position detection of large objects, e.g. in automotive manufacturing.



Time-of-Flight cameras in a smart forklift for storage automation

5. Comparison of the Listed 3D Technologies

As already became apparent in chapter 4, there is no single perfect 3D technology to solve all vision applications that need the third dimension. The requirements always have to be taken into consideration before the optimal technology can be selected. The following table shows the performance of the individual technologies in respect to the important criteria of an application:

	Stereovision	Structured Light	Laser Triangulation	Time-of-Flight
Range	Medium to far	Medium	Short	Far
Resolution	Medium	Medium	Varies	High
Depth accuracy	Medium to very accurate in short working ranges	Medium to very accurate in short working ranges	Very high	Medium
Software complexity	High	Medium	High	Low
Real-time capability	Low	Low to medium	Low	High
Behavior in low light	Weak	Good	Good	Good
Outside area	Good	Weak	Medium	Currently weak ¹
Compactness	Medium	Medium	Weak	Very compact
Material costs	Medium	High	High	Medium to high
Total operating cost	High	Medium to high	High	Medium to high

¹However, this will improve in the coming years thanks to the new sensor generation

6. Which Is the Right 3D Technology for My Application?

There is no single perfect solution for each application. That is why each application has to be newly evaluated in terms of its requirements and the appropriate technology. First it must be decided whether 2D or 3D should be used for the solution. If a solution requiring the third dimension is selected, the suitable technology has to be chosen according to the application requirements and the advantages and disadvantages of the respective 3D technology.

It is important to outline the criteria and basic conditions for the application again. Listing the basic conditions and requirements makes it easier to determine which technologies should be considered at all.

The following points should be clarified:

- How much accuracy does my application require? (sub-mm, mm or cm)
- What is the surface condition of the objects? (cooperative/uncooperative)
- What kinds of working distance does the system have to fulfill?
- What is the required speed of the system?
- Does the system have to be real-time capable?
- What are my requirements for the installation and the setup? Can the setup be complex or does it have to be very easy to implement and integrate?
- What is the total budget for the application? (Total cost of ownership)
- What is the maximum cost for the 3D solution as an individual component?
- Will the application be used indoors or outdoors with direct exposure to sunlight?

After the most important requirements are listed, they have to be prioritized in order to find the most crucial ones. This works best by asking yourself the following: What is an absolute must-have and what is more a B priority? Which advantages of another technology would be worth the omission of one requirement?

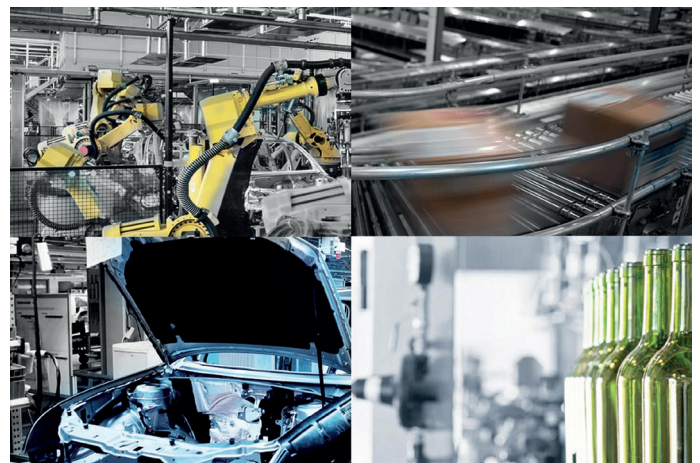
7. Summary

In the selection of technologies for image processing, there is no 100% certainty that you have found the single right one. Nor are there always single definitive solutions in the choice between 2D and 3D technology. The image processing and the applications behind them are often so complex that individual decisions have to be made depending on the use. Each application is different – one that offers a feature with a B priority, which could be ranked a little lower in favor of other factors, is a top priority in another application, which is then also mandatory at a higher price or with disadvantages in respect to other factors.

Choosing between 2D or 3D is the first step in deciding on the right technology. Only after this choice has been settled it can be decided which 2D camera – such as an area scan or line scan camera – or which 3D technology is most appropriate.

Here it is important to consider the total costs of such an investment which accumulate over the entire lifecycle, not just the individual components. The installation of the system and the software solution may result in high costs, even if an individual component appears cheap.

In the development of image processing solutions, the demand for 3D will continue to rise. This increase is caused particularly by Industry 4.0 and the ever-growing automation in all areas of industry as well as our daily life. Existing 2D solutions can also profit from the third dimension and make the system more efficient.





Author

Jana Bartels

Product Manager

Jana Bartels is responsible for Basler's 3D camera portfolio. She provides support for the Basler ToF Camera as the first 3D camera by Basler throughout its entire life-

cycle and coordinates the expansion of the current portfolio and the establishment of a 3D camera portfolio.

Jana started at Basler in 2005 as part of a work/study program in industrial engineering. After completing her degree, she first worked as a trainee in product management and then earned a Masters from the Polytechnic University of Kiel in 2008 alongside her normal job. She's been a constant part of the product management team at Basler AG since then, providing support for the Basler ace camera family before becoming a 3D product manager in 2015.

Contact

Jana Bartels – Product Manager

Tel. +49 4102 463 158

Fax +49 4102 463 46158

Email: jana.bartels@baslerweb.com

Basler AG

An der Strusbek 60-62

D-22926 Ahrensburg

Germany

Basler AG

Basler is a leading manufacturer of high-quality digital cameras for applications in manufacturing, medicine, traffic and retail. Product development is led by the demands of industry. The cameras offer simple integration, compact sizes, excellent image quality, and an outstanding price/performance ratio. Basler has more than 25 years of experience in image processing. The company is home to more than 500 employees at its headquarters in Ahrensburg, Germany and its subsidiaries and sales offices in Europe, Asia and the USA.

Basler AG

Germany, Headquarters

Tel. +49 4102 463 500

Fax +49 4102 463 599

sales.europe@baslerweb.com

www.baslerweb.com

Basler, Inc.

USA

Tel. +1 610 280 0171

Fax +1 610 280 7608

sales.usa@baslerweb.com

Basler Asia Pte Ltd.

Singapore

Tel. +65 6367 1355

Fax +65 6367 1255

sales.asia@baslerweb.com