

A Literature Review on Low Cost 3D Scanning Using Structure Light and Laser Light Scanning Technology

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ABSTRACT: The 3D scanning system is increasingly used in various fields. The 3D scanner having the capability of capturing the real 3D objects in digitised form in the computer world. The generation of 3D model is required in various applications like in manufacturing industry to reverse engineering the existing components, to inspect the quality of manufacturing component, animation industry to model the character from the real world. The 3D scanning results in ease in the inspection process and hence decrease the manufacturing costs. The use of 3D scanning is enhanced by lowering the cost of 3D scanning device. In this paper the past studies done on the development of 3D scanning system are studied and also the various scanning factors are studied which results in increase the quality of 3D scanning system.

KEYWORDS: 3D Scanning, Reverse Engineering, Laser Light scanning, Literature Review.

I. INTRODUCTION

3D scanning is becoming one of the most important parts of reverse engineering and inspection purposes. Reverse Engineering is the process of recreating and improving the existing product. The recreation of the product is studied under various aspects like its design considerations, material properties and one of the most important aspect is the recreating its shape and size. Reverse Engineering starts with the generation of CAD model, for creating a CAD model physical dimension are required which are measured from the product. It is mainly undertaken to redesign the existing product for better design or producing a copy without having any excess to the original design. Computer vision applications have been widely used in the area of reverse engineering. Computer vision is a computer process concerned with image processing of real world images. Computer vision uses image processing to enhance the image quality e.g. remove noise, increase. Three-dimensional (3D) computer vision uses two-dimensional (2D), images to generate a 3D model of a scene or object.

The generation of 3D model is required in various applications like in manufacturing industry to reverse engineering the existing components, to inspect the quality of manufacturing component, animation industry to model the character from the real world etc. Manufacturing industry uses reverse engineering along with rapid prototyping of the existing product to achieve highest level of accuracy for the production of new parts. The 3D scanning is the process of obtaining the 3D shapes of the component whose physical attributes are difficult to measure, the 3D scanning obtains the 3D data in the form of 3D point cloud data or triangular mesh, these 3D data is used to create the 3D model of the component by using some CAD software. 3D scanning is a fast and accurate method of putting physical measurements of an object onto the computer in a manner, resulting in 3D scan data. 3D data obtained from 3D scanning is the exact replica of the existing product. The 3D scan data obtained can be used for various purposes like obtaining the physical

International Journal of Innovative Research in Science, Engineering and Technology

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Website: www.ijirset.com

Vol. 6, Issue 7, July 2017

attributes of the existing components, for inspecting the various parameters of the components against existing drawing.

3D Laser Scanning or 3D Laser Scanners can generally be categorized into three main categories:

- Laser triangulation
- Time of flight
- Phase Shift

These laser scanning techniques can be used independently, but can also be used in combination to create a more versatile scanning system.

Laser triangulation is accomplished by projecting a laser line or point onto an object and then capturing its reflection with a sensor located at a known distance from the lasers

Source. The resulting reflection angle can be interpreted to yield 3D measurements of the part.

Time of flight laser scanners emit a pulse of laser light that is reflected off of the object to be scanned. The resulting reflection is detected with a sensor and the time that elapses between emission and detection yields the distance to the object since the speed of the laser light is precisely known.

Phase shift laser scanners work by comparing the phase shift in the reflected laser light to a standard phase, which is also captured for comparison. This is similar to time of flight detection except that the phase of the reflected laser light further refines the distance detection, similar to the vernier scale on a caliper.

White Light Scanning (structured light scanning) is used to describe a wide range of 3D scanning devices. The basic technique is to project a known pattern of light (usually black and white lines) and use sensors (typically CCD cameras) to capture images of the object with the patterns projected on it. In order to capture 3D information, multiple patterns and/or multiple sensors can be used. If multiple patterns are projected, the software uses referencing and the change in shape of the known pattern to interpret 3D measurements. If multiple sensors are used the software uses the known pattern and referencing between image angles to determine the 3D measurements. The main disadvantage of using commercial scanners is the cost involved with it. The commercial scanners are about 1000 of dollars it creates the limitation of its use in low cost projects. This created the opportunity of developing the low cost 3D scanners which can produce good results without much comprising in qua-lity in comparison to commercial 3D scanners.

I. Need and Use of Low Cost 3D Scanning Tools

The 3D scanning is used for various engineering purposes. The 3D involves the creation of 3D model in computerised world. The 3D scanning is widely used for reverse engineering as well as for inspecting the quality which in turn eases the process of reverse engineering and hence results in decrease the cost involved with it.

The uses of the scanning technology are:

- Reverse Engineering
- Inspecting the quality
- Computation of 3D Animation Character from Real world
- Increase the speed of inspection
- Increasing accuracy working with complex parts and shapes

The first step of the reverse engineering involves the generation of 2D drawing by measuring the physical dimensions of the component under study. For each existing product it is always not possible to create 2D drawing for the components whose shapes are very complex. For those components 3D CAD model is generated by using 3D scanning process.

International Journal of Innovative Research in Science, Engineering and Technology

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Website: www.ijirset.com

Vol. 6, Issue 7, July 2017

II. WORKING PROCEDURE OF 3D SCANNING TECHNOLOGY

3D Scanning is the technology which is used to obtain the 3D shapes of the real objects from the real world in computerised form as three dimensional representations. The data collected by the 3d scanner is in the form of point cloud data and this data is used to obtain 3d shapes of the component.

For experimental set up of **3d laser scanner** the hardware requirement are as follows:

Line Laser: Line laser is a modified laser which projects a line instead of a point. It can be green laser or red line laser.

Camera: A good quality web cam can be used for more accurate results good ccd camera can be used.

Motorised set up: For moving the laser line on to the work piece either the component is rotated or line laser is rotated across the component to be scanned for controlling the movement some controlling software along with some motor can be used.

Following is the working principle of 3D Scanning Systems:

The First step is to calibrate the camera. It involves in recognising the 3d points corresponds to 2d points being captured. This method uses the checkerboard pattern for calibrating the 2D points of the camera plane with the 3D points of the real world. In this technique a planar checker board pattern is rotated for at least two different orientations and these orientations are checkerboard pattern for calibrating the 2D points of the camera plane with the 3D points of the real world.

The Second step is to position the camera and line laser at some angle generally less than 20 degrees.

The Final step is to project the line laser on the component being scanned and the will produce the 3d data from 2d points by using some algorithm.

III. LITERATURE SURVEY

Zhang (2000) [1] proposed a flexible new technique for camera calibration required for 3D scanning. This method uses the checkerboard pattern for calibrating the 2D points of the camera plane with the 3D points of the real world. In this technique a planar checker board pattern is rotated for at least two different orientations and these orientations are observed by the camera. The proposed calibration technique is easy and flexible. Chang & Chen (2005) [2] uses the 3D laser scanning technique to obtain the shape of welded surface profile so as to measure the quality of weld. A 3D laser scanning system along with CAD software is used to reverse engineering the weld profile to obtain the accurate measurement of weld. Yao (2005) [3] paper studied the application of 3D scanning and reverse engineering techniques for quality control of quick response products. The comparison of fabricated parts and an original CAD design is often a difficult and time consuming. This paper uses the integration of three techniques reverse engineering, 3D scanning and rapid prototyping for rapid producing products. In his project he takes the cellular phone model and its 3D CAD model is prepared, then uses 3DP RP machine to produce parts as per the CAD model and then its dimensions are measured using callipers and 3D scanning and the dimensional comparison is carried out and it is found that integration of three technologies results in quick quality check of quick response products. Furukawa and Kawasaki (2005) [4] presents a new method of structure light scanning. This system consists of a video projector and a camera which together will use as a stereo system the video projector is used as substitute for camera. In this method the camera and projector need not to be calibrated only the intrinsic parameters of the camera need to be known the extrinsic parameters of both the camera and the projector need not to be known. In comparison to image-based multi-image reconstruction, this system able to obtain dense shapes data with higher precision. In conventional structured light system both the camera and projector is calibrated and then they are fixed to their respective positions if either camera or projector is moved the entire system is to be calibrated. In this system, a multi-image uncalibrated stereo method is achieved by moving either the camera or the projector. The correspondence between the camera and the projector is only obtained by scanning either the camera or projector is allowed to move both the camera and projector will not move simultaneously. Multiple scanning of the objects can be obtained by moving one of the devices while the other one being fixed is an efficient method to improve precision of the results. This type of scanning is called pivot scanning. The position of the fixed device is called pivot position and the position of the movable device is called

International Journal of Innovative Research in Science, Engineering and Technology

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Vol. 6, Issue 7, July 2017

peripheral position. In this paper two scanning methods are used. The first method involves keeping either the camera or the projector fixed and the other device moving. Since this method utilizes the information of multiple images, the precision of the camera positions improves, producing a better quality 3D reconstruction. The second method involves fixing each of them alternatively. In this method of scanned first the camera is fixed and the projector is moved and scan results are taken and then projector is fixed and camera is moved and the steps are repeated. This method has the advantage of covering wide area of scan. Zhang and Huang (2006) [5] develop a high resolution 3D scanner for real time scanning of moving objects. The scanner is based on digital fringe projection and phase shifting technique. It uses a digital light processing projector to project fringe pattern generated by the computer on to the object being scanned. A high speed CCD camera synchronized with projector is used to capture the image at the rate of 120 frames per second. In phase shifting technique for construction of 3d image it requires three frames therefore the image acquisition speed of this system is 40 frames per second. In this system the more the pattern is projected on to object the better the accuracy is obtained. For producing color image the red, blue and green channels are continuously and repeatedly projected at a very high speed. In order to produce realistic rendering of the object to be scanned the texture mapping is used. The sinusoidal phase shifting method consists of three fringe pattern having a phase shift of $2\pi/3$ between each pattern. This phase shifting algorithm is used to obtain the 3D shape of the real moving objects. Lanman et al. [6] (2007) paper presents a new method of scanning for obtaining complete 3D surface models using a structured light projector using a pair of planar mirrors, and one or more synchronized cameras. In this method of 3d scanning the structured light patterns are used to illuminate the components not from one side but from all the sides of the components to be scanned. The system requires that projected planes of light to be parallel so the orthographic projector is constructed using a Fresnel Lense and DLP projector. Two planar mirrors are used which is set at right angle with respect to each other and the component to be scanned placed in front. This scanning system is able to capture full 360° scan without the object being orientated as well as the camera also remain fixed in one position. The structured light patterns fall on the component and illuminate the component from all the sides, by using two plane mirrors we get one real image and four virtual images and these five images together will make the component visible from all around and hence the scanned results consists of five scans of five different views and the component is completely scanned. Peiravi & Taabbodi (2010) [7] presents a laser triangulation 3D scanner using two different colour laser one is green and other one is red and one ccd camera, by using this approach it is found that the occlusion problem is minimized and the overall system reliability is increased. The proposed scanner is much cheaper and is less complex than the scanners having two cameras and one laser. The various scanning parameters are studied and calculated which include Red Laser Beam Angle, Green Laser Beam Angle, Red Laser Tilt, Green Line Laser Tilt, Red Laser Base Line, Green Laser Base Line, Focal Length by using those parameters value the accuracy of scanner is greatly enhanced. Martinez et al. (2010) [8] uses laser scanning for metrological applications in order to test its accuracy for geometric dimension and tolerance control. It uses two scanning systems one is laser scanning and other is touch trigger probe both are mounted on coordinate measuring machine. The test parts which are designed to be tested are spheres, planes, conical surfaces, holes. The common alignment method is used to compare the accuracy of both the scanning systems. It uses computer aided design software CATIA V5 for converting point cloud data into Cad model and GEOMAGIC Studio for reverse engineering of scanned data into 3D surface reconstruction, Geometric Qualify software is used for inspection. Three artifacts are designed to evaluate the suitability of 3D Laser Scanning for Geometric Dimensions and Tolerance Control. The artifact A consists of geometric shapes like cylinder, horizontal, vertical and inclined planes. The artifact B consists of fillets, slots and chamfers. The artifact C consists of holes, counter bores and countersinks. The shiny and highly reflective surface does not produce good scanned results so the artifacts are made of aluminum so that the surface prepared is diffusive reflective. It has been found that the accuracy of touch probe is around 5 microns and the accuracy of the laser scanning is about 15 microns and also the laser scanning is not able to completely scan the holes Martynov et al. (2011) [9] solved the problem of video projector calibration. In this method the projector is calibrated by inverting the camera calibration work flow. The calibration of projector requires a single camera, which does not need to be calibrated and which can be uses as a sensor to see whether projected dots and calibration pattern landmarks, such as the checkerboard corners, coincide. In this method the projector projects the known pattern on to the flat surface and the camera captures the images of pattern projected by the projector and various pictures are captured for various orientations and by using Zhang method the projector is calibrated. Park et al. (2011) [10] uses a hand-held 3D scanning technique to reconstruct 3D models of real objects. A sequence of images is captured from a hand-held

International Journal of Innovative Research in Science, Engineering and Technology

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stereo camera and these images are automatically registered to a reference coordinate system. The scanner is portable one and is hold in hand, the conventional 3D shape matching techniques may fail to automatically align a sequence of images. This paper uses fine and coarse registration of multiple range images to automatically align to reference coordinate system. Anwar et al. (2012) [11] presents the method to calibrate the projector. The experimental set up includes a non calibrated camera, projector, a flat surface on which pattern from the projector will be projected. In this method both the camera and the flat surface are fixed with respect to each other and the projector is rotated and translated. First of all printed checker board pattern is fixed on the flat surface and camera captures the image and then projector projects the image of known pattern and then the holography is established between camera and projector. The calibration of the projector involves the calculation of intrinsic as well as extrinsic parameters. Hence the projector is calibrated by treating it as inverse camera. Ouji et al. (2013) [12] proposed a structured light camera/projector system for 3D scanning, using three calibrated cameras coupled with a non calibrated projector device, for 3D face scanning. This paper proposes a multi camera 3D acquisition solution which is particularly suited for 3D face scanning. It uses stereo based acquisition for 3D scanning .it uses a video projector and two cameras which is mounted on both side of the projector. The Fringe pattern is projected on the component to be scanned and its deformation is recorded using two cameras. O.Aubreton (2013) et al. [13] presents a new method called Scanning from heating is introduced to scan highly reflective metallic surfaces, glass materials. It has been found that in non contact based scanning, the scanning quality depends on the optical quality of the surface to be scanned, and the results obtained by active 3D triangulation on specular and reflective surfaces are not as good as diffuse surface. This paper presents the method to scan highly reflective surfaces with good quality scan results. The reflective surface which has to be scanned is heated by a laser light source and after heating its thermal emission is used to obtain the scan results. Reyes et al. (2013) [14] developed a prototype of 3D scanning device that can be used to obtain virtual 3D objects by using one d optical distance sensor. The device consists of three elements, an electromechanical platform, data acquisition hardware and a microcontroller which is used to control the electro-mechanical platform and software which is programmed in Matlab language. The electromechanical platform consists of two stepper motors one controls the vertical movement of the optical distance sensor and other stepper motor controls the rotation of the platform on which the object is mounted. The maximum weight that this rotating platform can take is 450gm. In order to check the quality of 3D scanner the components scanned are one plastic cylinder, two toy head are used. Zhao et al. (2014) [15] presents a method of calibration for stereo vision system based on phase matching and bundle adjustment algorithm. For calibration of the camera intrinsic and extrinsic parameters are required as the position of the camera are mechanically held at the desired position the intrinsic parameters of the camera will remain same. The need is to calibrate the camera for extrinsic parameters in real time. For stereo vision system the images from the two cameras need to be matched, the corresponding points between two images are matched by multi-frequency phase shifting technique. The number of pairs between two corresponding images taken by two cameras depicts the accuracy of calibration. Gerbino et al. (2015) [16] studied the influence of scanning factor on the laser based 3D scanning system. The internal factors that influence the quality of 3D scanning are scanning resolution and accuracy and the external scanning parameters which influence the quality of 3D scanning are ambient light, surface colour, glossiness and shape. A complex shaped sheet metal test part is taken for studying the effect of scanning factors, the scanner to object relative orientation and the ambient lighting, as well as internal scanning parameters were tested. This paper uses Design of Experiments approach, and setting root mean square error as response function The outcomes of the results found that that the scanning factors that influence the quality of 3D scanning are scanning to object relative orientation as well as its position within the field of view of the measurement device are the main factors that influence the accuracy of the measurement process. Galantucci et al. (2015) [17] developed the 3D laser scanner using semi automated low cost motorized system. This paper is focused on the testing and implementation of low cost semi automated laser light scanning system. The scanner is based on the software platform of the DAVID Laser Scanner Vision Systems GmbH's., the movement of the laser stripe was controlled by using Mach3 CNC software which controls the movement of stepper motor using controller. The controller is based on numeric control system. It has been found that the speed of laser based scanning is slower as compared to existing system such as Structured light system. But the accuracy of laser light scanning system is greater than the structured light system. Wang & Feng, (2016) [18] studied the effects of scanning orientation on outlier formation in 3D laser scanning of reflective surfaces. The scanning orientation greatly affects the quality of scanning of reflecting surfaces .By selecting the proper scanning path the quality of scan can be enhanced to a great effect. Jurado et al. (2016) [19]

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paper proposed multiple camera and projector system which can simultaneous scan the whole object without being oriented. It uses the multi-view structured light system for full 360 degree scan of the component in one go. In this method multiple camera and projector system are set around the work piece to be scanned and simultaneous scanning around the work piece is obtained. This paper proposes a method to automatically calibrate the extrinsic parameters of the multiple camera as well as projector without requiring any special equipment. In this method the structured light sequence is projected by the multiple projectors one by one in well defined sequence and the multiple cameras are used to capture them simultaneously. The intersecting field of view between the devices will determine the sequence by which structured light sequence are projected

IV. CONCLUSION

From the past study we concluded that the 3D scanning is very useful tool to create the 3D shape of the components from the real world into computerised form as three dimensional representations. The 3d scanning is widely used for Reverse engineering purposes it helps in extracting the exact shape and size of the components whose physical attributes are difficult to measure and it is also widely used for checking the quality of the components which otherwise take very long time. Researchers have also studied various scanning methods and various scanning factors are studied which greatly influence the quality of 3D scanning to scan the components it is found that Laser Light Scanning and Structured light scanning are widely used in reverse engineering and inspection purposes as the results produce by these methods are quite accurate.

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