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THE GRADUATE SHCHOOL OF NATURAL AND
APPLIED SCIENCES

DESIGN OF A FAST 3D SCANNER

Zardasht Abdulaziz Abdulkarim SHWANY
(142129105)

Master Thesis
Department: Computer Engineering
Supervisor : Prof. Dr. Erhan AKIN

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MASTER THESIS

ZARDASHT ABDULAZIZ ABDULKARIM SHWANY

(142129105)

Department of Computer Engineering

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Thesis Supervisor: Prof. Dr. Erhan AKIN (F.U.)

Other Juries: Assoc. Prof. Dr. Mehmet KARAKÖSE (F. U.)

: Asst. Prof. Dr. Özal YILDIRIM (M. U.)

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ABSTRACT

DESIGN OF A FAST 3D SCANNER

Nowadays, 3D Laser Scanning technology is utilized in a variety of fields in modern world technology including healthcare systems, sciences and educations, arts, designs and industrial designs, and manufacturing. 3D Scanning of any objects can be done by three major processes which are; 3D data acquisition, cleaning, alignment and surface reconstruction. The project goal is describing the whole process steps of a three-dimensional scanner of any indoor object from 3D data and also characterizing forms each of the data acquisition, alignment, and surface reconstruction processes in detail separately. However, the design of hardware, software and completion have already been made and described each and every step of the object 3D modeling with a perfect realizing of the scanner is obtained. After reviewing the existing data acquisition frameworks and discuss their advantages and disadvantages, as a result, three-dimensional laser scanner was selected to be the most precise and fast data acquisition system suitable for scanning indoor objects. Red laser line diode utilized.

The project 3D laser scanner is a simple and lightweight light which is easily moved from one place to another and also can be easily configured as well as, 3D laser scanner operates properly, and the accuracy and high resolution of the scan results in 3D model form. For the alignment or registration of 3D data obtained by the 3D laser scanner, in this research, we utilized the method formed with an academic software called Meshlab which is heavily rooted in the VCG library developed at the Visual Computing Lab of ISTI - CNR. A few initial examples result of this method are given in this paper. Also, additional work is desirable to apply this method to reconstruct the surfaces of a complete 3D model of any scanned object.

Keywords: Camera, Laser Line, Coordinate Systems, 3D point cloud, Meshlab

ÖZET

HIZ BIR 3BOYUTLU TARAYICI TASARIMI

Günümüzde 3boyutlu lazer tarama teknolojisi, sağlık sistemleri, bilimler ve eğitimler, sanatlar, tasarımlar ve endüstriyel tasarımlar ve imalat da dahil olmak üzere modern dünya teknolojisinde çeşitli alanlarda kullanılmaktadır. Her hangi bir objektin 3boyutlu taranması, ana üç işlemle yapılabilir; 3boyutlu veri toplama, temizleme, düzeltme ve yeniden yüzey yapılandırma. Bu araştırmanın amacı, 3boyutlu verilerden gelen herhangi bir iç nesnenin üç boyutlu bir tarayıcının tüm işlem aşamalarını ve ayrıca veri toplama, hizalama ve yüzey yeniden yapılandırma süreçlerinin her birinin formlarını ayrı ayrı ayrıntılı olarak açıklamaktır. Bununla birlikte, donanım, yazılım ve tamamlamanın tasarımı yapılmış ve her aşamada anlatılmış ve nesnenin her adımında 3boyutlu modelleme ile mükemmel bir tarayıcı elde edilmiştir. Mevcut veri toplama çerçevelerini inceledikten ve avantaj ve dezavantajlarını tartıştıktan sonra, kapalı nesneleri taramak için en hassas ve hızlı bilgi toplama sistemi olarak üç boyutlu lazer tarayıcı seçildi. Kırmızı lazer hattı diyot kullanıldı.

3boyutlu lazer tarayıcı projesi, bir yerden diğerine kolaylıkla taşınabilen basit ve hafif bir ışıktır ve ayrıca kolayca konfigüre edilebilir, ayrıca 3boyutlu lazer tarayıcı düzgün çalışır ve taramanın doğruluğu ve yüksek çözünürlüğü 3boyutlu model formunda sonuç verir. Bu araştırmada, 3boyutlu lazer tarayıcı ile elde edilen 3boyutlu verilerin hizalanması veya kaydedilmesi için, ISTI - CNR Visual Computing Lab'da geliştirilen VCG kütüphanesine kök salmış Meshlab adlı akademik bir yazılımla oluşturulan yöntemi kullandık. Bu metodun birkaç ilk örnek sonuçları bu yazıda verilmiştir. Ayrıca, taranan nesnelerin tam bir 3boyutlu modelinin yüzeylerini yeniden oluşturmak için bu yöntemi uygulamak için ilave iş arzu edilir.

Anahtar Kelimeler: Kamera, Lazer Çizgisi, Koordinat Sistemleri, 3boyutlu nokta bulut, Meshlab

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ABBREVIATIONS

1D	: One Dimensional
2D	: Two Dimensional
3D	: Three Dimensional
AO	: Analog Output
ASC	: American Standard Code
ASCII	: American Standard Code for Information Interchange
CAD	: Computer Aided Design
CAM	: Computer Aided Manufacturing
CM	: Centimeter
CMM	: Coordinate Measurement Machine
CMOS	: Complementary Metal-Oxide Semiconductor
COM+	: Component Object Model
GND	: Ground
HD	: High Definition
IDE	: Integrated Development Environment
ISO	: International Organization for Standardization
KHZ	: Kilohertz
LD	: Laser Diode
LDC	: Laser Diode Cathode
OBJ	: Object File
PC	: Personal Computer
PD	: Photo Diode
PDA	: Photo Diode Axle
PNG	: Portable Network Graphic
PWM	: Pulse Width Modulation

STL **:** Stereo Lithography

TOF **:** Time of Flight

USB **:** Universal Serial Bus

VCG **:** Visualization and Computer Graphic

VRML **:** Virtual Reality Modeling Language

SYMBOLS

$\vec{V}$	**:** Oriented Points
A	**:** Stepper Motor Pulse Phases
B	**:** Stepper Motor Pulse Phases
c	**:** Speed of Light in Vacuum
p	**:** Range
r	**:** Distance from the Center to Edge of the Object
t	**:** Round Trip
V	**:** Point Vector
x	**:** X Axis
$\mathbf{X_m}$	**:** Indicator Function
y	**:** Y Axis
z	**:** Z Axis
Δn	**:** Stepper Motor Delay
$\mathbf{\Delta X_m}$	**:** Indicator Gradient
θ	**:** Angle Between Each Two Profile

1. INTRODUCTION

Three-dimensional (3D) scanner also named as “real-scene copying technology” is a tool that analyzes assets (or objects) to gather data on its form and sometimes outward appearance (such as color). These data are used to construct digital models of 3D which are used in many applications. One of the modern 3D scanners utilizes laser line to scan the body directly without contact to any object surface, and then the resulting 3D point cloud of the object is obtained. Addressing this point cloud and using some other processes a 3D model of the body will be obtained, which is valuable for a wide variety of applications [1].

Usually for obtaining 3D model, 3D laser scanner will pass through several stages until it reaches the results, during these stages there are some preliminary processing such as, collecting 3D data from the object surface which also has its own some other partial processing, such as camera rotating table utilizing stepper motor which controlled with a stepper motor driver microcontroller and C programming language, and a laser line to create points for the surface by shining a laser radiation towards continuously. Then converting the collected 3D data into 3D point cloud using coordinate system's conversation at the end surface reconstruction methods required to the output of suitable result and with high-resolution 3D model [2, 3].

1.1 Overview

Three-dimensional laser scanners are being considered as a standard source that delivers an input data in many application areas ranging from cultural heritage documentation, industry, manufacturing, and surveying to medicine [4]. While modeling programming can make fake models, this work will concentrate on modeling from reality in the earthly range. Truth be told, making a virtual 3D model is now considered a simple errand. Yet, the recuperation of an exact and photograph sensible computerized model for genuine objects still requires significant exertion. The computerized photogrammetry and the laser scanning are the most two normal strategies utilized for the recuperation of such advanced models.

The laser scanning strategy could not care less about the surface shape. Likewise, it can create promptly an exceptionally thick 3D point cloud with a somewhat decent exactness in only one stage. Various point clouds are generally expected to recoup the entire question. The caught point clouds require then a registration venture keeping in mind the end goal to place them in one coordinate system. Solid programmed registration techniques for numerous point clouds registration are just accessible in the event of utilizing simulated targets [5]. After the registration step, the entire model is accessible in type of 3D points. Lamentably, the laser beam cannot identify the shade of the deliberate surfaces. Besides, it cannot catch the surface between the deliberate points. This implies the acquired point clouds from the laser scanner are dry and for a situation of modeling these point clouds into surfaces the came about 3D models are surface less.

In this manner, keeping in mind the end goal to accomplish ideal 3D modeling comes about, a blend between the advanced photogrammetric strategy and the laser scanning system is prescribed. In current laser scanners, the makers mount high-determination computerized cameras on the highest point of the laser scanner which empowers photograph catching in the meantime of catching the geometry. With this equipment setup, the sought blend can be accomplished yet with specific impediments. The nature of the acquired photographs is terrible because of catching the pictures from a similar position of the scanner position. Scanner fields of view are the fundamental impediments of this setup. In this way, approaches utilizing free or greater scanner box to gather photographs autonomous of the laser scanner gadget are required. Laser scanning will not offer a clarification to the greater part of the recording assignments. It does not give boundless geometric precision and fulfillment over the objects. Much of the time, laser scanning may be viewed as superfluous for the level of required deliverable yield [6].

In this work, another advancement named fast 3D scanner is presented as a consequence of exhibiting the intertwined information in a 2D situation. The mechanization in the information combination step is likewise accomplished through three recently created designs.

The fundamental reasons behind 3D laser scanners are to catch and test the geometric shape and appearance of an object's surface. This is finished by making the range information or 3D point cloud model. Post-handling techniques utilize this range information to reproduce the state of the inspected object, and this procedure is named as surface reconstruction. An additional preferred standpoint is that in picture preparing applications, it empowers a reasonable perspective of structures, for example, windows and stairs, which are imperceptible if a 2D model, were utilized. This makes the 3D models appropriate for differing qualities of assignments including reconnaissance for security and safeguard applications [7].

Most of the time, a one-scan shot will not suffice to prepare a whole model of a given object. To precisely catch adequate data and information on every one of the sides and diverse edges of a thing, up to a few several scans might be taken. Every one of these scans must be allowed in an interesting and basic reference coordinate system. This methodology is ordinarily named alignment or registration [8]. The scans are then converged to make a whole 3D model. The whole procedure from beginning from single range information to model the total object is ordinarily known as a 3D scanning pipeline.

1.2 Thesis Goal

Precision and exactness in science and technology are basic in the production of any logical gadget so as to make it available to human. Since in the past 2D systems were used for laser scanning and recreation, their mistakes and inability to check and remake indoor environment incited the arrangement of 3D systems.

Also, another important fact within the 3D modeling is to apply textures on the produced surface in the last stages. It makes the model more and more accurate and easier in reception. Different tools for proceeding with texturing will also be examined.

Additionally, as can be seen currently, computer applications for behavior laser scanning and 3D data acquisition of every object has continued to develop throughout the last years successfully. It improves the whole methodology for dealing with 3D datasets. However, it is extremely hard to make a decision from the tool that is perfect for each step of the process of processing. This matter can also be one of the several aims associated with this study and various workflows were examined.

The main aims of current research are to design and build a fast 3D scanner system using commodity hardware, and software where a user could scan their objects in the 3D model. Another goal is to make a device for 3D data acquisition and modeling system in a fast, robust, simple to use, and in a near to real-time. Also, the aim is to create an algorithm capable of conduct these challenges and examine advantages and limitations of this technique.

The main research question is

- How to design a low cost, good quality and fast 3D scanner?

1.3 Important Terminologies

This section briefly examines a portion of the prevalent terms that have been utilized through this report as presented in Table 1.1 [9].

Table 1.1. Significant terminologies [9]

Terminology	Explanation
3d Scanning	The process of graphically capturing as-built physical elements of an object, facility or area and applying surveyed information to each point. The process of collecting 3d coordinates of a given region of an object surface automatically and in a systematic pattern at a high rate (hundreds or thousands
Laser Scanner	A device used to capture 3D surface geometry, consisting of a laser output and a sensor to interpret the data. Spatial position can be defined through a series of devices, including CMM, portable CMM, handheld and time of flight LIDAR systems.
3D Modeling	From the point cloud, 3D modeling is the recognition of geometric shapes that represent the scanned equipment. Torus, sphere, plane, cylinder, extrusion. Will be generated by "fitting" on the point cloud to match the reality of the scene.
Point Cloud	A set of hundreds of millions of points defined by X, Y, and Z coordinates that represent the external surfaces of an object the rendering is close to the "3D Model".
Alignment	The process of aligning two point sets in a common coordinate system. Commonly refers to aligning scan data.
Mesh	Is the most convenient way to numerically represent a complex surface. The point clouds obtained by laser surveys are ideal for creating mesh. Indeed, algorithms developed allow calculation of triangular surfaces connecting points of the cloud three by three. The process of creating a 3D surface from point clouds.
Profile	Is a section (see definition) usually perpendicular to the general direction of the site, often used for tunnels and galleries.
ASCII (or ASC)	(American Standard Code for Information Interchange) -- ASCII (or ASC) a point cloud file in text format.
Coordinate System	In geometry the coordinate system is a system that uses one or more numbers, or coordinates, to uniquely determine the position of a point or any other geometric element on an manifold.
3D Reconstruction	It is the process of capturing the shape and appearance of real objects. This process can be accomplished either by active or passive methods.

1.4 Methodology

In this study, the sensible system will be utilized to accomplish the objective. The regular pipeline in shaping a 3D model from a 3D scanning result is appeared in Figure 1.1 beneath. This pipeline incorporates four particular procedures, which are; data acquisition, alignment or registration, surface reconstruction and surface drawing.

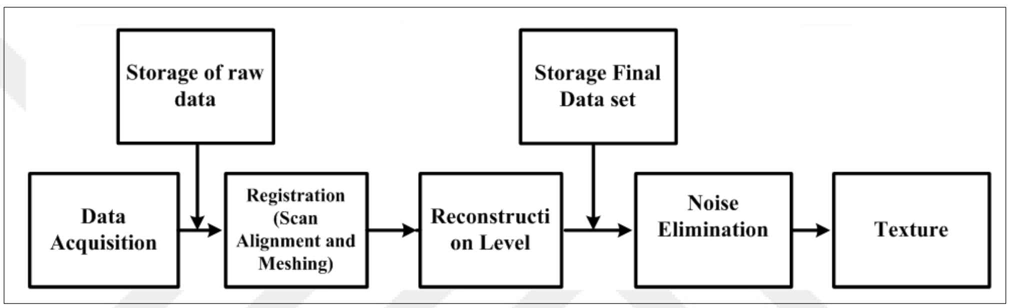

Figure 1.1. 3D modeling workflow

1.4.1 Data Acquisition

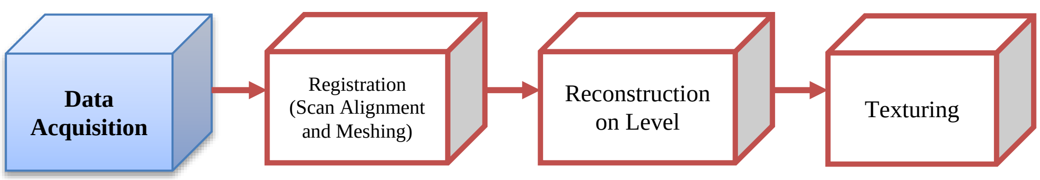

Figure 1.2. Data acquisition step in 3D modelling pipeline

Data acquisition basically means to the way the system collect 3D coordinates data from nature or object. For this reason, this examination utilizes a red laser line and a gathering of software and equipment to gather 3D territory information more precisely which is less demanding than the past techniques. In the initial step, the drawn dish tilt connected to the laser line scanner makes it ready to scan in 3D space and cover the whole extension. Moreover, keeping in mind the end goal to pivot the turning stage in 360 degrees, the system utilizes one stepper engines as actuators. The second step requires the 3D scanner to be introduced over the composed situation which is a primary box for covering the entire scanner's parts with a specific end goal to build the execution. Figure 1.2 shows the data acquisition step in 3D modelling pipeline. This enhanced execution permits the system to perform indoor situations. In spite of the fact that this permits the system to be easy to use, the system created in this venture makes one stride further and gathers the profiles information, by connecting a HD wide-edge camera and a red laser line to the system. The camera gathers or takes profiles (pictures) relating to every object information and the position data secured by the product of the system inside the operation. As a consequence of these procedures, a 3D model of the earth is acquired in the as a point cloud [10, 11].

1.4.2 Alignment or Registration

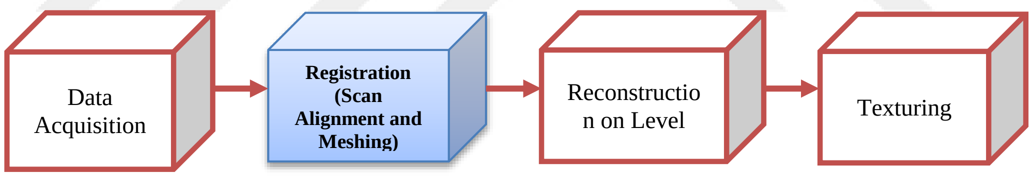

Figure 1.3. Forming the Point Cloud Model (Alignment or Registrations)

As a rule, one scan shot will be deficient in covering an entire object or environment. A few scans must be taken to form various edges and headings for ideal results. For the most part, there is a need to gather data and information about all sides of the object. Every one of these scans must be amassed in a one kind of regular reference coordinate system. This strategy is ordinarily named alignment or registration. Regularly, the commotion excess and shifting strategies are performed in this progression, and this procedure is shown in Figure 1.3 [12, 13]. Taking profiles from different angles in 360 degree performed see Figure 1.4.

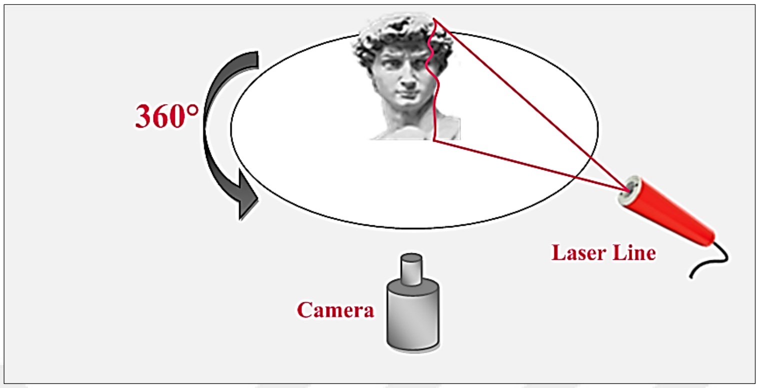

Figure 1.4. Taking Profiles from different angels

1.4.3 Surface Reconstruction

This alludes to the procedure, which tries to gauge and reproduce a discretionary surface topology from the point cloud model [14, 15]. This venture utilizes a summed up certain surface reconstruction strategy in view of Poisson reconstruction strategies [16]. The capacity to remake a persistent and consistent surface from scattered example points makes this strategy exceptionally famous. The proposed technique enhances the execution precision of the surface reconstruction strategy by including additional data about the development of scattered specimen points. This extra data is delivered through the sharp component extraction strategy, and Figure 1.5 demonstrates the Surface reconstructions pipeline.

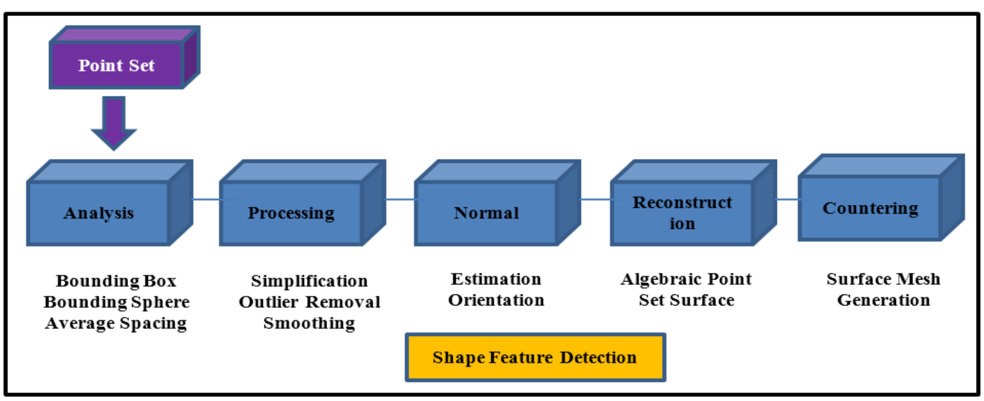

Figure 1.5. Surface reconstructions pipeline [2]

1.4.4 Texture Mapping

Surface mapping is the realistic methodology system in which a 2D surface, called a surface guide, is a 3D object. In this manner, the 3D object procures a surface like that of the 2D surface. Surface mapping is the robotized relating of applying backdrop, paint, or lacquer to a genuine object. The least difficult surface mappings include procedures, for example, that appeared in the beneath Figure 1.6. Three equivalent rectangles, each secured arbitrarily with dabs, are specifically mapped onto the three unmistakable features of a 3D block. This bends the sizes and states of the specks on the top and right-hand feature. In this mapping, the surface guide covers the solid shape with no obvious breaks as a consequence of the way the dabs are sorted out on the squares [17].

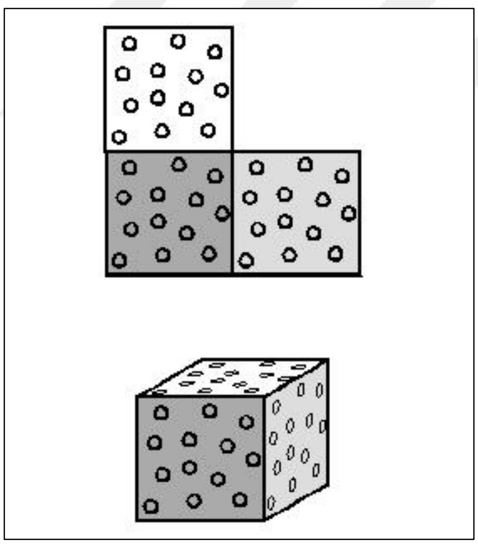

Figure 1.6. Mapping a 2D surface into a 3D rendition alters sizes and shapes of image elements [17]

In specific mappings, the correspondence including the 2D map texturing furthermore the 3D object's shallow end up being messy. A specimen could be the use of an example of squares towards the surface of a circle. It truly is unrealistic to glue checkered backdrop onto a circle without cutting the paper in a route as to create discontinuities when the gander at the example is taken. This issue happens with a few surface mappings. A mind-boggling example can, in a few occurrences, be consistently married towards the surface of a 3D object utilizing a propelled design program. The example is created ideal on the 3D interpretation, rather than utilizing a surface map. For example, a circle could be given a wood-grain wrap-up. The squares-on-a-circle issue may not be illuminated, be that as it may, it is conceivable to coordinate an example of triangles onto a circle by confirming the sizes connected with the triangles [18].

1.5 Organization of the Thesis

This project includes five chapters that represent the research work within the thesis's scope.

Chapter 2: Primarily concerns about 3D laser scanner and laser based scanning technology and the literature review. Firstly, it explains what 3D laser scanner is and provides an understanding of what it can do, in terms of functionality and importance. Additionally, it addresses methods and phases of laser scanning. An explanation of the techniques and tools of based 3D laser scanning and their uses in areas are also provided. Then, the meaning of each and every important method of 3D laser scanning system and their requirement and work efficiency, in addition their advantages and limitations is also outlined. Types, applications, tools and specifications of the 3D laser scanner and how to set up a scanner testing lab are also mentioned. It then addresses the installation of the scanning tools such as laser, camera, scanner box and rotating table.

Chapter 3: A number of experiments show how 3D laser scanner is implemented using several tools and techniques. Furthermore, information is gathered about the 3D data acquisition, alignment, registration and surface reconstruction and applying scanning tools such as Meshlab and GLC player.

Chapter 4: This chapter shows a summary of the results achieved throughout the designed 3D laser scanning in a real time. This chapter also concludes whether the objectives and research questions determined in the first chapter have been resolved or not.

Chapter 5: Conclusion summarizes and discusses the contributions of this research work. It also discusses the limitations of the features introduced in this research work, and future directions of our research.

1.6 Summary

This chapter introduces the common scanning concerns and concept of 3D laser scanning with regards to the research question. It then presented the project aims and goals. Finally, a brief summary of all chapters is given. The next chapter provides a background to 3D laser scanning and literature review of research on several techniques that comprise forms of 3D scanning.

2. BACKGROUND AND LITERATURE

This chapter presents 3D laser scanning background and 3D scanning methods. It shows most recent techniques that are widely practiced by professional testers to carry out successful laser scanning experiments that help to design and develop a fast 3D scanner.

2.1 Overview

The initial 3D scanning innovation was created in the 1960s. Within research and design fields, there was a necessity to be able to competently reconstruct surfaces of objects and plates for a way to easily access and alter projects to make way for improvements. Since the last half of 20th century marked the beginning of dropping to the possibilities computers have in a technical industry. The number of choices for capturing the physical world and putting it in the digital appealed to numerous people 3D scanners were the best way to achieve this [19].

Early 3D models are scanning to execute this approach by utilizing a combination of lights, cameras and projectors. However, due to the complex nature of the scans, in order to replicate an object accurately a lot of effort, and time was required. Also, necessary improvements needed to be made for the current system. Therefore, the same number of fine detail could very well be collected due to the scanners but at a bit more efficient and effective rate than currently possible. The models used are not ideal, nevertheless, the technology was restricted until hard disk drive storage could possibly be increased as a result of the mass number of data that has been collected with the scanners. It was not through to the 1980s that laser technology was put to work to 3D scanning, marking the start of the techniques familiar with the current day [20].

The employment of optical technology was preferred as using light to assess the surface of an object not just to likely be faster than a physical probe but additionally will likely be non-contact. This meant it was absolutely possible to expand the horizons of what objects could come to be scanned, as soft or fragile surfaces would not normally be impacted by optical technology. In 1985, the traditional method of 3D scanning was replaced with scanners that rather utilized white lights, lasers and shadowing to gather data points of an object's surface [21].

Three forms of optical technology were produced point, area and stripe point and location were soon disregarded as 3D laser scanning techniques because of the fact that 'area' was an extremely complex technical task to execute, and 'point' used an individual point of reference and was, therefore, most considerably faster compared to the older technology. Stripe, having said that, outshone one other two technologies by far and it is still found in modern-day 3D laser scanners. Stripe technologies pass over an object making use of multiple points of reference to evaluate the surface region from. Due to a large number of data collected in a part of the required time, stripe technology is incredibly accurate and fast. In the late 1980s, exactly the same technologies came into this world in the form of a head scanner which captured the surface components of human features to be utilized throughout the animation industry. It was actually well received available today, and innovations always been designed to the point where through the mid-1990s top animation studios were utilizing full body scanners to capture the data points of real human Figures [22].

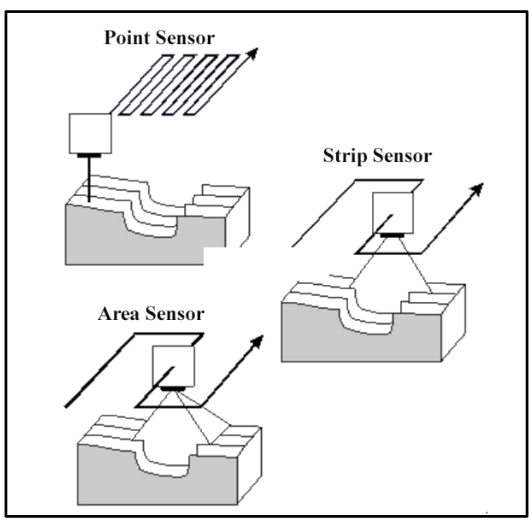

Figure 2.1. Sketch of the three different optical technologies [27]

Three kinds of optical technology were available shown in Figure 2.1.

The point, which can be fundamentally the same as a physical test for the reason that it utilizes an individual point of reference, rehashed a few times. This specific arrangement was the slowest approach since it included a lot of physical development from the sensor.

Area, which will be actually troublesome. This may be shown with the insufficient hard zone systems accessible available to be purchased.

Stripe, the third system was soon observed to be faster than point testing since it utilized a band of various points to go through the object in the meantime. It was completely precise as well. In this manner, it coordinated the twin requests for speed and accuracy [23].

Having said that, all through the 1980s a tremendous issue designed 3D scanning fans that to catch an object with its actual 3D type, the sensor would need to make a few scans from various positions that have been presently a testing assignment to achieve. Right now, 3D laser scanners were exceedingly expensive, for the most part out of reach and were constrained in lifting ideal on up the different shades of a surface. This had not been settled before the mid-1990s when the REPLICA was released which marked a big leap forward in laser scanning technology. The hardware permitted quick and very exact scans of point by point objects, Figure 2.2 demonstrates the course of events of 3D scanning improvements [20].

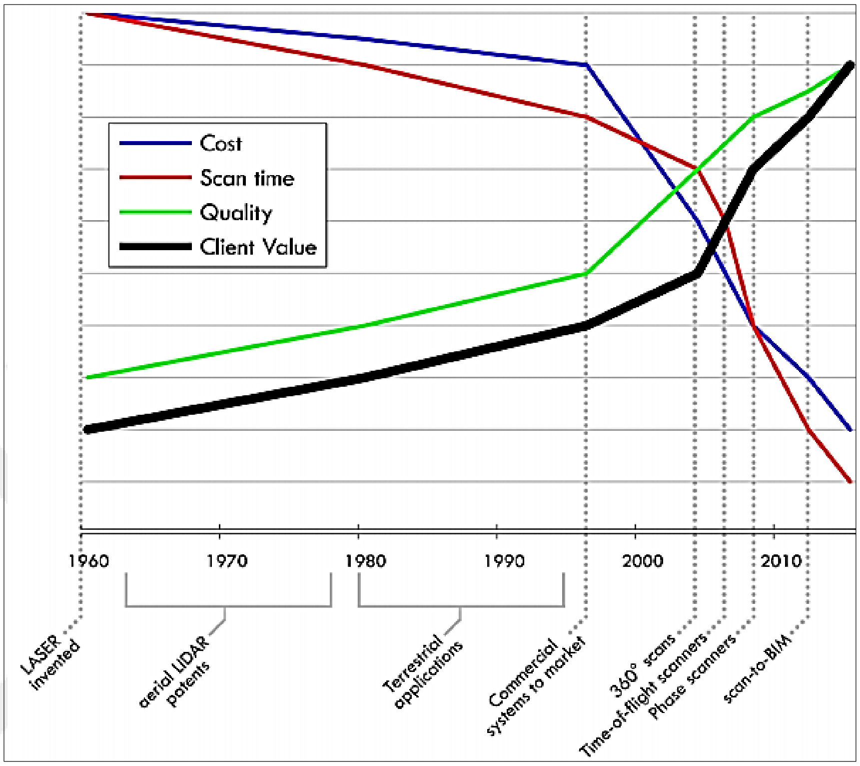

Figure 2.2. The timeline of 3D scanning development [26]

In 1996 3D Scanners took the essential thing advances of a physically oversaw arm and a stripe 3D scanner and consolidated them in ModelMaker appeared in Figure 2.3. This is to a great degree quick and adaptable system that could then begin of the world's reality catch system. It produces confounded models, and textures those models with color. The colored 3D models are presently ready to be created in minutes. Since that time the fundamental objective in enhancements of laser scanning happens to make the innovation reachable as is conceivable and growing the imaginative uses connected with the information points gathered [24].

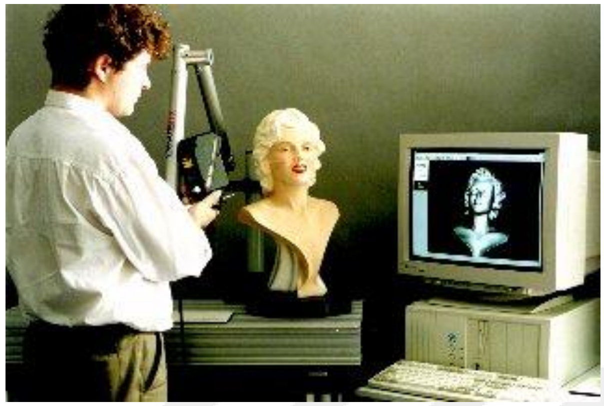

Figure 2.3. ModelMaker stripe 3D scanner [27]

2.2 What is 3D Scanner?

3D scanner that is also named as “real-scene copying technology” is a tool that analyzes assets (or objects) to gather data on its surface and also sometimes outward shape (such as color). This data is used to construct digital models of 3D which are used in many applications. One of the modern 3D scanners utilizes laser line to scan the body directly without contact with him, and then the resulting 3D point cloud of the body is obtained, with addressing this point cloud with some produces a 3D model of the body will obtain, which are practical for an extensive diversity of applications and usually used for obtaining 3D Model [25, 26].

2.3 What is 3D Laser Scanner?

3D laser scanner works by sending a laser beam everywhere throughout the field of view. At whatever point the laser fire hits a surface that is reflected once again into the heading of the scanner. The 3D laser scanner utilizes polar coordinates which comprise connected with the even point, the vertical edge and additionally the deliberate separation relative toward the laser scanner's area to determine the position in space connected with the got object. Singular scans are later enlisted together utilizing basic references and the producing point cloud made up of all the venture scans can be seen and controlled [27]. The 3D laser scanner will pass through a several stages until it reaches the result. during these stages, there are some preliminary processing such as collecting 3D data from the object surface which also has its own some other partial processing, such as camera rotating table utilizing stepper motor which controlled with a stepper motor driver microcontroller and C programming language, and a laser line to create points for the surface by shining a laser radiation towards continuously. Then converting the 3D that is collected into 3D point cloud with the use of coordinate system's conversation at the end surface reconstruction methods necessary to the output of recommended outcome and with high-quality 3D model [28].

2.4 The Importance of 3D Scanner

The advantages of 3D scanning are numerous. The requests are rising furthermore for many applications. Scanning helps with understanding the working of confusing parts and shapes and surely will plan an altogether better item. A scanner may likewise be utilized to produce an upgraded adaptation for any outdated computer aided design models. This robotizes the procedure of figuring out the fresh out of the plastic new plan sparing both cash and time. In dentistry, these scanners are utilized catch the 3D model of a person and in addition, the computer aided design or CAM application is used to plan and produce dental inserts. Digitization of true objects in different application spaces is extraordinary noteworthiness despite the fact that it helps in figuring geometric measurement appropriately. Numerous Mechanical things are unpredictable and subsequently, depend on computer aided design. For example, a contemporary auto has its own particular confounded parts that need to fit and meet up. The 3D scanners help with keeping up a fabulous measure of mechanization for quality confirmation [29].

2.5 Methods and Tools

2.5.1 Software Tools

The market of 3D laser scanners for terrestrial application has grown rapidly for the past few years such as LibreCaAD, RiSCAN PRO, FARO SCENE, PolyWorks, Geomagic Studio, GOM Inspect, MeshLab, SimLab and etc. It led to developing numerous new tools and solutions for handling the data and improving the final output [4]. Tools that can be used with laser scanning data usually also have an application in other disciplines, like architecture, industrial design, computer graphics and much more. Currently, to acquire high-qualified 3D model of an object and to process data efficiently there is almost obligatory to use different packages. It is impossible to proceed with all operation within on software package. Of course, there are tools that provide the final output but the question is if the output is the most advanced and the most accurate as can be. It is very difficult to decide on few packages and what is more to decide which one should be used in each step of the workflow. That issue is one of the main aims to examine within the thesis.

2.5.2 Formats

On the market, there are numerous ways to store data. Especially, when working on the project and multiple software packages are used it is important to operate with different formats. In order to exchange data between each software essential formatting was required. Following chapter will briefly present alternative types of formats used while working on the project.

ASCII is The American Standard Code for Information Interchange. The code represents any text in computers and other equipment that use text. It was originally based on the English alphabet. In encodes numbers, letters and basic punctuation symbols are translated into the 7-bit binary integers. ASCII data files are simple text files that can be edited by many programs. The files are adapted to move easily between multiple software packages. Because of its simplicity, ASCII files can lose some information while coding. However, they can be imported to many programs that are highly popular [30]. Within the thesis, the format was used to transfer point clouds, which was mainly from raw data from scanners, between initial tools-RiSCAN PRO and FARO SCENE to modeling tools.

VRML could be the Virtual Reality Modeling Language. This might be probably one of the most popular 3D file format and navigation language. The existing standard is VRML 2. It is a regular model (ISO standard) for providing 3D models. Making use of a browser plugin, as an example Cosmo Player, the user can navigate with some various 3D views. It is also possible to create a key-positions defined in few viewpoints and later generate automatic flights through the model [31]. Within the thesis format was used to export the 3D model of the house from Geomagic Studio and import it into RiSCAN PRO in order to texture object. It did not work very well so was replaced by another type.

OBJ is a geometry design created by WaveFront advancements. It discovers its application in 3D illustrations region. It is a plain information organize for representation 3D geometry, it incorporates position of every vertex, the position of the surface coordinate vertex, vertex ordinary and appearances that characterize polygon. The coordinates have no units, yet can contain scale data [32]. The OBJ format was mainly used within the thesis to move models between several tools. Especially, when exporting from geometry studio and importing into RiSCAN PRO and then into SimLAB in order to create a 3D model.

STL stands for STtereoLithography and is also known as Standard Tessellation Language. It is a triangular representation of the 3D object. The surface is broken down logically into small triangles-facets. Each of the triangles is described by a perpendicular direction and three points-corners of the triangles [33]. The format was used to transfer polygon models created in PolyWorks software into geomagic studio and others.

2.6 Types of 3D Scanning Techniques

Mapping indoor situations utilizing versatile robots is an outstanding issue which has balanced researchers throughout the previous two decades. Notwithstanding, most methodologies used to map indoor situations cannot straightforwardly be utilized as a part of open air situations. The three essential purposes behind such difficulties while doing outside mapping or scanning are for the most part brought on by nature representation, scale, and unpleasant territory. In this regard, the kind of scanner clearly utilized as a part of the procedure assumes an imperative part in information securing succession [34]. There are the extensive variety of innovations, which can catch extend information to build the 3D models of things and objects. They can be ordered into two primary sorts: contact and non-contact 3D scanners. The non-contact class can be further partitioned into two sub-classifications; dynamic and inactive scanners. There are numerous systems and advancements, which can fall under each of these gatherings. A brilliant discourse on these will take after from this segment.

2.6.1 Contact Technique

The 3D contact scanners are generally calibrated to use on a firm stage, ordinarily have a test arranged toward the complete of a clarified mechanical arm. The arm might be actually or physically controlled through the part's surface. In light of reality test contacts the object's surface, the scanner records the X, Y, Z position from the test by insistently conveying positional estimations connected with the structure. The recorded positions shape a point cloud, which will be connected with pick a 3D work. Some phenomenally rectify 3D scanners known as Coordinate Measuring Machines (CMMs) tend to be utilized by the amassing business to examine allocate the early indications of improvement issues. 3D contact scanners continue with direct scan rates and may even never be fitting for delicate objects, for instance, profitable show-stoppers, as physical contact may hurt or twist the surface [35].

2.6.1.1 Traditional Coordination Measuring Machine (CMM)

Contact 3D scanners test the point through physical contact. A CMM (Coordinate Measuring Machine) is an average instance of a contact 3D scanner. A coordinate measuring machine (CMM) is an instrument for figuring the physical geometrical characteristics of an object. This machine will likely be physically directed by a manager or it may be PC controlled. Estimations are described by an examination connected with the third moving center point with this machine. Tests will likely be mechanical, optical, laser, or light up light, and others. Figure 2.4 shows one of a handful CMM [35].

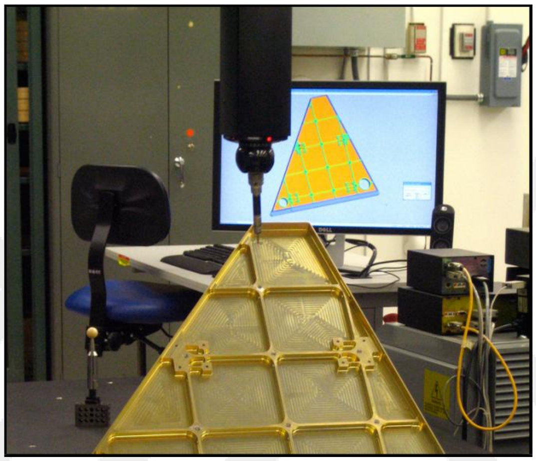

Figure 2.4. Coordinate Measuring Machine (CMM) [37]

This might be used generally as a piece of collecting and it will be incredibly correct. The burden of CMMs in any case is the way that it needs contact with the object getting scanned. Consequently, the show of scanning the object may change or destroy it. This particular truth is basic when scanning touchy or profitable objects, for instance, unquestionable relics. One different shortcoming of CMMs is the way that they are really moving when stood out from other scanning ways. Physically moving the arm that the test is presented on can be exceptionally direct. Moreover, the speediest CMMs is simply prepared to continue running on a few hundred hertz. On the other hand, an optical system like a laser scanner can continue running from 10 to 500 kHz. Diverse cases would be the hand driven touch tests used to digitize earth models in PC development industry [35].

The standard CMM includes three tomahawks, an X, Y, and Z. These tomahawks are orthogonal to each other in an ordinary three-dimensional coordinate system. Each of centers has a scale system that demonstrates the arranging of the center. The contraption will see the data as for the touch test, as educated by the manager or engineer. The device then customs the X, Y, Z coordinates of each and every of those points to decide size and position with micrometer precision [35].

2.6.2 Non-Contact Technique

Non-contact 3D scanners, since the name suggests, more often do not reach an object surface, rather the non-contact 3D scanners rely upon many dynamic or latent procedures to scan an object. The last result is a to a great degree precise cloud of points which can be utilized for figuring out, virtual get together, designing examination, highlight and surface review or quick prototyping [36].

2.6.2.1 Non-Contact Active Techniques

Dynamic scanners emanate some kind of radiation or light and find its reflection to have the capacity to test an object or environment. Conceivable diverse sorts of outflows utilized incorporate light, ultrasound, or x-beam, 3D laser scanning or 3D laser scanners can without much of stretch, for the most part, to be arranged into three principle bunches; time of flight, stage move, and laser triangulation. These laser scanning strategies are by and large utilized independently yet could likewise be utilized in the mix to make a significantly more adaptable scanning system. There are furthermore numerous other laser scanning innovations which are mixtures as well as mixes of other 3D scanning advances, for example, accordion periphery interferometry or conoscopic holography [36]. TOF technique uses a laser source to scan a surface. Principle associated with the method computes distance based on time of light (Δt) measurement associated with the laser pulse between sending and receiving signal. The pulsed laser beam will be directed to the scanned object, and then the receiver is returned by an integral part of the light reflected by the surface. This construction gives a chance to measure time delay formed by light traveling from a source to a reflective object (target) and back again to a sensor. Feigning the exact speed of light in vacuum pressure this might be a good way to calculate the exact distance [37]. Equation 2.1 presents a basic formula for calculation.

$$p = c.\frac{t}{2} \qquad (\mathbf{2.1})$$

ρ: range

c: speed of light in a vacuum

t: round trip

The principle implemented in TOF scanners is presently the greatest prevalent and commonly used technique. TOF system allows measuring at the distance of several hundreds of meters with the satisfying precision of few millimeters to centimeters based on the range. Instruments with 'time-of-flight' principle are able to measure longer distances and cover a larger volume of the area than scanners that use triangulation method. Unfortunately, they are less accurate if we consider close range measurements. The triangulation 3D laser scanners will likewise be the dynamic scanners which utilize laser light to test the natural environment. Identifying with time-of-flight 3D laser scanner, the triangulation laser shimmers a laser about the subject and enterprises a camera to think about the arranging associated with the laser spot [37]. In perspective of to what degree away the laser strikes a surface, the laser bit appears at better places inside the camera's field of view. This system is named triangulation considering that the laser detects, and then the camera and the laser diode draw a triangle see Figure 2.5.

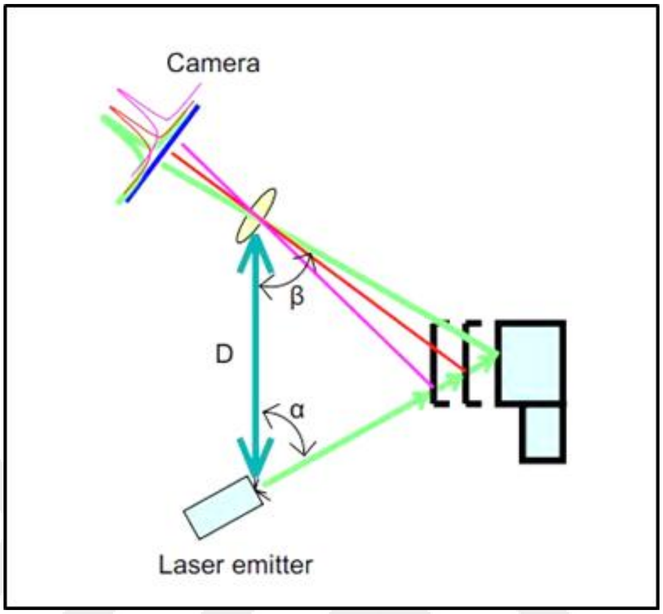

Figure 2.5. Triangulation laser scanning principle [38]

The measure of one area of the triangle, the right division including the camera despite laser emitter is known. The edge associated with the laser emitter corner can in like manner be known. The edge associated with the camera corner will presumably be picked by exploring the correct range of the laser spot inside the camera's field of view. These three bits of information totally choose the edge and size of the triangle and give the arranging as for the laser spot corner among this triangle. When in doubt, a laser stripe, instead of an individual laser spot, is cleared all through the object to quicken the data securing technique. The national research board of Canada was one of the essential organizations to create the triangulation subject to laser scanning innovation in 1978. Figure 2.6 demonstrates the era of point cloud utilizing triangulation with a laser stripe [38].

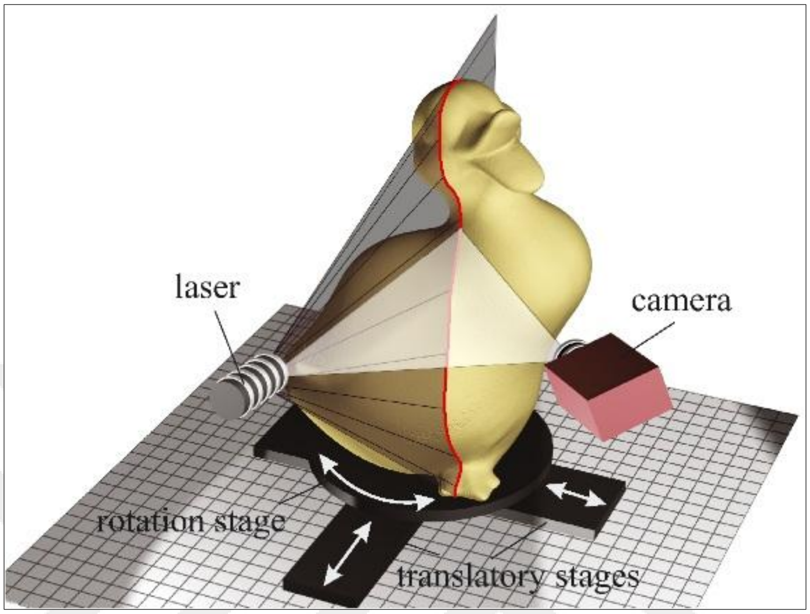

Figure 2.6. Point cloud producing with triangulation using a laser stripe [38]

Strengths and Weaknesses: Time-of-flight and triangulation extend discoverers each have qualities and shortcomings which make them suited to various circumstances. Time-of-flight range discoverers are the way that they are intended for working over long separations, about kilometers [39]. These scanners are thusly ideal for scanning immeasurable structures like structures or geographic characteristics. One of the weaknesses of time-of-flight range pioneers is the exactness. As a result of the fast of light, timing the round-trek time is not straightforward in undertaking and also the exactness for the detachment estimation is by and large low, about millimeters. Triangulation develops pioneers are precisely the converse. They generally have a restricted grouping of a couple meters, nonetheless, their exactness is for the most part high. The exactness of triangulation range pioneers is, for the most part, around a few micrometers [40].

Time of flight scanners precision will probably be lost once the laser hits the side of an object because of the reality data this may be conveyed back towards the scanner is from two unique areas for only one laser beat. The coordinate in respect to every one of the scanners position for a point which has had strike the side of an object will probably be computed by normal and along these lines will put the point in the wrong place. At the point when making utilization of a higher determination scan on an object the likelihood of the shaft hitting an edge is supported. Furthermore, the subsequent information will indicate commotion simply behind the edges of the object. Scanners with a littler estimated bar width will helps to understand this issue yet will probably be restricted by range while the bar width will increment over separation. Likewise, the software will help by verifying that the underlying object to be hit in light of the laser beam would shut out the second.

At different 10,000 illustration points for every second, low assurance scans may take lower than an additional, yet high assurance scans, requiring huge amounts of tests, may take minutes for a couple time-of-flight scanners. This problem creates the distortion from motion. Since each point is tried at a substitute sort of time, any development of the subject or perhaps the scanner will twist the accumulated data. Along these lines, it is regularly required to mount both the subject and furthermore the scanner on stable stages and minimize vibration. Making use of these scanners to scan objects in development is extremely troublesome [41].

At the point when scanning inside one position for pretty much any time frame slight development may happen inside the scanner position as a consequence of modifications in temperature. On the off chance that, for instance, the scanner is set on a tripod then there is solid daylight utilizing one district of the scanner, then that area of the tripod will grow and gradually mutilate the scan information from only one side to some other. Some laser scanners have the level built into them to check any development for the scanner all through the scan procedure [42].

2.6.2.2 Non-Contact Active Scanners

Normal dynamic non-contact 3D scanners incorporate laser scanners, organized optical light scanners, regulated light scanners, PC tomography scanners, attractive reverberation imaging scanners, and so forth. Some of these scanners will be displayed in the accompanying sub-segments [43].

2.6.2.3 Non-Contact Passive Technique

The passive non-contact 3D technique will not emanate the point with vitality. Rather, passive 3D scanners rely upon reflected surrounding radiation. Most scanners of this sort recognize unmistakable light since it is effortlessly accessible [43].

2.6.2.4 Non-Contact Passive Scanners

The passive scanners, for the most part, do not emanate any sort of radiation themselves, yet then again rely upon distinguishing reflected surrounding radiation. Most scanners for this sort recognize unmistakable light since it is a promptly accessible encompassing radiation. Different types of radiation, for example, infrared might be utilized. Inactive techniques can be enormously humble, in light of the way that when in doubt they just need trouble with the particular hardware yet fundamental propelled camera models. Fundamental reserved non-contact 3D scanners fuse stereoscopic video scanners, photometric scanners, outline scanners and picture based modeling scanners. Sorts of non-contact inactive scanners ought to be shown inside the going with sub-regions [43].

2.6.2.5 User Assisted (Image Based Modeling)

There are distinctive methodologies that as per the customer helped recognizing confirmation and distinguishing proof of a couple of components and shapes on a gathering of different photographs of an object can build up a gauge among this object itself. This sort of methodologies is beneficial to create estimation this will be snappy of formed objects, for instance, structures. Distinctive groups are proficient displayed, for instance, D-Stone worker, iModeller, Autodesk ImageModeler or PhotoModeler.

This sort of 3D scanning is on the values of photogrammetry. It is also somewhat similar in methodology to panoramic photography, except for that the photos are taken of just a single object on a 3D space in order to have the ability to replicate it instead of taking a series of photos from one point in a 3D space to replicate the surrounding environment [44].

2.7 Main Applications and Benefits

Improving the design of a new product, it is usually taking the measurements of objects with complex geometry or largely automatic operations at manufacturing facility used to take days or weeks to finish. Now this can be achieved in a matter of minutes with 3D scanning technology. 3D scanners can be utilized the quickly capture just about any manufacturing object, with stunning precision. The resulting 3D model is able to be exported to a different diversity of CAD or CAM uses and from there measure and adjust to upgrade the product's design and performance. Its major application area involves healthcare system, science and education, Arts and design and Industrial design and manufacturing [45].

2.8 Limitations of 3D Laser Scanning

The primary limitation will be the extricating the important data in regards to the 3D model created through 3D laser scanning system with endeavor for solidification with 3D scanner systems. Essentially on the grounds that the laser scanner obtains a mind-boggling number of point information among these objects which are existing additionally contains non-significant. As result, it prompts to the issue in extricating data this could be vital and quick from non-significant information such as highlight lines for 2D and 3D computer-aided design arranges and models. Something else, usage among these model this could be post-prepared of laser scanning system is positively not easy to handle for another system [46].

The precise limitations are outlined as mentioned bellow

- The objects surface to be digitized should be within "line of sight" among these instruments.
- Complex internal geometries, such as for example hole features, threads external or internal popular features of size.
- Trapped or enveloped volumes or any part that has internal features not discernable from the laser scanning equipment.

2.9 Coordinate Systems

The 3D scanner math or coordinate systems have somewhat anxious. It may appear that people would all decide not to have to do a ton of math to make the designed 3D scanner work. However, since 3D scanners tend to plan the reality by and large in many viewpoints, furthermore this present reality regularly acts pretty scientifically, it need to contemplate 3D scanner math at whatever point have been making a 3D scanner. In this venture, two diverse 3D coordinate systems will be observed. Coordinate systems are made to make life simpler for the general population. Some coordinate systems are less demanding for a couple errands, while different systems are simpler with different undertakings. It will support anyone to think about these diverse systems, with the goal that can pick the best one for the 3D scanner [47].

2.9.1 Cartesian Coordinates

Cartesian coordinates would be the most often used a coordinate system. In reality, the rendering system only understands this system. In this system, for just about any particular point, there is certainly an x-, y-, and z-coordinate, which usually correspond to how far the object is left and right, forward and back, and up and down correspondingly. Needless to say, in the 3D scanner, the user might be able to maneuver around and view the scene from different directions, so that the directions from the different coordinates are going to change because the user moves around. If it ever had a math class that goes beyond the basic principles, probably used this coordinate system. The user might be able to consider this coordinate system such as standing at a specific point, and also to arrive at another point, it will need to go to a specific distance left or right (x), a specific distance forward or back (y) and a specific distance up or down (z) [47]. Figure 2.7 show representing 3D points in artesian coordinates.

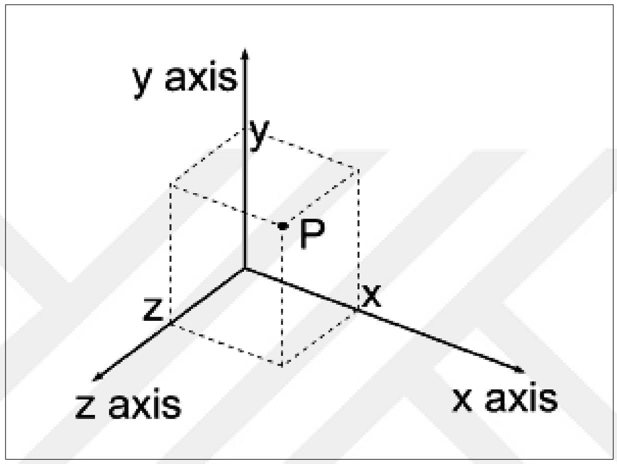

Figure 2.7. Representing 3D points in Cartesian Coordinates [47]

2.9.2 Cylindrical Coordinates

The genuine tube cylindrical coordinate strategy is not likely as commonplace. This technique can be utilized at whatever point the 3D scanner has an adjust over a pivot. This technique has three value, r, theta, and z. Could r be the real separation in course of the genuine point inside the real XY-plane, theta could be the real edge in a bearing of the real point inside the real XY-plane, and z is the manner by which far up or down the real point is. This may understand among these coordinate techniques, for example, it may remain at a particular point, furthermore to get at another point, choosing how far should going over the genuine level surface (the real XY-plane) to obtain it at (the real r coordinate), what bearing client should make a beeline to acquire it going (theta), and precisely how far up in the real air, or down inside the real surface the real object is (z) [47].

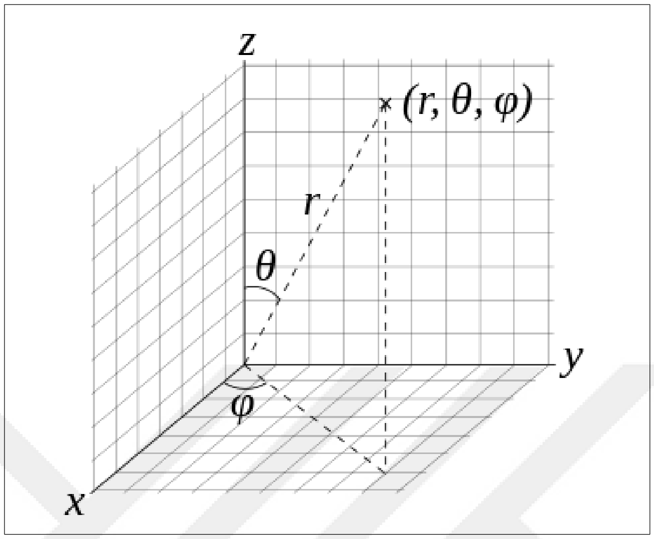

Figure 2.8. Representing 3D points in Cylindrical Coordinates [47]

for example, I expressed some time recently, however, (and for all intents and purposes all design libraries for example) just comprehend Cartesian coordinates, so to have the capacity to permit things to be drawn, we will require absolutely to change over our barrel cylindrical coordinates back by and by to Cartesian coordinates. This may be less demanding than it might suspect to achieve, if continue with the following conversion functions [47]. Figure 2.8 shows the representing 3D points in cylindrical coordinates.

$$x = r\,Cos\,(\theta) \quad (\mathbf{2.2})$$

$$y = r\,Sin(\theta) \quad (\mathbf{2.3})$$

$$\mathrm{z} = \mathrm{z} \quad (\mathbf{2.4})$$

To convert from Cartesian coordinates to cylindrical, follow these functions

$$r = \sqrt{x2 + y2} \quad (\mathbf{2.5})$$

$$\tan\,(\theta) = \frac{Y}{X} \quad (\mathbf{2.6})$$

$$\mathrm{z} = \mathrm{z} \quad (\mathbf{2.7})$$

2.10 Summary

One of the modern 3D scanners utilize laser line to scan the body directly without contact with him, and then the resulting 3D point cloud of the body is obtained, with addressing this point cloud with some produces a 3D model of the body will obtain. 3D laser scanner will pass through a several stages until it reaches the result, during these stages there are some preliminary processing such as collecting 3D data from the object surface which also has its own some other partial processing, such as camera rotating table utilizing stepper motor which controlled with a stepper motor driver microcontroller and C programming language, and a laser line to create points for the surface by shining a laser radiation towards continuously.

Conceivable sorts of emanations depicted incorporate light, ultrasound, or x-ray, 3D laser scanning or 3D laser scanners can, for the most part, be classified into three principal classifications, phase shift, time of flight and laser triangulation.

Basic dynamic non-contact 3D scanners incorporate laser scanners organized optical light scanners, adjusted light scanners, PC topography scanners, attractive reverberation imaging scanners, and so forth. Normal latent non-contact 3D scanners incorporate stereoscopic video scanners, photometric scanners, outline scanners and picture based modeling scanners. Through the endeavor for mix with 3D scanner systems, the fundamental impediment is the extricating the important data from the 3D model created through 3D laser scanning system. Be that as it may, since 3D scanners tend to model this present reality in many perspectives, and this present reality more often than not carries on pretty scientifically, we have to mull over 3D scanner math when we are making a 3D scanner.

3. DESIGN AND IMPLEMENTATION OF A 3D SCANNER CONTROL SYSTEM

3.1 Design Principles

Usually, such as any other devices 3D laser scanner includes hardware and software which has been planned and built keeping in mind the end goal to produce a 3D laser scanner with appropriate speed and accuracy. Hardware part mainly consists of a laser line, stepper motor, rotation platform, a box that covers the scanner environment. Figure 3.1 shows the hardware used. HD camera and with the need of a computer. Software system mainly includes interface software which coded and programmed. The used red laser line is able to generate a wave of light using only a very narrow band of the light. This might be as opposed to a source of light, for instance, the incandescent light, which emits into a specific solid angle and over a broad spectral range of wavelengths. This is enabling an individual laser line to be used for many different 3D scanner applications. By acquiring the concurrent position data of the objects through the laser line, and controlling the stepper motor to rotate the orientation of the object by 360°, 3D scans of a location can be generated. The scanning system mounted to provide an exact 360° free 3D scan of the indoor environment. The project of the 3D scanner is provided with several controllers and a wire communications system enabling direct monitoring with a software based controlling. The development of the system will describe in detail within the following sections.

3.2 Structure of the Scanner Mechanical Parts

As mentioned in the previous section the 3D laser scanner system includes both hardware and software components. Hardware part mainly consists of a laser line, stepper motor, stepper motor driver (ULN2003AN), rotation platform, a communication interface with USB cable, HD camera and a box that cover the scanner environment as same as suitable. Figure 3.1 shows the hardware used in the system, HD camera and with the need of a high-performance computer.

Figure 3.1. System hardware component: a- Laser line (650nm 5mw 5V) b- Stepper motor (M49SP-2K 7.5°, 5.8 Ohms) c- stepper driver d-microcontroller e- USB cable f- rotating table g-HD-camera h- scanner box

Figure 3.2 shows the block diagram of the configuration of the system. The Atmega328P-PU microcontroller starts the rotating stage actuators to rotate the object 360° clockwise, and then the laser line fire the object unceasingly till the end of a rotating process which the whole steps of the acquiring process are controlled by the microcontroller. First, data acquiring will be done with a camera that takes about up to 400 frames with a frame rate of 30 fps of each scanned object.

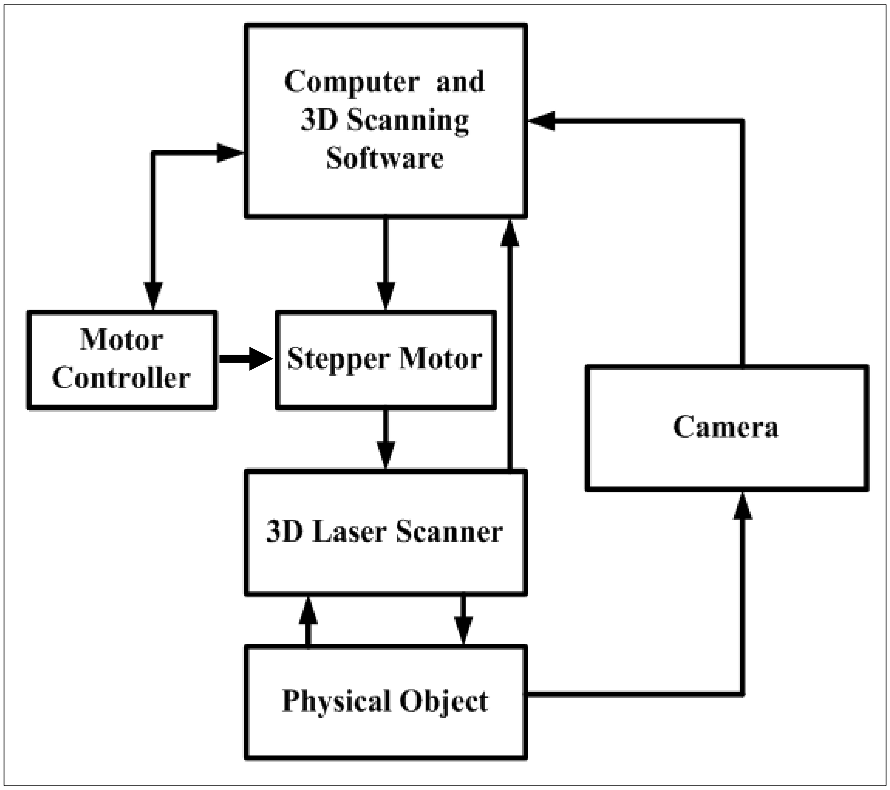

Figure 3.2. 3D Scanner system framework component

3.2.1 Microcontroller Based Scanner Controlling

This system has been outlined based on an ATmega32P microcontroller, which fills in as a power supplier and control system. The microcontroller initiates the stepper driver to stand at starting position by creating the PWM pulses for stepper motor, which is specifically associated with the microcontroller's pins. The laser line that works with the PWM pin 9 and GND pin connector is associated with the microcontroller straightforwardly with no serial port interfaces.

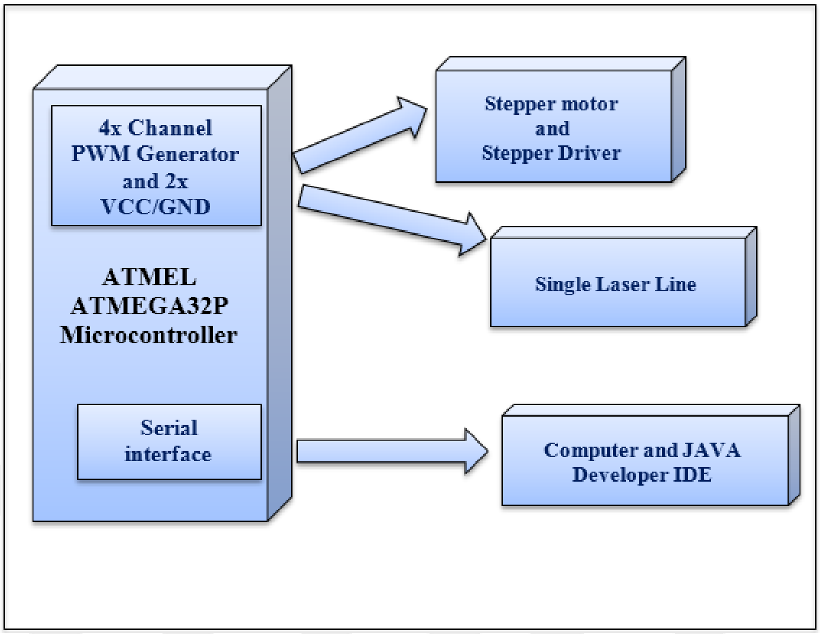

Figure 3.3. Microcontroller based scanner controller

The microcontroller is capable of activating the laser line and is able to control it through the PWM, which have been noticed by the camera. The computer saves the laser line result in an ASC file, and all measured coordinates of the scanned object can be supervised on the IDE text area. Checking and tracking the results, and sending them to the PC through the USB port will be performed automatically with zero value of the user. microcontroller based scanner system shown in Figure 3.3. The user interface software is developed with JAVA developer IDE, in which the codes are written in pure Java mode and it could read the data from the microcontroller and store them in the related directory. At the end of each measurement, the PC sends an information signal to the smaller scale controller and then it has to be prepared for next measurement phase. After getting information from the PC. It consequently starts to deliver the PWM pulses accordingly and this succession is iteratively proceeded the length of the scanning procedure carry's on repetitively.

3.2.2 Stepper Motor and Stepper Motor Driver

The movement system utilizes a stepper motor driver which converts electrical pulses into the distinct mechanical movements. The shaft or spindle of a stepper motor rotates in separate step increments when electrical command pulses are performed to it while in the proper series. The motors revolving has a number of straight relations to those input pulses.

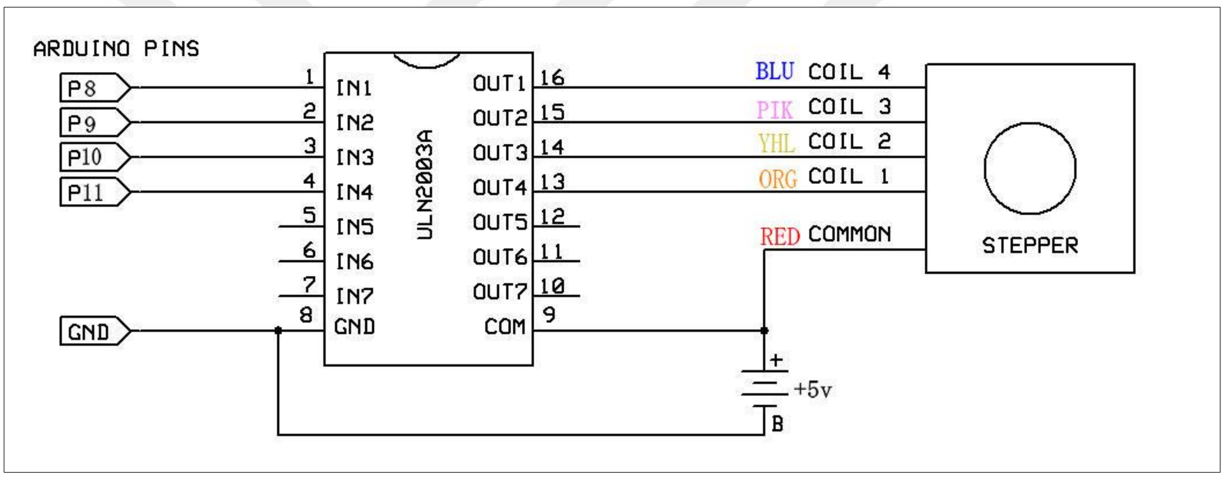

Figure 3.4. Stepper motor driving schematic

The group among these performed pulses is straight linked to the path of motor shafts rotation. The speed of these motor shafts rotation pertains to the frequency of these input pulses straight as well as the duration of rotation pertains to a number of input pulses applied straight. Perhaps one among these most important benefits of a stepper motor is its capacity to be precisely controlled in an open loop system with a "ULN2003" stepper motor driver which could be a range of seven NPN Darlington transistors with the capacity of 500mA and 50V for output. Figure 3.4 shows stepper motor driving schematic the drivers could be paralleled even for higher current output. Generally, it is also utilized allowing to connect with a stepper motor, in which the motor requires high ratings which may not be supplied by some other connecting devices. Figure 3.5 shows an illustration of how exactly does the motor motion system works.

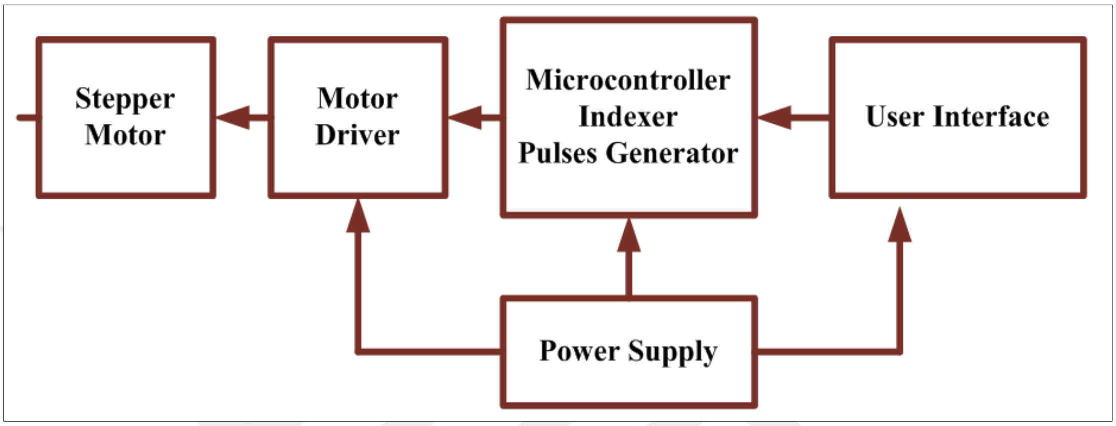

Figure 3.5. Stepper motor block diagram

3.2.3 Camera

Utilizing wide angle lens makes this camera suitable even for a large image which helps to scan small size to individual middle size objects. With free plug and play installation property. Anti-reflections and color dampening automatically and video transmission maintains high imaging quality. Its image sensor is 1080p HD, video quality up to 2 megapixels and 30 fps recording and image quality 16 megapixels which mean 4608 x 3456 resolution. Figure 3.1 (g) shows the camera used in the system.

3.2.4 Laser Line

Red laser line utilized in the system has a great quality focusable line laser module and completely self-contained with laser diode, an incorporated laser driver circuit, glass a spherical focal point optics, and focusable barrel shaped focal point producing an exact laser line with the red light straightly line 650nm, size 12x35mm, cable length is about 135mm, working with 4.5-5 voltage, current between 20 to 35ma (3.5-40ma max) and line length 2.0 to 2.4 meters (at 1.5 meters' distance).

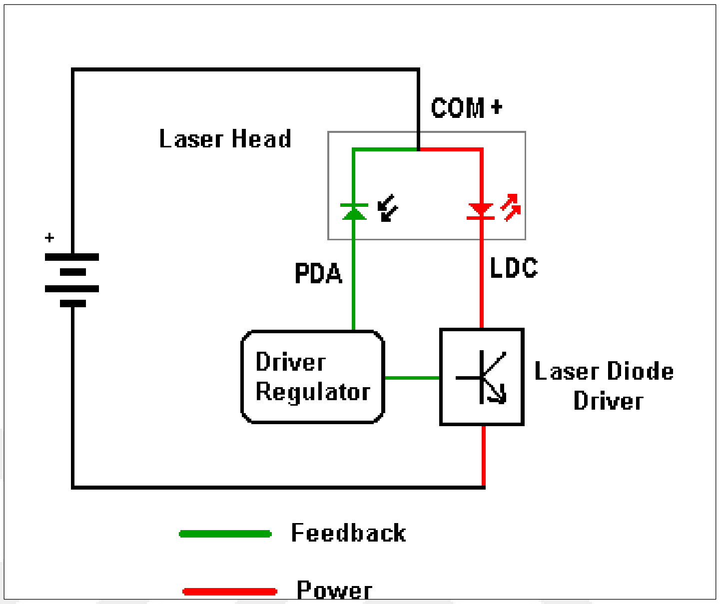

Figure 3.6. The basic circuit for powering a laser diode [49]

Most basic laser heads have two semiconductors: an LD and a PD. The laser diode will be forward biased and its cathode LDC will associate with a driver transistor and/or system to regulate the LD current and flow based on the photodiode ebb and flow (feedback network). The photodiode will be switch biased, its anode PDA will encourage a driver regulator and along these lines, the control will give a feedback signal for the LD driver. Figure 3.6 shows the basic circuit for powering a laser diode. The feedback is an optical one with part of the laser beam going backwards to reach the photodiode intersection, as appeared in Figure 3.7, the laser diode head has three leads labelled: LDC, PDA and COM+. Inside the laser diode head is the laser diode itself and a photodiode, used to regulate the laser diode current via an external feedback loop [49].

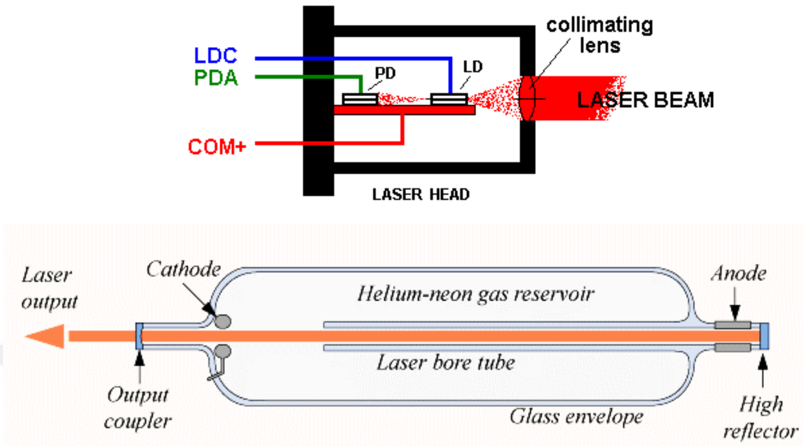

Figure 3.7. The laser diode head has three leads [49]

3.2.5 Rotating Table Platform

The rotating platform created from a small box with the volume of 21x12x12 cm^3 and placed the stepper motor on the top center of the box, also created a rounded thin plate which is made of wood, with 21 cm diameter and directed the center of it with a small hole, this hole is important during scanning process because it will be the center of each scanned object. So, it helps the scanner for acquiring the exact points, then placed the rounded plate on the top of the box and joined to the stepper motor with a screw. The scanning volume of work is 21x21x21 cm^3. Figure 3.8 shows the rotating platform.

Figure 3.8. Rotating table platform

3.3 Construction of Device Parts

Usually as any system after selecting electronic parts which is needed for the system, another operation comes out which is joining these parts all together. The electronic parts are a stepper motor, stepper motor driver, laser line and microcontroller. First of all, a box is created as a cover for the scanner system, and it contains all the parts and is made of MDF plastic. Figure 3.9 shows the configuration of the system electrical parts. The dimensions of the box are the height is 50 cm, the width is 40 cm, the length is 60 cm. On the other side, the camera is joined in the center of one of the sides, with the 40 cm height. In the same level on the right corner, the laser line has been joined in a form that the laser light should interact with the center of the rotating platform and the rotating platform placed in the box’s flat surface with approximately 40 to 50 cm distance in front of the camera.

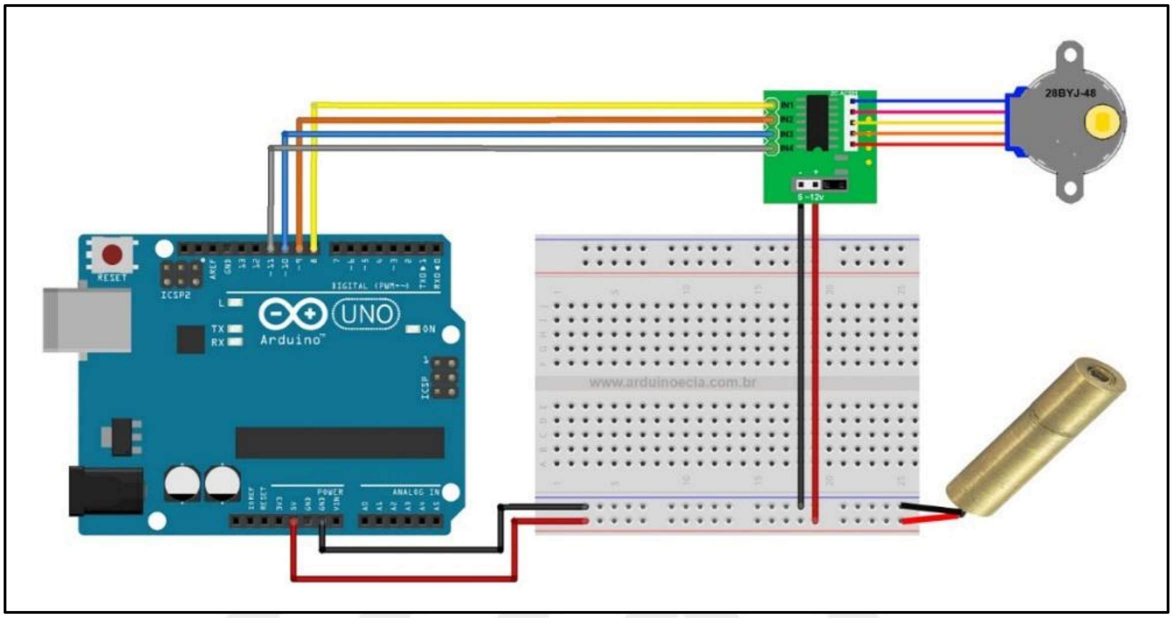

Figure 3.9. Configuration of the system electrical parts

Each of stepper motor driver's pins 1, 2, 3 and 4 are connected to the pins 8, 9, 10 and 11 of the microcontroller's pins. The laser line connects to the pin 13 and GND pin of the microcontroller, also the power wires of the stepper motor driver connected to each of 5 volts and GND pins of the microcontroller. The benefit of connecting the laser line to the pin 13 as mentioned above is the laser lighting can be controlled for each scanning process which means that when the scanning is started the laser light will fire through the object placed on the rotating platform and when the scanning progress is ended the laser light will turn off. All of these operations will be done by the microcontroller. Also, the stepper motor speed and revolution is controlled by the microcontroller which is programmed in C programming language. The pseudo code of the process shown in Figure 3.10.

```
#include <Stepper.h>
Stepper Lydia (48,8,9,10,11);
int led = 13;
int incomingByte;
   setup
  {
     pinMode(led, OUTPUT);
     Serial.begin(9600);
     oki.setSpeed(10);
     Serial.flush();
 }
   loop
 {
    incomingByte = Serial.read();
    Lydia.step(4);
     String input = "";
      while (Serial.available() > 0)
     {           input += (char) Serial.read();}
        if (sensor_read= "on")
     {           digitalWrite (turning motors on);}
     else if (sensor_read == "off")
    {           digitalWrite (turning motors off);}
}
```

Figure 3.10. Stepper motor controlling code

3.4 Software and User Interface Design

The system software consists of three main parts;

- User interface

The user interface created with the visual studio for indicating what happened inside the scanner device. It shows some important information about the object which currently in scanning progress such as showing and counting the number of profiles created in the middle of the interface. Also, it shows the scanning elapsed time and the progress bar. Also, there are some buttons for controlling the revolution of the taken profiles. Figure 3.11 shows the main system interface.

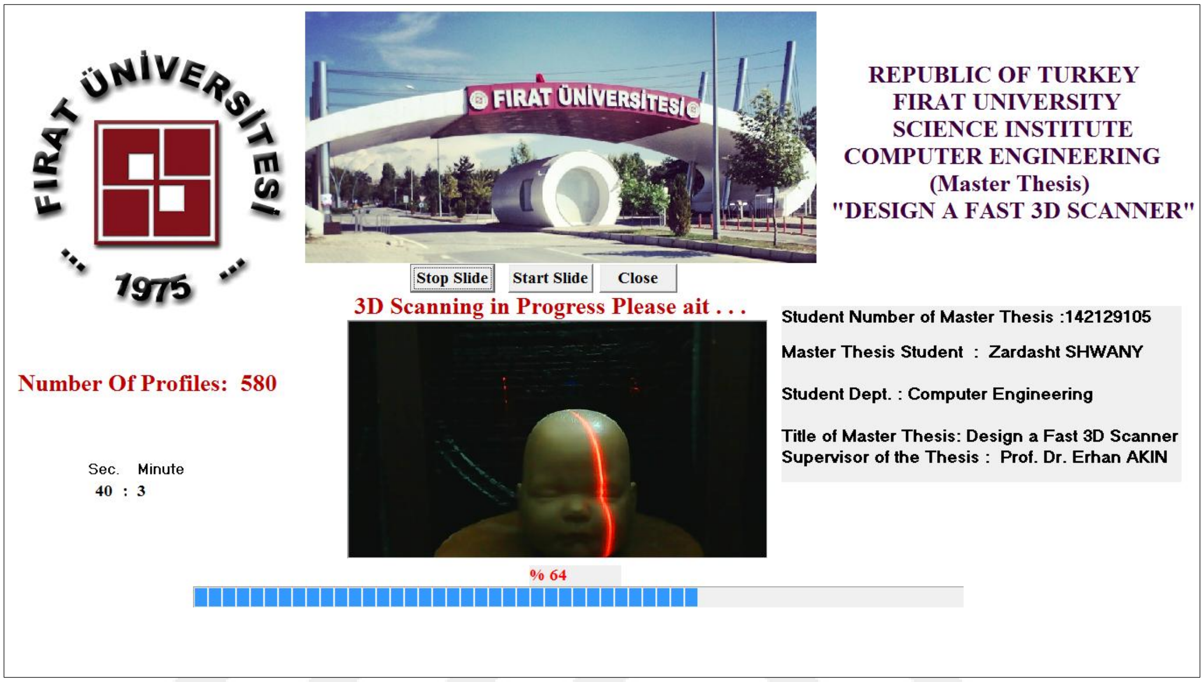

Figure 3.11. The system user interface

- Batch files for controlling the user interface and the system folders

A batch file is a type of script file in Windows, DOS, and OS/2. It is made from a number of instructions to be executed based on the command line interpreter, kept in an ordinary text file [50]. Within the system, we created significantly more than one batch file, and each one of these batch files is accountable for performing a specific task, for instance, one of them is used to open the main graphical user interface after the scanner is started scanning an object. Another one is used to show the output directory at the end of the scanning process. Also, one batch file was created for closing the user interface automatically following completion of the scanning.

- The main system software for scanning process

The main program of the system consists of three parts; first part used to take and store the profiles into a directory called "Captured" with Portable Network Graphics (PNG) format because this format is a faster graphics file format that supports lossless data compression [51] and do not take a large amount of storage which is one of the advantages of the system. Also, a copy of each profiles is saved into another folder called “CapturedBMP”. Moreover, during this stage, we ensure that the scanner is connected to the computer and it works properly. Figure 3.12 shows the first main part code of the system software.

```
//this.frame.setExtendedState(JFrame.ICONIFIED);  // Minimize window

PImage Zard=createImage(ScannerCam.width,ScannerCam.height,RGB);
ScannerCam.read();

delay(500);

epoch=0;
while (epoch<Profiles) {
  ScannerCam.read();
  Zard.loadPixels();
  ScannerCam.loadPixels();
  for (int n=0;n<Zard.width*Zard.height;n++)
  {
    Zard.pixels[n]=ScannerCam.pixels[n];
  }

  Zard.updatePixels();

  set(20,20,ScannerCam);

  String FileName="Captured/Zard"+nf(epoch+1, 0)+".png";

  String FileNamebmp="CapturedBMP/Zard"+nf(epoch+1, 0)+".bmp";

  Zard.save(FileName);
Zard.save(FileNamebmp);

 delay(250);
 epoch++;
```

Figure 3.12. First part of the system software for image creation

The second part of the system software is loading the taken profiles, and then the laser line detecting procedure will become in work in the system in which the maximum brightest pixel’s algorithm has been used. First the row and column of the profile will be found, then the algorithm finds the brightest pixels and change its color to white and the rest of profile to black color and this process will perform for all profiles. After that, the new profile will be stored again in other name but in the same format type for next process. Figure 3.13 shows the codes of laser line detection from profiles.

```
epoch=0;
    while(epoch<Profiles) {

    String FileName="Captured/Zard"+nf(epoch+1, 0)+".png";
    PImage Scan=loadImage(FileName);
    String Filename2="LineSegmented/Lydia"+nf(epoch+1, 0)+".png";
    PImage Lydia=createImage(Scan.width, Scan.height, RGB);
    Scan.loadPixels();
    Lydia.loadPixels();
    int currentPos;

    theta=epoch*TwoProfileAngle;
  //  println(theta);

    row=0;
    while( row<Scan.height){  //starting row analysis

    MaBriPixPos=0;
    MaBrPix=0;
    colom=0;

      while ( colom<Scan.width){

        currentPos = row * Scan.width + colom;
        BriPix=red(Scan.pixels[currentPos]); //brightness --> red
        while(BriPix>MaBrPix){
          MaBrPix=BriPix;
          MaBriPixPos=currentPos;
        }

        Lydia.pixels[currentPos]=black; //setting all pixels black
        colom++;
      }

      Lydia.pixels[MaBriPixPos]=white; //setting brightest pixel white
```

Figure 3.13. The code of laser line detection from profiles

The last part of the system software is the main and important part because in this part the 3D points are exactly acquired. After the second step finished the profiles will be saved again and detected with the laser line. The profiles are load to determine the XYZ and then saving the points into an ASC file which then can be read the 3D modeling application in our system and we used geometry technique with a simple trigonometry technique. In the Figure 3.14 the codes for determining the 3D points are shown.

```
//Creating Output *.ASC File
  output=createWriter("Output/Result.asc");

b=((MaBriPixPos+1-row*Scan.width)-(Scan.width/2))/HoriPixPerMil;

     //Used Trigonometry Techniques for Finding r
     // Sin(theta)= Opposite / Hypotenuse
     // Sin(LaserCamAngle) = b/r

      r=b/sin(LaserCamAngle);

      //Converting From Cylindrical Coordinate to Cartesian Coordinate

      x=r* cos(theta);
      y=r* sin(theta);
      z=row/VeriPixPerMil;

      if( (r>=-30) && (r<=60) ){ //printing coordinates
        output.println(x + "," + y + "," + z);
        println("X=" + x + " , " +"  Y=" + y + " ," + "  Z=" + z);
      }

     row++; }//end of row analysis

    Lydia.updatePixels();
    Lydia.save(Filename2);

   epoch++;
```

Figure 3.14. The code for determining the 3D points from line detected program

3.4.1 Collecting and Data Princeple From Scanner Through the Software

The Atmega328P microcontroller starts the rotating platform actuators to rotate the object 360°. The laser line fire the object continuously until finishing of rotation that works and controlled with the microcontroller. First data acquiring will be done with a camera that takes approximately 400 to 500 frames with a frame rate of 30 fps of the object. The software is developed with java developer IDE and it is able to read the data from the camera and save them in the related directory. At the end of taking and saving all frames with portable network graphics (.PNG) format, the software load pixels from saved images and determine the maximum brightest or red pixels which are actually the laser line position into a white color and the rest into black color then it saves the new images in another folder [7]. After that the software will determine the polar coordinate of each brightest/red pixels by calculating the angle with each of "d" which calculated from equation 3, the angle of each two-profile fetched from rotating table and "z" value, then all points in polar coordinate system should be converted into a Cartesian coordinate system. The result will store into an action script communication (. ASC) file, also the software has a user interface that tells the user what is happening inside the box and there is a counter for counting the taken profiles. Also with directing elapsed time for scanning any object. For cleaning, filtering, rendering, registration or alignment of the assigned coordinate point cloud acquired by the 3D laser scanner, an extensible mesh processing system application used called Meshlab which load and resolve saved ASC files. After the whole process finished the output will be the OBJ or STL (Stereo Lithography) files which are the common file used in 3D printing [51,52].

3.5 Laser Line Detection Using the Brightest Pixel Algorithm

The brightest pixel algorithm as characterized in this project is straightforward, that selects the brightest N pixels inside a given Shack-Hartmann sub-aperture, and sets all other pixel qualities to zero. This adjusted sub-aperture will be handled inside the standard strategy to process wave-front inclined, for instance utilizing a focal point of gravity algorithm to survey the spot position hence securing the wave-front slant over the sub-aperture. This algorithm focal points from the end of pixels which contain commotion just instead of the valuable flag, and it is less receptive to arbitrary clamor contrasted with the outspread threshold system proposed by which sets a limit at a segment among these brightest pixels in a sub-aperture. To be important for open-loop AO systems, the linearity and execution among these brightest pixels' choice algorithm should unquestionably be researched.

An altered adaptation of the brightest pixel choice algorithm is additionally conceivable, and incorporates subtraction of the estimation of the N + 1th brightest pixel in a given sub-aperture from all pixels in the sub-aperture, after which every single negative esteem is set to zero. The execution of both of these algorithms is examined also Figure 3.15 shows the pseudocode of brightest pixel selection algorithm [53]. Figure 3.16 demonstrates the brightest pixel selection algorithms.

a) A quicksort algorithm can be utilized to sort the greater part of the pixels of a given sub-aperture.

b) The nth brightest pixel is picked while the threshold value (the first pixel being the brightest).

c) The n + 1th brightest pixel is picked as an optional offset (bias) value.

d) The sub-aperture pixels with intensity underneath the threshold value are set to zero.

e) Optionally, pixels with intensity corresponding to or higher than the threshold value have the offset (bias) value subtracted. We hereafter term the type of this algorithm that include this subtraction the "N + 1th subtracted algorithm".

f) Shack-Hartmann slope measurement then proceeds in a regular way (e.g. weighted center of gravity, correlation… etc.).

Figure 3.15. The brightest pixel algorithm pseudocode [53]

The usage of this algorithm inside the real-time control system is very immediate. However, it should positively be effective all together that the system latencies are not incredibly increased, which may bring about execution corruption. This might carry out the following on a sub-aperture by the sub-aperture basis. Sorting the pixels in every sub-aperture is computationally costly, especially for systems with bigger quantities of pixels per sub-aperture.

Figure 3.16. Demonstrating brightest pixel selection algorithm

3.6 Poisson Surface Reconsctruction

After the scanning an object into a point cloud, we need to obtain a work from those points. Strategy ought to have the capacity to gather the topology of the obscure surface, precisely fit the uproarious information, and fill gaps sensibly. Poisson surface reconstruction is one of the ways to deal with getting a smooth and watertight surface. The point tests may not be consistently conveyed over the model surface. The positions and normal are for the most part loud because of testing incorrectness and scan misregistration. What is more openness imperatives amid scanning may abandon some surface areas without information? It registers a 3D pointer work X (characterized as 1 at points inside the model, and 0 at points outside). The inclination of the marker capacity is non-zero just at points close to the surface, at such points, it is taken (proven) to be equivalent to the internal surface ordinary. In this manner, the arranged point tests can be seen as tests of the slope of the model's marker work the issue diminishes to discovering X whose angle best approximates a vector field V characterized by the information points.

$$\nabla x = v \quad (3.1)$$

If we apply the divergence operator, this problem transforms into a standard Poisson problem: Compute the scalar function X whose Laplacian (divergence of gradient) equals the divergence of the vector field V, the implicit function X is represented using an adaptive octree rather than a regular 3D grid.

$$\Delta X \equiv \nabla \cdot \nabla X = \nabla \cdot V \quad (3.2)$$

Applying the divergence operator, we can transform this into a Poisson problem:

$$\nabla \cdot (\nabla \chi) = \nabla \cdot \vec{V} \quad \Leftrightarrow \quad \Delta \chi = \nabla \cdot \vec{V} \quad (3.3)$$

Reconstruct the surface of the model by unraveling for the indicator function of the shape. There is a relationship between the normal field and gradient of indicator function

$$\chi_M(p) = \begin{cases} 1 & \text{if } p \in M \\ 0 & \text{if } p \notin M \end{cases} \quad (3.4)$$

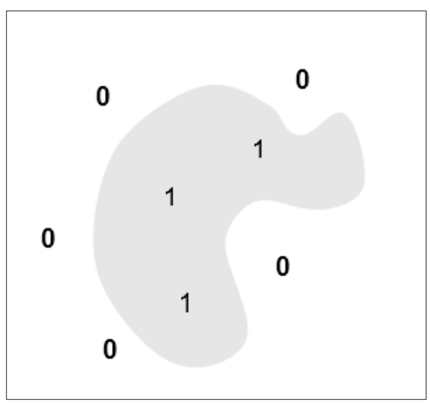

Figure 3.17. Indicator Function X_M of Poisson reconstruction algorithm [54]

Represent the points by a vector field to find the function whose gradient best approximates, the output scalar function X represented in an adaptive octree, is then ISO contoured using an adaptive marching cube to obtain the mesh shown in Figure 3.17.

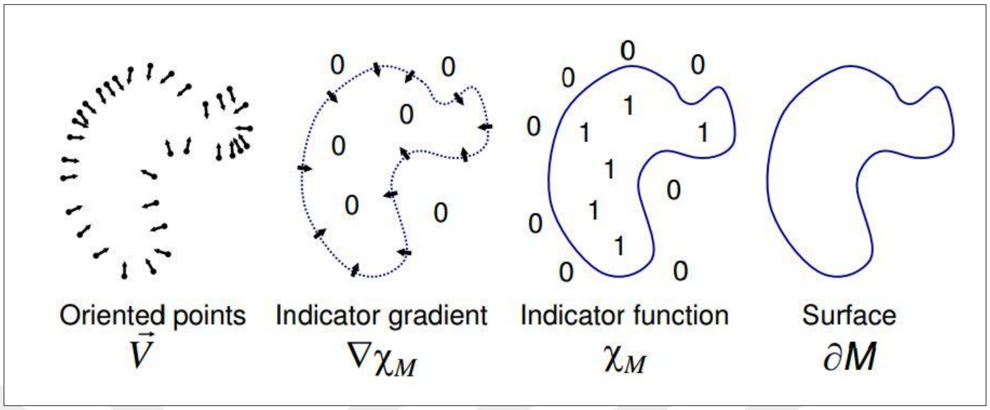

Figure 3.18. Poisson reconstruction workflow steps [54]

For assessing this calculation, we have utilized Meshlab for experimentation. The created work is influenced by-octree Profundity, tree-profundity that is utilized for the reconstruction. Samples per-node determines the most extreme number of test points that ought to fall inside an octree hub. For commotion, free data are 1.0, 5.0, loud data are 15.0, 20.0. The impact of octree profundity we gave the higher esteem for more itemized result, bring down esteem for smoothing surface precisely for boisterous 3D information and higher esteem for more vertices work. The calculation has impacts of the dataset which meager testing which expects an adequately thick cloud and may do not remake the thin examined. Fill gaps where information that is missing basically for an extensive opening. However, it may utilize coarser triangulation for filling gaps, see Figure 3.18. Poisson reconstruction endeavors to inexact the indicator function of a deduced strong. The Figure 3.19 show the holes filing process. It is genuinely vigorous in filling little gaps and managing non-uniform information [54]. For sureness, the result the Poisson reconstruction algorithm preformed and the pseudocode shown in the Figure 3.20.

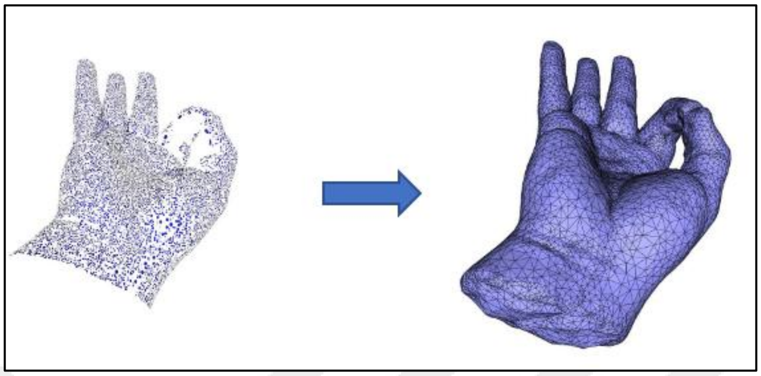

Figure 3.19. Filling holes [54]

Algorithm 2 : Poisson Reconstruction Pseudocode

```
Read Input Gray Image
Find gradinets
Reconstruct image from gradients for verification
function [img_direct] = poisson_solver_function(gx,gy,boundary_image)
Inputs; Gx and Gy -> Gradients
Boundary Image -> Boundary image intensities
Gx Gy and boundary image should be of same size
DST Discrete sine transform
Y = DST(X) returns the discrete sine transform of X.
The vector Y is the same size as X and contains the
discrete sine transform coefficients.
Y = DST (X, N) pads or truncates the vector X to length N
before transforming.
If X is a matrix, the DST operation is applied to each
column. This transform can be inverted using IDST.
IDST Inverse discrete sine transform
X = IDST(Y) inverts the DST transform, returning the
original vector if Y was obtained using Y = DST(X).
X = IDST (Y, N) pads or truncates the vector Y to length N
before transforming.
If Y is a matrix, the IDST operation is applied to
each column.
```

Figure 3.20. Poisson reconstruction algorithm pseudocode

4. RESULTS AND DISCUSSION

The testing of the system's performance is performed by scanning the different real physical object. The scanner controlled by using the control software. The scanning process starts manually and ends automatically and the whole scanning process takes place in less than four minutes until creating a point cloud with around 1 million points. Figure 4.1 shows the environment of the scanned object.

Figure 4.1. A face of the scanned object.

Table 4.1. Scanner configuration parameters

Parameter	Value
Camera angle	Wide angle
Angle between camera and laser	12°
Laser type	Line laser
Laser color	Red
Frame rate	30 fps
Frame size	640 x 480
Laser line detecting algorithm	Brightest pixel selection algorithm
Number of profiles	200 to 500 profiles per scan
Distance between camera and laser	15 cm
Volume of work	210x210x210 mm^3
Number of acquired points	Around 100000 pts

The Table 4.1 is shows the setup for testing camera angle which affects the capturing area and type of the laser utilized. Frame size is the resolution of the image captured by the camera. Laser line detecting algorithm is the algorithm used to determine laser on the image. Brightest pixel selection algorithm utilized to locate the laser fire on the object. In this work the volume of work is 210x210x210 mm^3. The height (150 mm) can be greater if the rotating table, laser line and camera reconfigured to larger objects. The point cloud is the number of points acquired through the scanning process, usually can be configured to obtain around 1 million points per a scan which is the result of taking 200 to 500 profiles with a frame rate of 30 fps, and the size of 640 by 480 pixels. Figure 4.2 shows the acquired point cloud without the registration process and Figure 4.3 shows the aligned point cloud result.

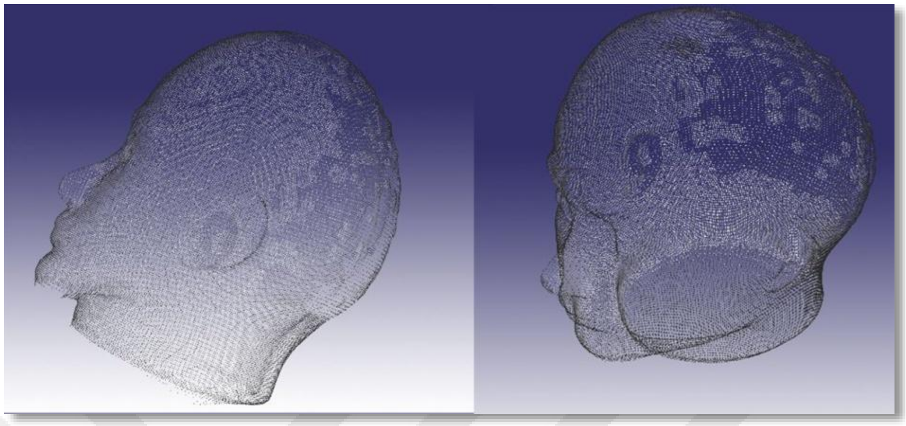

Figure 4.2. The point cloud result without 3D alignment

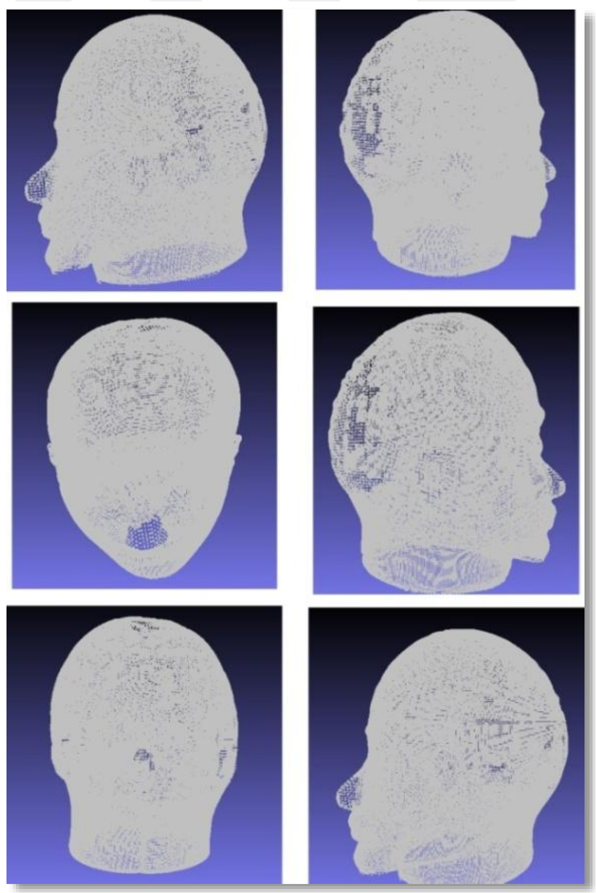

Figure 4.3. The point cloud result with 3D alignment

Then, by using the Meshlab filters which is the Poisson surface reconstruction algorithm, smooth surface is performed using aligned point cloud. Before doing this process, a cleaning process is done due to removing duplicate points and faces. The conditional filter will remove the scanning rotating table. Figure 4.4 is the final result of our 3D scanning system in different view using Poisson surface reconstruction. Also, this reconstruction algorithm gives smooth and clean surface.

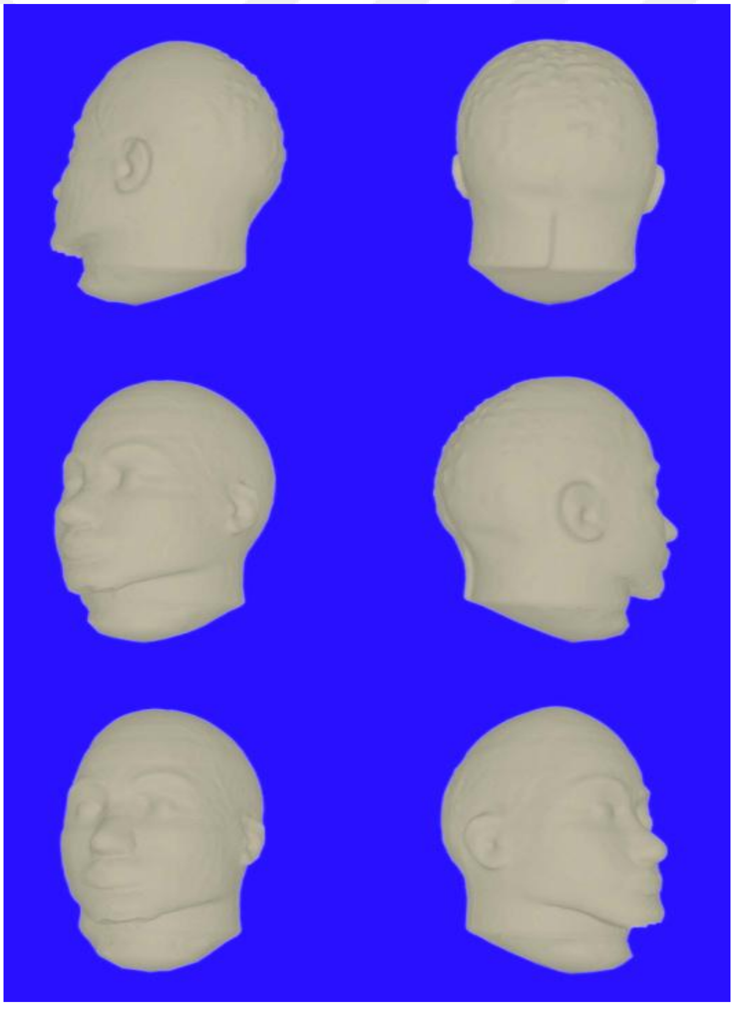

Figure 4.4. The final result of 3D surface reconstruction using poisson

4.1 Enhancing Shining and Reflective Object Surface

All 3D scanners have issues with shiny or reflective objects. They are like the kid with the short attention span, but instead of getting distracted, the scanners freak out because the lasers are sent in wonky directions causing this little prize. There are many ways to avoid tragic scan.

4.1.1 Powder the Object

Use a paintbrush to coat object in baby or talc powder before scanning. Here is the same scan with a little baby powder sprinkled into the mix.

4.1.2 Spray Paint

If the color of the scan is not important and scanning an object that can be altered, painting the shiny object with matte grey spray paint will allow to obtain the most accurate and detailed scan of the shape.

4.2 Comparison of the System With the Other Systems

Contrasting with the other 3D scanning systems our framework has a decent examining time result see Table 4.2, XYZprinting a scanner which scans object in five minutes, the Wins Can-S compact 3D scanner by Chinese assembling organization shining 3D, utilizes structured light technology. The machine then scans the object in 3 minutes. Matter and Form MFS1V1 is comprising of a moving camera head on a 360 degree turning stage and a double laser camera makes a beeline for a Z-pivot. Bringing about precise 3D scans in as meagre as 5 minutes or high-definition scans in 10 minutes. Eora 3D scanner utilizes green laser technology. As the designers clarify, computerized camera CMOS sensors are twice as delicate to the green range as they are to red. This implies can check in an assortment of lighting conditions, even outside. The final product is an effective 3D scanner that can examine a protest inside. Makerbot's putting forth to the 3D scanner commercial center was intended to work consistently with the Makerbot replicator, and in this manner, is perfect for examining very small sized, moderately straightforward articles for 3D printing purposes, one output from one point takes roughly 12 minutes to finish. Figure 4.5 demonstrates the compassion between our system and other 3D scanning systems [55].

Table 4.2. Comparison of common 3D scanners in scanning time and volume of work

No.	3D Scanner Systems	Time For single Object	Volum of work in m^3	Used method
1	***Our System***	2-8	210x210x210	Laser line
2	Fuel3D Scanify	10	210 x 300x 400	Photogrammetry
3	XYZprinting	5	200x200x200	Photogrammetry
4	Matter & Form MFS1V1	5	250x180x180	Optical distance sensor
5	EORA	5	200x200x200	Laser line
6	MakerBot Digitizer	12	203x203x203	Laser line
7	BQ Ciclop	2-8	450x330x230	Laser line
8	Artec Eva	4-15	Outdoor	Photogrammetry
9	Go!SCAN	5	150x171x251	Lighting
10	Open source DIY Laser	2-8	250x205x205	Laser
13	3D Scanner DIY	2-8	170x200x210	Optical distance sensor

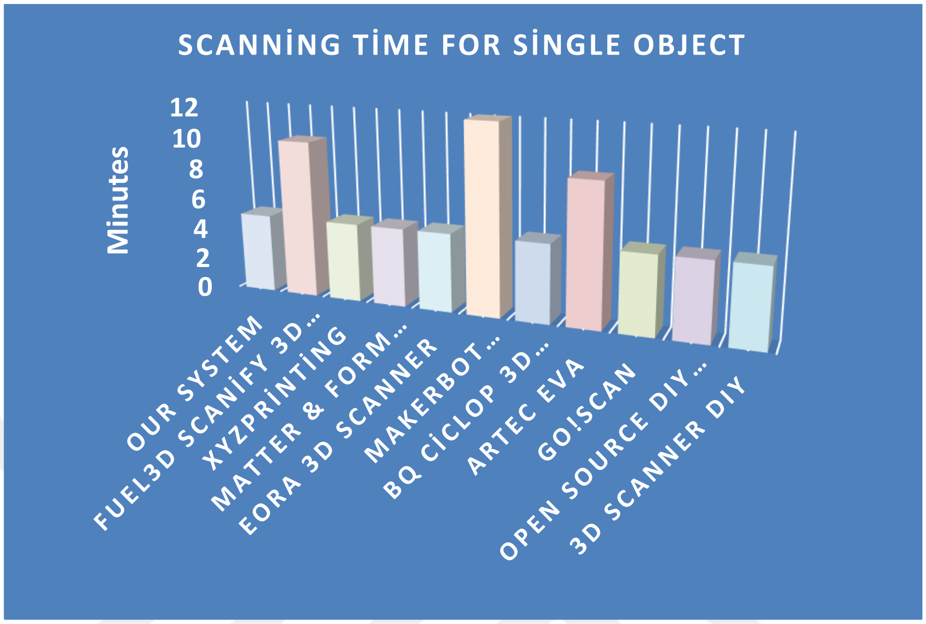

Figure 4.5. Comparison of common 3D scanners in scanning time

4.3 Daylight Effects and Decreasing Scanning Noise

The daylight has a negative impact which makes the scanning noisy because in our system we used the brightest and red pixel algorithm for detecting the laser line on scanned object. If we scan an object with the opened box it makes the scanner noisy because the scanner fetches brightest pixels everywhere around the scanned object with daylight effect, therefore we created a dark box for the system for scanning indoor objects with the desired volume. There is a method for solving this issue but it increases the scanning time which we can use a subtracting technique between two images. The first one with laser firing and the second one without laser firing then perform subtracting between both, then the result will be the laser line only. The daylight does not make negative impacts for this technique. Another suitable solution for our system is trying to calibrate the laser line to reduce the noisiness by changing the position of the laser until it reaches the minimum noise.

5. CONCLUSIONS

Three-dimensional laser scanner method is selected because it is an efficient, economical, and fast computational technique, and because of its speed and precise result for scanning real 3D objects compared to other 3D scanning methods. A fast 3D scanner device designed to scan real physical objects. A required hardware and software are accomplished and improved at each step. During this research 3D scanning of real physical objects were investigated, in which the main stages of obtaining high-resolution 3D model were 3D data acquisition, cleaning, registration and object reconstruction that were completely described and executed with the limited performance such any scanning systems.

The results connected with the 3D scanning procedure have faced the PC through a USB channel and then the related point cloud model is formed. To have the capacity to give a screen to the whole scanning progress, an interface for the system has been developed which could give enough information about what happening inside the scanner directly such as counting a number of taken profiles, elapsed scanning time, showing rotating table and a progress bar. The 3D laser scanner happened to be installed on it to really make the strategy in a position to scan small to medium indoor objects.

This thesis has used an extensible mesh processing system application called MeshLab utilized to combine and align many point cloud models of the identical object and reasonable 3D model was obtained. For that reason, these studies have tried to mostly review and cover existing systems and applications on data acquisition and surface reconstruction sequences. Also, these studies have partially protected many elements of indoor 3D modeling starting from scanned data.

The research question was how to design a fast, good quality and low coast 3D scanner. As it is discussed in the previous chapters, consequently, according to the result we reached the research goal aspects of the speed, precise and low cost 3D scanner system.

5.1 Future Work

As described within this thesis, the resolution of a captured point cloud strictly depends on the accuracy of the laser line and the surface of the object. The first problem of scanning shiny objects is that it does not let the system to achieve a dense 3D scan result. To solve this problem, the resolution of the captured point cloud is to be increased and the time of procedure needs to be reduced. In this approach, to solve the problem of the reflection and distortion from the images an algorithm can be used.

In the upcoming opportunities, I will make efforts to build automatic calibrations for the scanner to be able to automatically calibrate its camera, laser and rotation platform in order to obtain the lowest value of the user for scanning objects. As well as, I will attempt to design a suitable box for the scanner in such a way that its parts could be easily assembled with one another, similar to the commercially available products in markets. Moreover, I am going to try to make auto-reconstruction process in order to reduce the noisiness, and increase points, as well as to reduce the scanning time to a shortest suitable time.

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CURRICULUM VITA

Zardasht SHWANY

zardasht.abdulaziz@gmail.com

Nationality:	Iraq
Place of birth:	Erbil
Date of birth:	02 / 09 / 1986
Marital status:	Married

EDUCATION

03/ 2014 – 03/ 2016 MCE (Master of Computer Engineering), Firat University, Elazig, Turkey.

09/ 2006 – 07/ 2010 Bachelor of Computer Science, Salahaddin University, Iraq.

09/ 2003 – 05/ 2006 High School, Azady High School Erbil, Iraq.

09/ 2000 – 05/ 2003 Intermediate School, Wali Dewana intermediate School Erbil, Iraq

09/ 1992 – 05/ 2000 Primary School, Korek Primary School, Erbil, Iraq

2013 Graduated from Advance English Language Proficiency Center, Erbil, Iraq.

2014 Advanced English language efficiency certificate

2014 Windows server installing and configuration certificate from Iraqi Microsoft partner

WORK EXPERIENCES

1. I worked in central admission as checker of student’s application forms.
2. ICDL 4 (International Computer Driving License) as a lecturer.
3. Data management in SHKODA company for cars.
4. IT assistant at Delta company in Erbil.
5. Taught information technology courses at Qala and Mnara Institute
6. Taught MS office courses for K. C. Syndicate.
7. Taught computer training course at Erbil Technical Institute.
8. Setup and configured computer laboratories (configuring, networking, sharing).
9. Working in my own computer maintenance office.

PUBLICATIONS

Published a Paper under the title of: “Design a Fast 3D Scanner Using a Laser Line” (1-3)-December- 2016 in INESEC / Diyarbakir-Turkey