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A Pipeline to create The Perfect 3D Object Scan

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Abstract -- A 3D scanner is a tool that examines real-world objects to gather raw information about their form and appearance. A new technology called 3D scanning of items and the environment has many real-world applications. The information gathered by a 3D scanner can be used to create a digital 3D model. Although 3D scanners are a relatively new technology with a wide range of practical uses, very few people actually own one, primarily because they are so expensive. We'll outline a method for building a cost-effective standalone 3D scanning system, which would enable the creation of digital 3D models using data collected by a camera and line lasers. The proposed 3D scanner creates a 3D model using laser triangulation. The main controller is a Raspberry Pi. The developed 3D models can be used in animation techniques or replicated using 3D printers for a variety of applications.

I.INTRODUCTION

3D scanners are extremely similar to cameras. They can only gather data about surfaces that are not obstructed, just like cameras, and they have a cone-like field of view. A 3D scanner gathers distance information about surfaces within its area of vision, whereas a camera gathers colour information about surfaces. A 3D scanner's "picture" indicates the separation from a surface at each point in the image. This makes it possible to determine the three-dimensional location of each point in the image. In most cases, a single scan won't result in an accurate representation of the individual. Typically, it takes many scans—perhaps hundreds—from numerous angles to get data on all aspects of the issue. A full model must be created by merging these scans into a single reference system, a step that is typically referred to as alignment or registration. The 3D scanning pipeline refers to the entire procedure from the single range map to the entire model. The final part of the 20th century saw the development of 3D laser scanning as a means of precisely recreating the surfaces of numerous things and locations. The technology is particularly useful in the design and research areas. Lights, cameras, and projectors were utilised by the earliest scanners to accomplish this task. It frequently took a lot of time and effort to correctly scan items because of the equipment's limitations. By 1985, they were superseded with scanners that could photograph a specific surface using white light, lasers, and shadows. The evolution of 3D scanning is briefly covered next. A 3D scanning equipment analyses real-world objects or environments, helping to gather raw data about the form and look of the thing. The data that has been gathered may be used to create a digital, three-dimensional model. The technical objective of this project is to create a 3D representation of the structure or item so that we can compute and scan the entire thing. Fundamentally, determining the precise measurements and creating a digital reproduction of an object are our key concerns. We need to take the colour into consideration in addition to the form and size. We must specifically compute the entire surface reactance of each and every point scanned over the structure. In general, 3D models are a useful tool for documentation and interactive display, creating a virtual reproduction. It takes a lot of work to create and compare 3D models that are aesthetically appealing. The basic requirements of the user are based on factors such the geometric and metric quality of the 3D model, processing time, modelling issues, and equipment cost, which should be reasonable while still being precise and efficient. For 3D laser scanning methods, there are two distinct fundamental working principles. The first method detects a picture of an object's surface texture and profile using the laser light interference phenomenon and analysis of the optical fringes generated. It may be used to measure tiny areas (less than 1 cm2) with high resolution (less than 1 micron). Micro-profilometry is a method used mostly in micro technologies, although it is not widely utilised elsewhere. The second working principle is known as laser triangulation, which mathematically connects the directions of the laser beam's emission and the direction of the reflection that is observed and is useful for determining the location of an object's surface point. This technology can obtain a few micrometres resolution on objects with typical size between 1 cm and 1 m. This method is excellent for musicological artwork and for learning more about specific areas of major monuments. Depending on the size of the scanned regions and the necessary resolutions, multiple methods can be used to scan a laser beam evenly across an object's whole surface.

A digital file may be used to create three-dimensional solid things via additive manufacturing, often known as 3D printing. Using additive methods, 3D printed objects are produced. An item is made via an additive technique by adding layers of material one after another until the full entity is formed. Each of these layers might be thought of as a horizontal cross-section of the final item that has been finely cut. It is a new technology in its early stages with enormous potential for the future. With the use of 3D printers, everything is possible; the possibilities are endless. The complexity of creating 3D models and the high cost of 3D modelling software, however, pose one of the main obstacles to the widespread use of 3D printers in homes. Here, we make an attempt to partially overcome this issue by incorporating a 3D scanner inside the printer to facilitate the creation of models. In this study, we combine a 3D scanner with a printer to create a standalone device that can easily scan and print items. As the 3D camera in this method, we employ a Kinect sensor because of its great availability and relatively inexpensive cost. The methods used to extract the depth information from a 3D scanner and to create a workable 3D model using the Kinect's noisy and aliased depth data are mentioned in the study. In their research, Jin Zhou, Ligang, Zhigeng Pan, and Hao Yan talk about depth cameras like the Microsoft Kinect, which are far more affordable than traditional 3D scanning technologies and can thus be easily purchased by regular people. Nevertheless, the quality of the depth data that Kinect collects over a given distance is really poor. This study proposes a unique scanning technique that makes use of numerous Kinects to capture 3D whole human body models. In Chaoching Ho's work, the research describes a low-cost scanning method for obtaining 3D geometry and texture information of huge objects as well as for doing multiscanning patch registration to produce an entire realistic 3D model. The suggested system consists of a colour CCD camera and a line-stripe laser.

II. METHODS AND ANALYSIS

The goal of 3d scanning is to gather information about a physical object or environment and then reconstruct it as a digital 3d model. This 3D model may be used for a variety of purposes, including industrial design, film production, and production quality control. The 3d scan is the initial stage in the creation of a 3D model. A point cloud—often millions of points arranged in a Cartesian coordinate system and structured like the scanned object—is the end outcome of this. These dots are frequently packed so tightly that they may seem like solid three-dimensional models. A camera may be used to capture the colour of each sample point. A "RGB point-cloud" is created as a consequence, which is a point cloud where each point has a colour from the RGB (red, green, and blue) colour spectrum. When the 3D scan is finished, a computer software analyses the point-cloud to produce a surface model from the point-cloud. To put it simply and as simply as possible, creating surfaces is "connecting the dots" (Figure 2.1). These surface reconstruction techniques are typically quite mathematically difficult and are not covered in this thesis. However, it is important to remember that the quality of the final surface model greatly depends on the accuracy of the 3D scan.

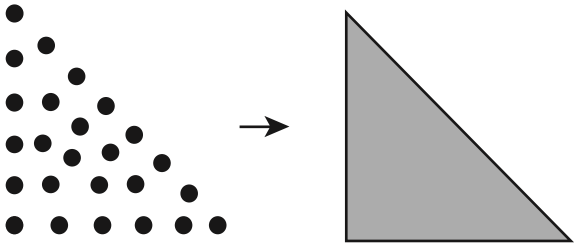

Figure 2.1:
Concept illustration, from point cloud to surface.

TRIANGULATION: - When extremely accurate and short-range measurements are required, such as when checking machined components, triangulation is frequently utilised. The technique makes use of at least one laser and one image sensor that are offset from one another. On the item being scanned, the laser often displays a point, line, or pattern, and the image sensor records its offset from the picture centre. The distance may be estimated by adding this offset to the focal length between the image sensor and the lens.

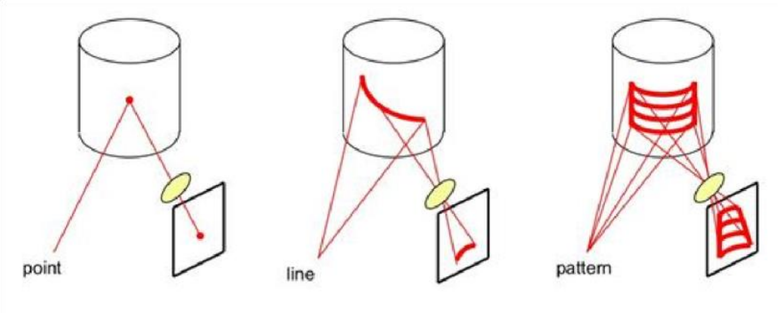

Figure 2.2:
Illustration of the principle of triangulation scanning.

In this project, we chose to employ one of the simplest scanning approaches, putting less emphasis on achieving the best results and more on getting the complete mechanism to function with off-the-shelf components. The main control board for the system is a Raspberry Pi, which also controls the Line LASER diode, the Pi Camera, and the EasyDriver using control signals (Stepper Motor Driver). I developed the algorithm in MATLAB and deployed it on the Raspberry Pi using the Hardware Support package. By taking this action, I was able to install the controller board more quickly and concentrate on perfecting the math behind the scanning algorithm. A 3D object's two-dimensional projection onto a plane can be seen in a photograph of the thing. As they are contained inside the picture plane, it is simple to determine the X and Y coordinates of any point on the object. Nevertheless, because of the projection, the details on the depth of the point in relation to the object's centre are lost. We require specific assistance to access this data. Fortunately, it's not as challenging as it seems. Let's assume that each line of pixels in the image has a corresponding Y coordinate that, after being scaled, corresponds to the real Y coordinate. A right-angled triangle is formed at each Y coordinate by the point on the object's surface where the LASER line projects itself, the intersection of the LASER line and the camera's field of view (assuming nothing is in the way of the line's path), and the perpendicular dropped from the point on the surface to the field of view. The distance of the surface point from the view direction is given by the length of the perpendicular dropped on the view direction, which can be thought of as our X coordinate with a scaling factor. The depth of the surface point in relation to the axis of rotation is provided to us by the other smaller side of the triangle, again with a scaling factor. The computations are straightforward trigonometrical processes, as you can see. Let's now construct our fundamental scanning method using this knowledge. We need to determine the points at which we may extract this information in order to extract 3D information for each point located on the surface of the object. By taking two photographs, one with and one without the laser on, you can easily do this. The difference between the two photos should show us all the spots that lie on the LASER line projected on the item since everything else in the camera's field of view remains unchanged. The majority of the unnecessary information in the difference image may be removed by transforming it into a binary image, which will then label all places along the LASER line as white and the remainder pixels as black. By establishing assumptions about the rectangular area that encompasses the entire item in the image, we may further focus on the area of interest. We currently have all the tools required to extract the 3D coordinates of each point located on the object's surface. There is still one component that need attention. The points that were recovered from the photos are improperly orientated in 3D space and all lie on the same image plane. To do this, we must rotate each 3D point that was extracted by a certain amount around the axis of rotation. We can readily calculate the angle by which the points must be turned following each rotation step if we closely monitor the object's rotation.

PHOTOGRAMMETERY: The science of photogrammetry involves extracting physical data from 2D photographs, frequently aerial photographs taken by drones. Software for photogrammetry may be used to create lifelike 3D reconstructions of topographic surfaces by merging enough overlapping photos of the same elements. Almost as old as photography itself is photogrammetry. In the roughly 150 years since it was first developed, photogrammetry has evolved from a purely analogue, optical-mechanical technique to analytical methods based on computer-aided mathematical algorithm solution, and finally to digital or softcopy photogrammetry based on digital imagery and computer vision, which is devoid of any opto-mechanical hardware. Making exact measurements of three-dimensional objects and terrain characteristics from two-dimensional photos is the main goal of photogrammetry. The creation of topographic maps, the measurement of coordinates, the calculation of distances, heights, areas, and volumes, as well as the creation of digital elevation models and orthophotographs are some examples of applications.

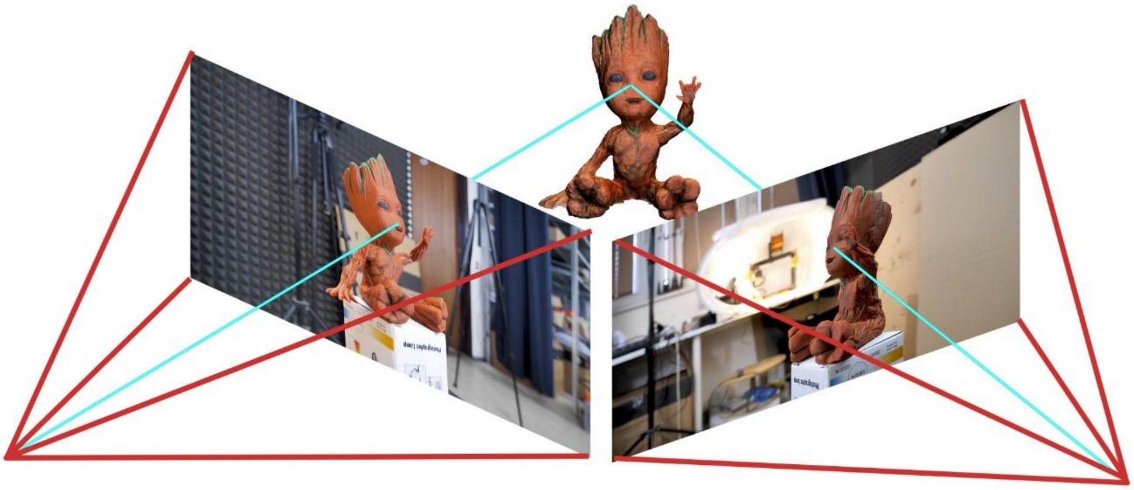

Figure 2.3:
Photogrammetry – 3D Scanning with camera

With specialised cameras, huge regions may be swiftly captured from the air, and blind spots that are concealed from terrestrial cameras are reduced. Using designated and well-known ground reference points to scale each image, a mosaic made up of thousands of images may be created. Complications are overcome using plotting devices and computers. The tools employed in photogrammetry have advanced significantly. Satellite photography, extremely large-scale photography, automated visual scanning, high-quality colour photography, the use of films sensitive to radiation outside of the visible spectrum, and numerical photogrammetry are just a few of the advancements made in the second half of the 20th century.

UML DIAGRAM

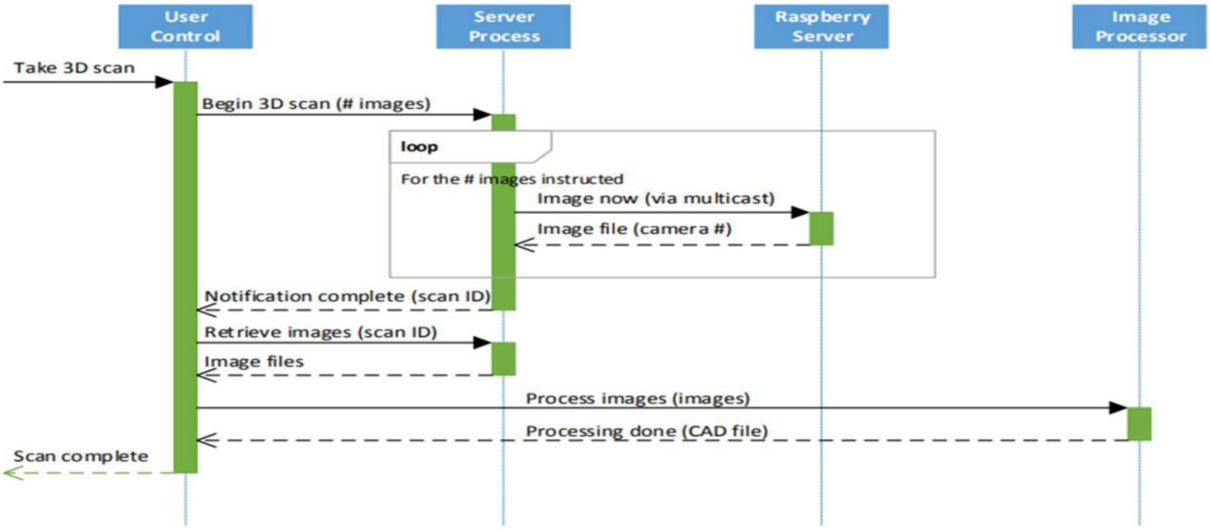

Figure 2.4:
Sequence Diagram:

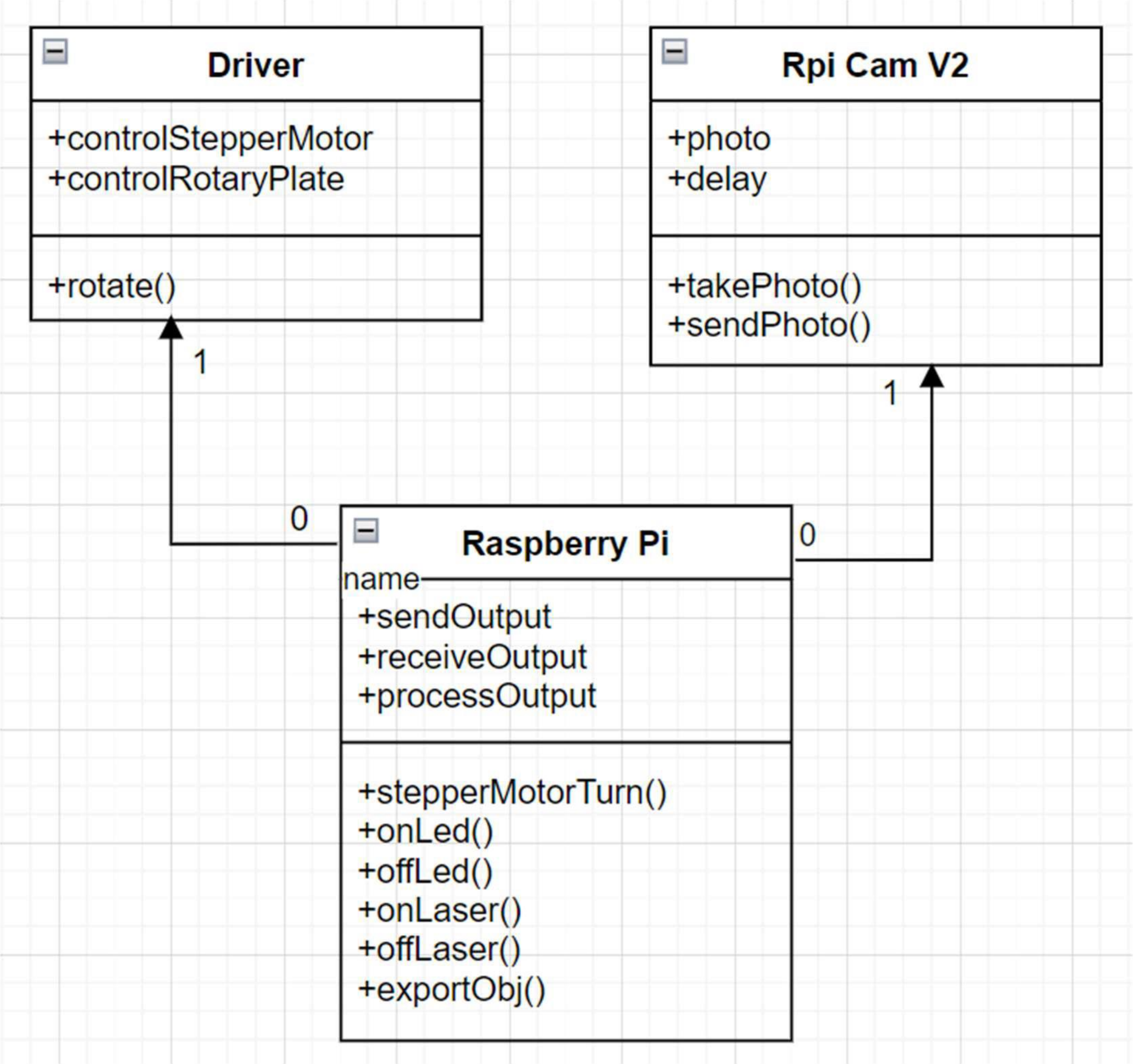

Figure 2.5:
Class Diagram

III.SOFTWARE AND HARDWARE REQUIREMENT SPECIFICATION

Stepper Motor: An electromechanical device known as a stepper motor transforms electrical power into mechanical power. Also, it is a synchronous, brushless electric motor that has a large number of steps per entire rotation. As long as the motor is correctly designed for the application, the position of the motor may be regulated precisely without the need of a feedback device. Similar to switching reluctance motors are stepper motors. When an electrical pulse is applied, the stepper motor turns the motor shaft a certain amount using the magnetism theory of action. A DC motor's structure and that of a stepper motor are quite similar. The Rotor, which resembles a permanent magnet and is located in the centre, rotates when force is applied to it. This rotor is encompassed by a number of stator that are coiled with magnetic coils all around it. To allow magnetic fields within the stators to govern the movement of the rotor, the stator is placed close to the rotor.

Figure 3.1 Stepper motor

The stepper motor may be controlled by individually igniting each stator. As a result, the stator will get magnetised and function as an electromagnetic pole that propels the rotor forward using repulsive energy. The rotor will move gently and turn with excellent control thanks to the stator's alternate magnetising and demagnetizing. The electro-magnetism concept underpins stepper motor operation. It contains a rotor made of a permanent magnet, as opposed to a stator built of electromagnets. The magnetic field will start to form inside the stator as soon as the supply is given to the winding. The motor's rotor will now begin to move in tandem with the stator's spinning magnetic field.

Laser Module In the electromagnetic spectrum, laser diodes and modules are semiconductor devices that can coherently generate a beam of high intensity focused radiation that is generally in the infrared, visible, or ultraviolet wavelengths (light waves of the same wavelength, phase and direction).

Figure 3.2 Laser Module/ Diode

LED light: An extremely energy-efficient lighting technology called LED has the potential to completely alter how Americans will light their homes in the future. Residential LEDs, especially those with the ENERGY STAR label, consume at least 75% less energy and can outlast incandescent lights by up to 25 times.

METHODOLOGY:

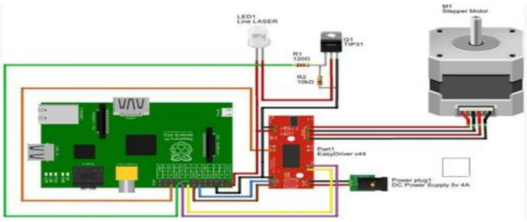

Figure 3.3
Framework

The above figure shows the components and their connection with each other.

In this experiment we are using:

- Raspberry Pi 4B+ (2GB)
- Line Laser Module 5V
- NEMA 17 Stepper Motor 12V
- Stepper Motor Driver
- Pi Camera
- Power Supply

The above setup is implemented in the below Diagram:

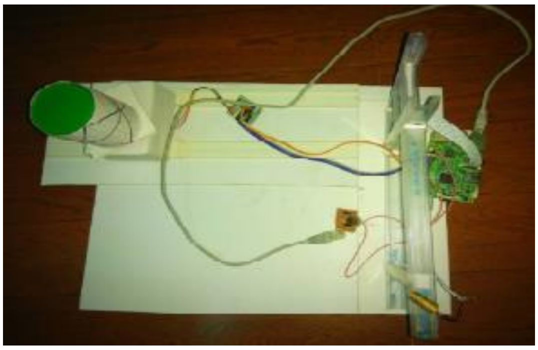

Figure 3.4

As you can see, the object is placed on the Rotary Plate which is rotated using the NEMA17 Stepper motor. When the Motor turns, Raspberry pi takes an image using its camera module.

A Line laser is used which projects a line shape on the object. The laser is turned off and an image is taken without the laser. Then the rotary motion is carried on and an image with and without laser is captured. This process goes on until the object has completed its 360-degree rotation.

A zip file is created containing laser images and non-laser images. This zip file is uploaded to the cloud (Raspberry Pi to Server). The images are then processed in a software called Meshroom which uses photogrammetry concepts and methods to process the images to generate a 3D object from provided image dataset.

IV.CONCLUSION & FUTURE WORK

CONCLUSION

Real-time demonstrations of the operation of a scanner that can capture a 3D model utilising a variety of parts have been developed. In comparison to a professional scanner, this project's component requirements are far cheaper, and the model that was scanned has a high degree of accuracy. The entire endeavour was an economical technique to make a 3D representation of the thing.

FUTURE SCOPE: -

1 By combining several camera systems, it is possible to scale up this project and produce a real-time representation of the item.

2 The use of several cameras or sensors (such as a lidar scanner) will shorten the time needed to produce a 3D model.

3 Taking photographs at really high resolution will lower the amount of storage needed.

4 The size of the scanner will depend on the object's dimensions; a bigger scanning equipment could be able to easily scan massive things.

REFERENCES:

1. Joao Braun, Jose Lima, Ana I. Pereira, Claudia Rocha, Paulo Costa, “Three-dimensional scanning system based on a low-cost infrared sensor”, IEEE 2021.
2. Thomas Heckman, Robert Kalb, Shreyes Nallan, “3D Scanner”, Spring 2020.
3. Jeremy Straub and Scott Kerlin, “Development of a Large, Low-Cost, Instant 3D Scanner”, 20 May 2020.
4. Pham Bui Anh Duv, “Rotary table modification for 3D-scanner”, 2020.
5. Stephen Jendritz, Logan Mendelson, Brad Scuzzarella, “Design, Fabrication, and Testing of a 3D Image Reconstruction Process”, 4/26/2018.
6. Vaishnavi K Bhat, Shilpa Prabhu K, Saideep D Ullal, Ashish Kini, “Three-Dimensional Scanning and Imaging of Miniature Objects”, 2018.
7. JOHAN MOBERG, “Accuracy, performance and challenges with a low cost 3d scanning platform”, 2017.
8. Ajeesh K, Lidin Joseph, Akhil Babu T, Arun KP, Muhammed Sherin TA, “Standolone 3D Printer with Interlaced Scanning”, 2017.
9. Sera Mathew, Ahnas Muhammed, Allen Boby, Sahid P, “Raspberry pi and MATLAB based 3D Scanner”, 2018.
10. Aditya Gaykar, Advyta Jujaray, Shalmali Mutalik, Prachi Waghmode, Prof. Sanjay B Matekar, “Design and Analysis of 3D Scanning System for Scanning an Object”, 2020