A Qualitative Survey on 3D Data Acquisition Techniques
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Abstract—Quality control is of almost importance in any industry. It requires online measurement and inspection system. Quality analysis has become a common requirement among the different systems developed for better service life of object. In the past, human vision has played a primary role in quality inspection and verification processes but using them the problems occurred like low working speed and prone to error. The solution to these problems has been the introduction of artificial vision-based inspection system. As a matter of fact, applications of these systems are nowadays widespread in many industrial sectors. Optical methods have the most important role for 3D data acquisition, and among those, the triangulation based method is the most important one. In this paper, various 3D data acquisition techniques are reviewed. From comparison of different techniques for distance less than one meter and for small scale objects laser triangulation technique gives better result. A triangulation-based method and system for high speed 3D and gray scale imaging and associated preprocessing of digitized information allows estimation or filtering of data height or depth and gray scale values. This estimation is based upon the confidence level of the information obtained from a camera and also based upon knowledge of the object structure and its reflectance characteristics.

Key words: 3D data acquisition, Laser triangulation

I. INTRODUCTION

Real time three dimensional data acquisition is one of the most outstanding research fields. Three-dimensional acquisition aims to compute a 3D model of the objects of a scene from one or more 2D images and known geometry of the scene. The wide range of applications of 3D acquisition covers the quality inspection and control, reverse engineering, object recognition, medical imaging, shape digitizing and many others.

In the past, human vision has played a primary role in quality inspection and verification processes. It is, however, now considered a limiting factor in the inspection of products coming out from modern industrial production lines, where high working speed and very limited tolerance are required, unlike traditional system which is slow and prone to errors. The solution to these problems has been the introduction of artificial vision-based inspection system.

Optical acquisition techniques are mostly used for 3D data acquisition. 3D machine vision methods for nondestructive testing are classified into two groups: Contact methods and non-contact methods.

Optical three dimensional data acquisition techniques are covered in Section II, analyzing their main advantages with respect to other techniques, as well as the light patterns that can be used. Survey about the various active methods is covered in Section III, while section IV reports the comparison table of different three dimensional data acquisition techniques and the conclusions are presented in Section V.

II. THREE DIMENSIONAL DATA ACQUISITION

The ever-changing demands for improved quality of products make the use of 3D measurement systems essential. These systems are usually required to operate in real-time with high speed.

Machine vision systems based on optical 3D shape measurement outperform mechanical systems, which are mainly based on contact principles and can cause scratching of the surface of the products during inspection. Also,

Downsides like,
- More friction and wear,
- Limited number of operating cycle,
- Less operating speed,
- Complex internal geometry.

Traditionally, 3D machine vision methods for nondestructive testing are classified into two groups: passive, which only requires environmental light to illuminate the scene; and active, in which light patterns are projected onto the surface of the object to be measured.

The most commonly used passive machine vision method is shape-from-stereo or stereovision method [1]. This method uses two cameras to simultaneously acquire a pair of images of the scene. Three-dimensional information about the scene can be obtained by finding corresponding pairs from the two images. In passive method, the problems are: illumination, shadow, complicated image analysis etc. So, generally, for industrial quality inspection, passive methods are not used.

![Optical Methods Of Shape Acquisition](https://www.ijsrd.com)

Fig. 1: 3D Shape acquisition techniques

III. ACTIVE METHODS

A. Time-of-Flight:
The time of flight (TOF) is an active method. The principle behind the TOF is to measure the time difference between the emitted and reflected signal [2][ 3], while signal is traveling over a known distance (Figure 2).
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Fig. 2: Principles of the time-of-flight method

The resulting reflected signal is detected with a sensor and the time that elapses between emission and reflection yields the distance to the object, since the speed of the laser light is precisely known. Most commonly used scanner is a time-of-flight laser range finder [4].

This method is mostly used by terrestrial scanning systems. This type of scanner only detects the distance of a single point. So, the scanner scans its entire field of view, one point at a time by changing its view direction. The scanning volume of these systems is very large (up to several kilometers). The view direction can be changed either by rotating the scanner itself, or by using a system of rotating mirrors. Sometime these both methods are used simultaneously. The second method is the most commonly used because mirrors are much lighter and so they can be rotated much faster and with greater accuracy. But for achieving the full 360° field of view, it is necessary to rotate the laser range finder. The accuracy of this method depends on how precisely you measure the time. Usually it is hard to achieve such precision. So, this method is mostly suitable for large objects such as room or buildings.

B. Phase Shift:

Phase shift is an active method. The basic principle behind it is to compare the phase shift between the reflected laser light with a standard phase [2]. It is some way similar to time of flight method, the only the difference is that the TOF method calculates the time difference instead of phase shift. In general, it can be stated that phase difference method is fast, but signal to noise ratio depends on distance range and lighting conditions. This method is also used by terrestrial scanning systems and also for scanning large volume objects.

Fig. 3: Principles of the phase shift method

C. Computer Tomography:

Industrial Computed Tomography (C.T) is a non-destructive three-dimensional measurement technology. Full three-dimensional scanning of samples and the possibility of creating cross-sections from any angle opens up new analysis-related and time-saving potential for foundry-based quality controls. The results produced from a C.T. scan provide an internal and external three-dimensional representation of the 3D data volume.

Fig. 4: Principle of industrial computer tomography [5]

The CT-based 3D measurement process chain is shown below [7]:

1) Data acquisition
2) Volume reconstruction
3) Surface data generation
4) Evaluation and analysis

1) Rules of C.T:
   - The sample must stay within the horizontal field of view of the detector.
   - The sample must be penetrated at all angles of rotation.
   - The sample or background surrounding the sample must not be over penetrated or “washed” out at any angle of rotation.

D. Conoscopic Holography:

Modern manufacturing requires on-line methods for testing every part. To stay competitive, manufacturers need a metrology system that can detect surface defects, measure dimensions, give fast feedback, and add to knowledge about the process. In addition, the system must be versatile, reliable, inexpensive, and easy to set up. Finally, the system must be able to work in real time in the often difficult conditions on the process line. These requirements are a great challenge to metrology science.

Conoscopic holography works well for this purpose. Unlike normal machine-vision systems that provide only 2D images of a part, CH provides depth information. This common-path interferometric technique is based in the double refraction property of uniaxial crystals, and offers high-precision measurements with a wide range of standoff distances. The system obtains an image of interference fringes when a laser beam is reflected off a part and passes through the crystal. One can calculate the distance to the part from the frequency of the obtained fringes [8].

E. Laser Triangulation:

Laser triangulation is a very common 3D data acquisition technique. It is an active method which uses laser light to probe the environment. In an industrial demanding purpose like a distance not more than 1 or 2 m, and for the small scale object, this technique is used very commonly.
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In this method, laser either dot, beam or structure light illuminates a point of the scanned object. Diffused or specular reflections from that point are monitored with a detector which is mounted at some distance from the axis of the laser. A lens focuses the reflected light onto a CCD/CMOS camera or a PSD. The position of the dot of the laser on the chip reveals the direction of the incoming light, from which the distance can be calculated. Since the focal length of the camera lens is known, the analysis of the resulting image can determine the angle of the scattered light. The angle is also known since it is the projection angle of the laser beam. By using simple trigonometry, the 3D spatial (XYZ) coordinates of a surface point can be determined. The position of the laser dot on the chip can be calculated with sub-pixel accuracy. The high detection speed makes it possible to monitor the position of a moving or vibrating part e.g. of some machinery. The accuracy obtained may typically be one thousandth of the measured distance in the order of tens of micrometers. They are used for high precision scanning or production process control.

There are several variations of laser triangulation scanners. The detector can be a one-dimensional (1D) or two-dimensional (2D) array of sensors. The object can be illuminated by a single point (Figure 6 C), line (Figure 6 A) or a raster. This technique can also be applied to microscopic objects.

### IV. COMPARISON

<table>
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<tr>
<th>Sr No</th>
<th>Techniques</th>
<th>Type of radiant Energy</th>
<th>Detection Method</th>
<th>Advantages</th>
<th>Disadvantages</th>
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<tbody>
<tr>
<td>1.</td>
<td>Time of Flight</td>
<td>Laser light</td>
<td>Measuring the time between emitted and reflected signals</td>
<td>1) Simple construction, 2) Many measurement points, 3) Large measurement volume, 4) Large view angle.</td>
<td>1) Point measurement (not suitable for moving objects), 2) Includes moving parts (such as rotating mirrors), 3) Not suitable for small objects (minimum measuring distance).</td>
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<tr>
<td>2.</td>
<td>Phase shift</td>
<td>Laser light</td>
<td>Comparing the phase shift between emitted and reflected pulse</td>
<td>1) Simple construction, 2) Many measurement points, 3) Large measurement volume, 4) High measurement speed, 5) Large view angle.</td>
<td>1) Point measurement (not suitable for moving objects), 2) Includes moving parts (such as rotating mirrors), 3) Only possible to measure range differences between points, 4) Not suitable for small objects (minimum measuring distance).</td>
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</table>
High-speed 3-D data measurement is required by any industry to meet challenging demands for improvements in the quality of products. In this paper we studied different 3D data acquisition techniques. We have seen that laser triangulation method gives better solution as compared to other for industrial type environment with some positive points. It is suitable for detecting moving object with high resolution and high speed, suitable for small objects. It finds a practical application in Wrinkle measurement on cloth and leather, Radius determination of cutting tool blades, Volume measurement, Body shape measurement. Generate a dense 3D image, Real time 3D defect detection etc. Every technique hold good in particular field under particular circumstances.

<table>
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<th>Table 1: Comparison of 3D data acquisition Techniques</th>
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<td>4. Conoscopic holography: Laser light</td>
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<td>5. Laser triangulation Laser light</td>
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V. CONCLUSION

REFERENCES


