جامعة الأمير محمد بن فهد
PRINCE MOHAMMAD BIN FAHD UNIVERSITY

College of Engineering

Department of Mechanical Engineering

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Senior Design Project Report

Design of a Low-Cost Smart Digital Microscope

In partial fulfillment of the requirements for the

Degree of Bachelor of Science in Mechanical Engineering

Team Members

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Abstract

Microscopic examination is currently being considered as the best and the most efficient method as a process for diagnosing several equatorial diseases. In addition, as a further factor of consideration, it is important in the process of examination of these diseases to use proper instruments for the microscopic examination of parasites. Because of the rapid growth of technology smart mobile devices, mobile health monitoring begun to play a main role in various engineering applications. In the light of that fact, we in this project are going to design a 3D printed microscope structure that is attachable to a wide range of electronic devices for the quick and efficient examination. Microscopes play an important role in the inspection of a very small objects which is unexaminable with just eyes. The main issues of the conventional microscopes are as following, it is not money-saving cheap and cannot be handled easily because of their weight. Therefore, in this project we are aiming to design such a microscope that is practical, easy to use, can able to magnify 500X, with the low production cost and with low price.

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Chapter 1: Introduction

1.1 Project Definition

In this project, with the guidance of the advisor, our group is going to design a lightweight microscope that is attachable to smart cell phones and tablets to use its camera as a microscope. Since we want to construct a cost-effective design so we have decided to use 3D printing technology. First, it satisfied our goal, the second point is that the parts made by 3D printing are easily replaceable and reproducible. Moreover, in this project, we are using a power LED and two convex lenses whose focal lengths are different, i.e. objective (which is near to the object and less focal length) and the eyepiece (From where the subject is going to be seen and have a larger focal length). The optical center of both of these lenses lie on the same line and joined through an adjustable tube. The output result is greatly magnified and inverted. Since the microscope is used to see very small objects like bacteria so it has nothing to do with the inverted image. This project can play a significant role in health applications specially in the third world and poor countries which need urgent medical instruments but cannot afford for it.

1.2 Project Objectives

Our project is based on the following objectives:

- Design and construct a cost-effective microscope.
- Domesticate the capabilities of 3D printing in daily applications.
- Portable, lightweight and user-friendly device capable of getting magnified images.
- A device that can be attachable to electronic devices and gives 500X precision images.
- Mobile health monitoring by the diagnosis of diseases in remote areas.

1.3 Project Specifications

The project specifications of our experiment are listed in the given table below.

Table # 1.3 Project specification

Item	Measurements
Convex Lenses	12-30 mm
Stand Base	5 cm long
Nut & Bolts	5 mm
LED Light	3.7 volts
Battery	9 volts
Recyclable Material	500 grams

1.4 Project Applications

The are several interesting applications of our project which are listed below

- It can be used in laboratory for the diagnosis of vital diseases.
- It provides rural health facilities due to its portability and ease of use.
- It can be used in the identification of Malaria and lymphatic filariasis.
- Use of diagnostic imaging and telemedicine.
- Use in taking micrographs of blood smears.
- Secondary educational applications to perform practical.
- It can be used to examine rocks, minerals and materials.
- It has the forensic applications in the detection of an evidence.

Chapter 2: Literature Review

2.1 Project background

The microscope is a device that uses normal visible light to convert intensively small objects into a magnified image which can be seen through the naked eye. We are living in a modern era where technology has brought revolutionized change. It has completely changed the human life from the field of economics to medical and now targeting the human body and emotions. Ultimately, it gave birth to many physical applications. The diagnosis of medical diseases with the help of using smart technologies like smart mobile devices is spreading like a virus. This is due to the fact that mobile technology has become very easy to use and it doesn't have the portability issues. Moreover, the availability of medical staff in remote areas is also a great problem. So, by considering this fact we aimed to design such a device that can easily address all those listed problems.

2.2 Previous Work

There is a lot of research has been done in the past few years to convert the smartphone into an economical microscope and have gained significant results. The idea that we are going to propose is unique and outsmarts all that previous work that has been done. Due to the technological advancements, it has been found that smart microscope allows mobile devices to detect and study malaria (Pirnstill and Coté 2015) and sperms analysis (Su et al. 2010). A simpler low-cost mobile device microscopy with a reversed camera was designed in a way that can facilitate to image blood cells (Switz, D'Ambrosio, and Fletcher 2014). Recently, (Ame et al. 2013) a mobile microscope was used for the diagnosis of soil-transmitted helminth infection by using a ball lens but it limits the effectiveness of their device. 3D printed smart mobile devices microscope with the ability to get 1000x magnification with the suitable resolution is recommended by (Rosado et al. 2017) but had some issues in their 3D printed parts and networking problems.

Instead of using a fixed lens, (Tseng et al. 2010) used holographic lens-free microscopy on a mobile phone for telemedicine application to address health problems. Images of blood cells and platelets taken by them were not clear and properly magnified. (Arpa et al. 2012) uses single-lens off-chip microscopy which is cost-effective and easily detachable which allows any camera to be used for microscopy. But unfortunately, cannot be succeeded in making more sophisticated structured background illumination. The majority of the issues in microscopy can be solved by the attachment-based devices which means coupling of the additional hardware component with the smart mobile devices. This approach is quite useful in getting a much-magnified image of approximately 1000X (Smith et al. 2011), but the system will not remain cost-effective this way.

A comparative work has been done at UC Berkeley where they have created the complex attachment that can transform simple mobile phone into a mobile microscopy and successfully gets the results of tuberculosis (Breslauer et al. 2009). And the concept of using telemedicine was used a few decades before but now it has been shifted towards the wireless communication networks (Braun et al. 2005).

2.3 Comparative Work

Instead of using a fixed lens approach, the researcher at the University of California decided to conduct their experiment by using lens-free holographic microscopy. This technique was very useful due to its cost-effectiveness and its ease to use due to its low weight (approximately 38 grams), (Tseng et al. 2010), but this method is having a major drawback which is it does not provide a clear and magnified image. Researchers at the UOCL used two attachments with the mobile phones which simply turned it into a microscope and spectrometer (Smith et al. 2011). This digital microscope can qualify to get the same quality image as the commercial microscope and its spectrometer can able to demonstrate white light transmission through diffused tissues. But this system will no more be cost-effective, and the main drawback is that the resolution does not extend through the whole field of view. The edges of the picture are not completely focused which can be seen in the given image.

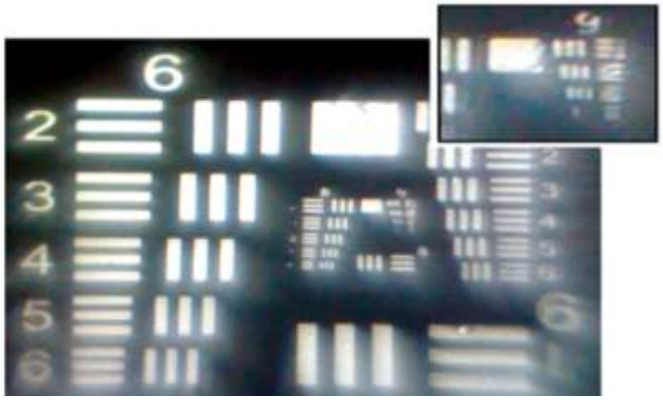


Figure 1 Image of resolution target taken with the iPhone 2G microscope, with slight distortions at the edge of the field (Smith et al. 2011)

One more attempt was made by (Ame et al. 2013) to diagnose soil-transmitted helminth infection. They use ball lenses with the help of double-sided tape attached to the smart devices for the better stability of the lens. This technique is not very advanced and hence give only modest diagnostic yield with the maximum sensitivity of 81%. That's why it limits its use to the moderate level studies only.

In this project, we are aiming to produce cost-effective microscope which can ease the process to provide a better magnified resolute image having much greater accuracies. Also, we aim to produce such a device that outsmarts the previous work that has been done in this field.

Chapter 3: System Design

3.1 Design Constraints and Design Methodology

Here come a lot of hurdles and design considerations while completing our project which we make by consulting our faculty and experts, and referencing to books and online research papers and studies. A few of them are listed below.

3.1.1: Geometrical Constraints:

We managed to finalize such a design that can be implemented to a large variety of applications and devices' dimensions. We ended up on the manufacturing of the subsystems of our design with 3D printing so that it can remain cost-effective. We have designed such a device which is easy to use and handle so that a student from a lab to a scientist can operate this product. Moreover, the length of the system is designed to cooperate with the sizes of smart phones and tablets up to 10.1 inches.

3.1.2: Sustainability

The sustainability of the project lies in the fact that how it is going to solve the global problems for the longer spans. The design that we are going to propose were made to consider the world's energy crisis. Everyone knows that the fossil fuels and the energy is ruling out of the world and it have been considered that by 2050 there will be no sign of fossil fuels present on the Earth. Therefore, we have decided in our future work that we can be able to charge our batteries of the bulb light with renewable sources such as mini-solar panel. We are using 3D printed parts in our major assembly, since these parts are easy to manufacture and replace. We are aiming to use renewable energy source which is clean, free and green energy having no environmental effects at all. Hence, our project satisfies all sustainability's fundamentals of cost, environment, ease of fabrication, quality and social impact.

3.1.3: Environmental Concern

Environmental concerns are those in which you carry out the study of renewable resources use, pollution creation and the diminishing of the non- renewable sources. The pollution generated from the projects should not exceed the low limits in comparison with current methods. So, we have decided in this project that it contains the advantage of charging batteries via solar energy. We are aiming to use renewable energy source which is clean, low-cost and green energy that does not negatively affect our environment. By doing this we can accomplish pollution limitation, waste reduction, resource conservation and carbon emission free environment.

3.1.4: Social

Social impact is another big target of the project, since we are seeking to get our project to affect the communities of the third world and the growing countries. So, as far as this project is concerned, we have decided to associate our project as much as we can so to social effect. Since most of the individuals are spending their lives under the poverty, we tried to maintain the low cost so that it can positively impact a lot of people's lives. It should improve the level of education as well as people’s livelihood by creating an opportunity for jobs and medical development.

3.1.5: Economic

To make a project economically suitable, a person should wisely estimate, allocate and control the cost of the project. In every project, the economic constraint is the biggest problem that can influence the success of a project. This problem can also come up in our project as well but we have chosen unique approach to reduce the price of the components used. As the title of our project tells, we are going to design a low-cost 3D printed microscope, so the first thing that should come to our minds is to keep the price as low as possible so that it can impact a lot of communities. One of the intents to keep the price low is, to market it for the 3rd world countries and its use in practical laboratories by students. This may generate jobs, and therefore decrease crime rates.

3.1.6: Safety

We have designed our product in such a way that it can safely be used. We have covered the lens so that no one can able to touch it. Touching the lens may cause various problems; it may indirectly hurt a person by leading to false blood analysis or can damage the lens too. To avoid unnecessary use of light we have put an automatic switch which turns off while not using it for 30 seconds, to save energy and protect eyes from damage. Since most of the parts are made of plastics and stainless steel it proves to be inflammable.

3.1.7: Ethics

We have analyzed our project ethically which means our product doesn't badly affect any kind of community, safety and privacy of the users, and we managed to produce such device that are morally desirable in the world of engineering. The idea behind the manufacturing of our product was to keep it simple and can easily be taken in to mass scale and production. Therefore, we need a sustainable, renewable and easily manufacture-able product. By keeping all these views in our aspect, we have decided to go for 3D printing since it has more advantages over other manufacturing techniques.

3.2 Engineering Standards:

We have developed mostly all the components like the rack, pinion, base, supports, etc. with the help of 3D printing so that it can sustain and easily replaceable. Moreover, these parts are able to sustain a safe load up to 1 KG. We have used a simple rack and pinion gear mechanism arrangement for this project since it is the most effective at that stage.

Specifications	ASTM Standard

Standard Specification for General Requirements for Steel Bars, Carbon and Alloy, Hot-Wrought	*ASTM A29/A29M*
Standard Specification for Poly (Vinyl Chloride) (PVC) Plastic Pipe	*ASTM D1785*
standard specification for carbon and alloy steel nuts for bolts	*ASTM A194*
Standard Specification for Additive Manufacturing	*ASTM52915*

Table 3.1: ASTM STANDARDS

3.3 Theory and Theoretical Calculations:

3.3.1: Rack and Pinion Calculations:

The most important thing in doing the rack and pinion calculation was to determine the drive size of the rack and pinion which basically depends on the three factors which are tangential force, pinion teeth and rotational speed. The tangential force acting can be calculated by the given equation ("Danielle Collins,2019," n.d.)

$$F_r = m.g.u + m.a + F_e \qquad \text{equation (1)}$$

$$F_r = m.g + m.a + F_e \qquad \text{equation (2)}$$

Where:

- Fr = force on rack (N, lbf)
- m = moved mass; includes the application load, plus any system components that are being moved, such as the pinion, gearbox, motor, etc. (kg, lbm)
- g = gravitational constant (921 ra/s2, 32.2 ft/s2)

- u= coefficient of friction of guide mechanism (typically 0.002 to 0.003 for ball or roller recirculating guides)
- a = maximum acceleration the system will experience (m/s2, ft/s2) Fe = pressing force due to the application; if applicable (N)

The torque on the pinion can easily be determined by just multiplying the force with the radius.

$$T_p = F_r * r_p \qquad \text{equation (3)}$$

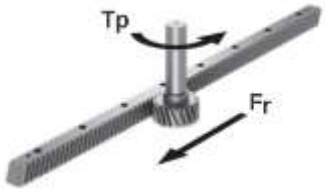


Figure 3.1: Danielle Collins, 2019

Where:

- T_p = torque on pinion (Nm, ft-lb)
- r_p = pinion radius (m, ft)

In order to calculate the maximum rotational speed just divided the linear velocity by the circumference of the pinion.

$$n_p = \frac{V_{max} * 60 * 1000}{\pi . d_p} \qquad \textit{(“Danielle Collins,2019,” n.d.)} \text{ - Equation (4)}$$

Where:

- n_p = maximum rotational speed of pinion (rpm)
- v_{max} = maximum linear speed of application (m/s, ft/s)

3.3.2 Lens and Magnification Equations:

In the projection of the real image in practical, magnification is the ratio of the size of the image to that of object and can be expressed as

$$\mathbf{M} = \frac{\textbf{length of the image}}{\textbf{length of the object}} \qquad \text{equation (5)}$$

The relationship from the lens to object and from lens to images is governed by the famous Gaussian equation which stated as

$$\frac{\mathbf{1}}{\boldsymbol{f}} = \frac{1}{\mathrm{p}} + \frac{1}{\mathrm{q}} \qquad \text{equation (6)}$$

Earlier, Isaac newton discovered that the position of the image by respecting two principal foci not by the position of the lens.

$$\frac{\boldsymbol{x}}{\boldsymbol{f}} = \frac{\boldsymbol{f}}{\boldsymbol{x'}} \qquad \text{(Lawrence 2000) - equation (7)}$$

The maximum load acting on gears can be calculated by the gear load equations. By simulating we came to know that our design can able to withstand more than 1Kg of load which means we are working in a safe region zone.

3.3.3 Product Subsystems and Selection of Components:

This is the most important phase in the selection and testing of our components. We intended to make such an output that has the minimum inputs or simply means required less amount of effort in terms of cost, sustainability, and manufacturability. Starting from the sizing and selection of the lens, the market is full of such products. First, we completed the calculation that exactly fits the sizes of the lens which should be required then we start searching it on the internet because the material available in our local markets is not that much good or hardly available. We ordered a set of 10 lenses from online shopping website in which matches our interest and requirements.

In the last few decades, healthcare expenditures in the world have escalated drastically. From a recent survey, it has been deduced that 16% of the total budget of the US has been utilized in healthcare application and curing of diseases. So, our basic aim was to construct such a device that costs a little and proves advantageous for mankind. That's why we decided to make most of the components using the method 3D printing method of manufacturing, because of the

low cost of manufacturing as compared to other materials. The parts of the microscope made by the zinc Alloy and steel are costly. For that reason, we preferred to use this technique. Moreover, it has an advantage over other manufactured parts, because these parts are easily replaceable and manufacturable. The material wasted during 3D printing can be recycled.

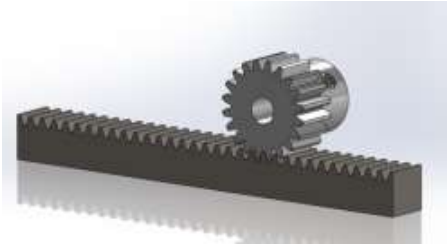


Figure 3.2: CAD Model Rack and Pinion

When we came upon the stage of choosing the lifting mechanism for the process of lifting the plates, we decided to use a gear of the type rack and pinion mechanism, since; it is much easy to use and related to engineering standards. Similarly, at the point of lifting the lenses, we decided to move it manually rather than automatically so that it gives more control to the user and save costs**.**

3.4 Manufacturing and assembly (Implementation)

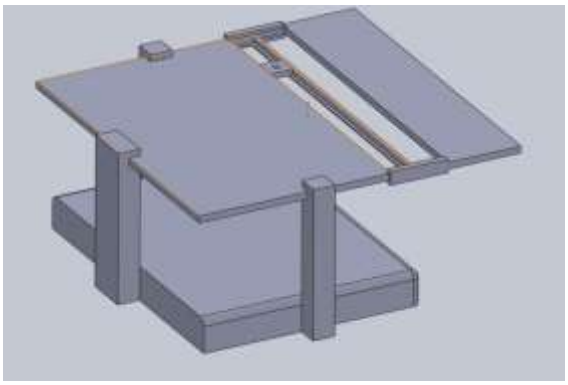


Figure 3.3: CAD Model Assembly

The manufacturing and the assembly phase were a bit difficult task for us. But because of efforts and the regular check by our faculty and advisory we managed to complete this phase. We learnt problem solving by finding a solution for every problem. The parts like pinion stand and focus knobs are constructed with high defined settings using Polylactic Acid (PLA). Since it is

eco-friendly, Fire resistant and uses less energy while working on this material. Some of the designed parts can be seen in the illustrations below:

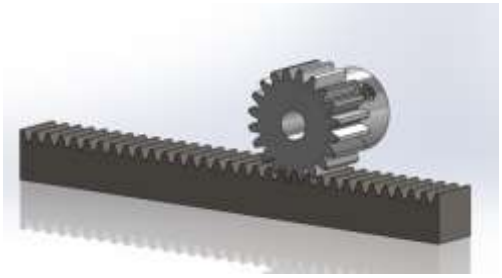


Figure 3.4: Rack and \Pinion assembly

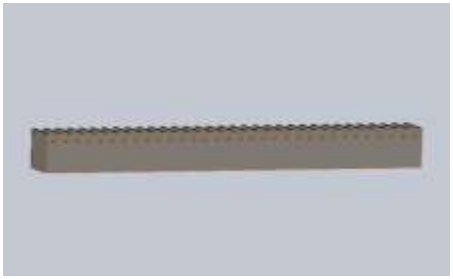


Figure 3.4(a): Rack

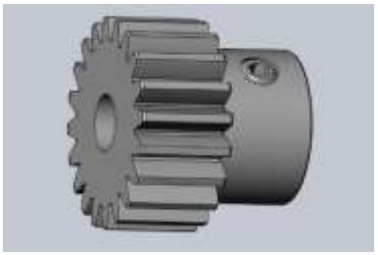


Figure 3.4(b): Pinion

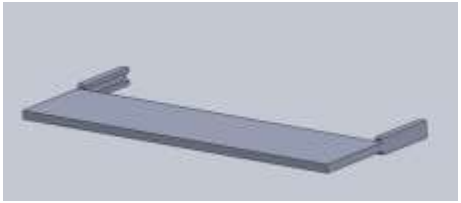


Figure 3.4(c): Extension

After the designing and manufacturing of these parts we move towards the assembly phase. Where we use one lens. The purpose of using this lens is to get maximum magnification.

The knobs are generated two positions of the rolling shaft and the main roller for the shaft of pinion to fix our sample plate. Moreover, the lens selected is fixed to a level of focal length 35mm. Focus knob is used to adjust the focus manually. We have attached our lenses in the allocated spaced created on lens plate. Then we came towards the assembly phase of plate and entered it in supports spaces which then fixed with small parts similar to screws. We designed device plate in such a way that it can be adjustable so we designed an extension plate and a sliding mechanism for both of the lens and sample plate. It has the capability to extend up to 10.1 Inches, vertically and/or horizontally.

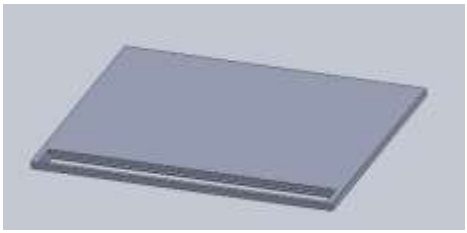


Figure 3.5(a): Device Stand 1

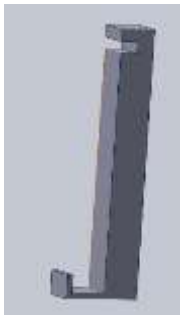


Figure 3.5(b): Stand Supports 1+2

To make it manually adjustable we put two holes in the main head block so that we can put focus adjusting knobs in these holes. The mobile stand is then attached to the head block. The overall assembly of the microscope is shown below.

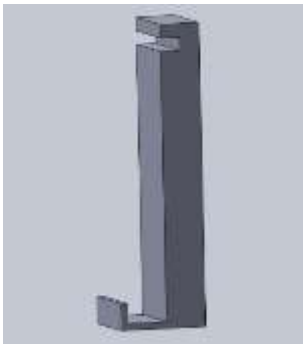


Figure 3.6(a): Support 3 (Rear)

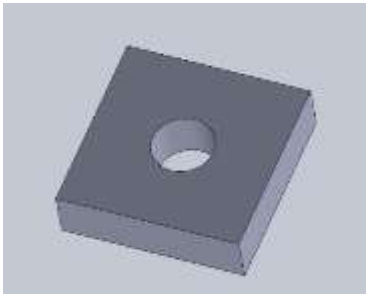


Figure 3.6(b): Mobile Stand

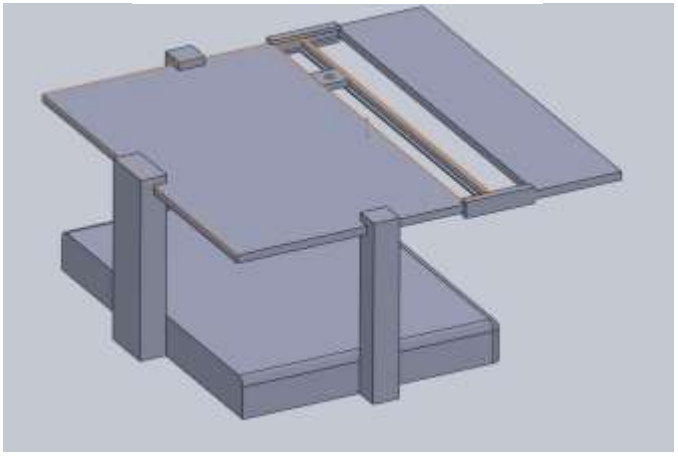


Figure 3.7(c): Assembly

Printed Parts

Chapter 4: System Testing and Analysis

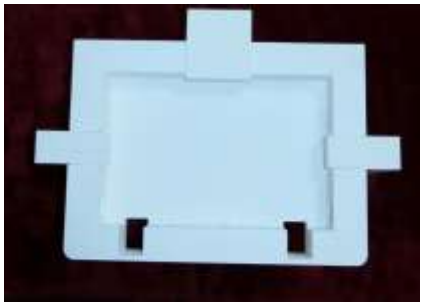
4.1 Experimental Setup, Sensors and data acquisition system

4.1.1 Experimental Set Up

In our experimental setup the smart tablet acted as data acquiring sensory device of the experiment. The performance of the setup was tested by the use of different devices to compare the images and results. In this study, we systematically addressed the issue of quantitative microscopy with a smart tablet and smart phone by constructing a smart digital microscope and evaluating the quality of images taken with a range of different devices.

Steps are as following:

1- insert base supports into spaces in rear and sides



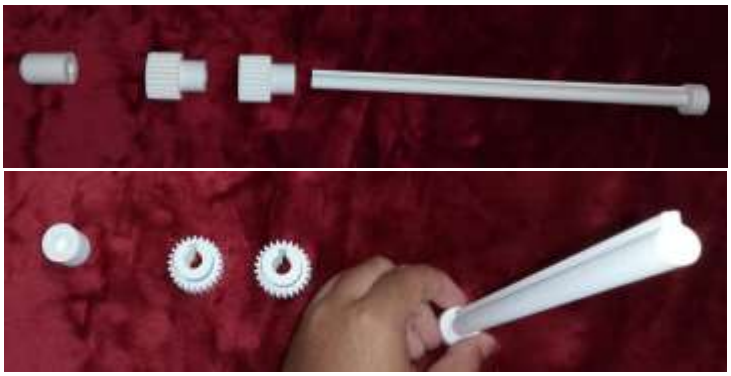
2- Insert racks and fix their supports

3- Fix sample slider on racks

4- Insert stand into spaces at the top of the three supports

5- Attach the lens to the lens plate and place the track located on the device and (if needed) you can attach this extension to fit larger dimensions

6- Insert toothed (key) shaft into holes of the two pinion gears and into the roller



7- Insert into the hole on the side of the base, and pair (fit) each pinion to a rack gear

Final Shape

4.2 Results, Analysis and Discussion

In order to assess the performance and system functionality firstly we calculated the external load on the stand as to see is stand can bear the load of external load. This was determined by dividing pressure by area.

- σ = Normal stress (Pa)
- P = Resultant normal force (N)
- A = Cross-sectional area (m^2)

$$\sigma = \frac{P}{A} \qquad \text{equation (1)}$$

$$= \frac{m \cdot g}{a \cdot b} = \frac{(0.3\ kg) \cdot \left(9.81\ {}^{m}/_{s^2}\right)}{0.3\ m\ \cdot 0.4\ m}$$

$$\sigma = 24.525\ Pa$$

Now to evaluate how strong is the setup, we will calculate the force acting on the pinion by the rack can be determined by

m_r= mass of rack (kg) , g = gravity (${}^{m}/_{s^2}$) , F_r= force acting on rack (N)

$$F_r = m_r \cdot g \qquad \text{equation (2)}$$
$$= (0.05\ kg) \cdot (9.81\ {}^{m}/_{s^2})$$

$$F_r = 0.4905\ N$$

To calculate the torsional shear, we used the following formula:

Where

- T_p = torque on pinion (Nm, ft-lb)
- $c = r_p$ = Radius of pinion (m)
- τ = Torsional shear (Mpa)

$$\tau = \frac{T_p \cdot r_p}{J} \qquad \text{equation (3)}$$

$$= \frac{T \cdot r_p}{\frac{\pi}{2}(c^4)} = \frac{73.575(10^{-4}) \cdot (0.015)}{\frac{\pi}{2}(0.015)^4}$$

$$\tau = 1.388 \cdot 10^{-3}\ Mpa$$

We also calculated the magnitude of the lens we used in our smart microscope by using a sample of small piece of onion using following formula:

$$\mathbf{M} = \frac{\textbf{length of the image}}{\textbf{length of the object}} \qquad \text{equation (4)}$$

Where

- Length of image = 16 cm
- Length of object = 0.3 mm

Now putting the values in the equation and will same units for both for convenience

M = 160mm/ 0.3mm

M = 533.3 x

Calculations and tests performed on our low cost smart digital microscope is proved to effective in microscopy and shows very good sensitivity level. The magnitude of the lens used is very impressive. Hence it is very inexpensive and highly efficient microscope which can be used for sensitive detections. As research and study prove it be useful even in detecting cancer cells.

Comparative Study

Commercial Microscope

Our Smart Digital Microscope

Comparative tests performed on our low cost smart digital microscope is proved to Show high quality result similar to commercial microscope, which is impressive. Hence it is very clear details and efficient magnification which can be used for sensitive detections.

Chapter 5: Project Management

5.1 Project Plan

Work break downs structure is a hierarchical and incremental decomposition of the project into phases, deliverables and work packages. It is a tree structure, which shows a subdivision of effort required to achieve an objective for example a program, project and contract. In a project or contract, the WBS is developed by starting with the end objective and successively subdividing it into manageable components in terms of size, duration, and responsibility which include all steps necessary to achieve the objective.

Table shows the list of tasks included break down structure of our project:

Table # 5.1: Project Plan

S. No.	Tasks		Start	End	Duration
1.	Chapter # 1: Introduction		09/09/19	19/09/19	10
2.	Chapter # 2: Literature Review	Project Background	20/09/19	30/09/19	10
		Previous work			
		Comparative Study			
3.	Chapter # 3: System Design	Design Constraints and Design Methodology	02/10/19	10/10/19	09
		Engineering Design Standards			
		Theory & Theoretical Calculations			
		Product Subsystems & Selection of Components			
		Manufacturing & Assembly			
4.	Chapter # 4: System Testing & Analysis	Experimental Setup, Sensors and Data	01/11/19	12/10/19	11
		Results, Analysis & Discussions			

5.	Chapter # 5: Project Management	Contribution of team Members	15/11/19	19/11/19	4
		Project Execution Monitoring			
		Challenges and Decision Making			
		Project Bill of Materials and Budget			
6.	Chapter # 6: Project Analysis	Impact of Engineering Solution	26/11/19	28/11/19	2
		Contemporary Issues Addressed.			
7.	Chapter # 7: Conclusion & Recommendation	Conclusion	28/11/19	29/11/19	1
		Future Recommendation			
8.	Design of Prototype		05/11/19	11/11/19	6
9.	Parts Purchase		20/09/19	05/10/19	15
10.	Manufacturing		05/10/19	19/10/19	14
11.	Testing		20/10/19	22/10/19	2

Table# 5.1 (a): Assigned Members for Tasks

S. No.	Task	Assigned Members
	Chapter # 1: Introduction	Mohammad S. & Mamdouh
	Chapter # 2: Literature Review	Saleem O. Bajaafar
	Chapter # 3: System Design	Everyone
	Chapter # 4: System Testing & Analysis	Everyone
	Chapter # 5: Project Management	Everyone
	Chapter # 6: Project Analysis	Mohammad S. Aldawas
	Chapter # 7: Conclusion & Recommendation	Ibrahim
	Design of Prototype	Salem, Mamdouh & Mohammad
	Parts Purchased	Nasser & Ibrahim
	Manufacturing	Everyone
	Testing	Everyone

5.2 Contribution of the Team Members

We have divided the complete task in to sub tasks in order to get the expertise of the individual ones in order to complete the project within the allocated time and resources.

Table # 5.2: Contribution of Members

S. No.	Tasks		Assigned Member	Contribution
	Chapter # 1: Introduction		Mohammad S. & Mamdouh	100 %
	Chapter # 2: Literature Review	Project Background	Saleem O. Bajaafar	50 %
		Previous work	Nasser Alammary	50 %
	Chapter # 3: System Design	Design Constraints and Design Methodology	Saleem	20 %
		Engineering Design Standards	Nasser	20%
		Theory & Theoretical Calculations	Mohammad	20 %
		Product Subsystems & Selection of Components	Ibrahim Alsamhan	20 %
		Manufacturing & Assembly	Mamdouh	20 %
	Chapter # 4: System Testing & Analysis	Experimental Setup, Sensors and Data	Ibrahim	100%
		Results, Analysis & Discussions	Mamdouh	
	Chapter # 5: Project Management	Contribution of team Members	Nasser	100%
		Project Execution Monitoring		
		Challenges and Decision Making	Saleem	
		Project Bill of Materials and Budget		

	Chapter # 6: Project Analysis	Impact of Engineering Solution	Mohammad S. Aldawas	100%
		Contemporary Issues Addressed.		
	Chapter # 7: Conclusion & Recommendation	Conclusion	Ibrahim	100%
		Future Recommendation		
	Design of Prototype		Salem, Mamdouh & Mohammad	100%
	Parts Purchase		Nasser & Ibrahim	100%
	Manufacturing		Everyone	100%
	Testing		Everyone	100%

5.3 Project Execution Monitoring

In order to complete the project within the allocated time and to take the project to the advanced manufacturability scope we keep on visiting our faculty staff and advisor. Moreover, we also conducted the feedback survey of professionals, engineers and key personnel in order to improve our product. The meeting schedule with the advisor has been shown in the table given below

Table # 5.3: Dates of Activities & Events

Time/Date	Activities/Events
Once in week	Assessment Class
Bi-Weekly	Meeting with the group members
Bi-Weekly	Meeting with the Advisor
12 November, 2019	Ordering parts

14 November, 2019	Midterm Presentation
29 November, 2019	First Test of System
30 November , 2019	Finishing Final Prototype
1 December, 2019	Test of the System
5 December, 2019	Final Submission of Report
12 December 2019	Final Presentation

5.4 Challenges and Decision Making

In order to make our project and reach a final stage of manufacturing, we have faced some problems which affect the progress of our project and acted as obstacle to overcome. Rack fixing need more fixing to assure that the rack stays vertical and on the other hand sample slider did not perfectly fit with rack positions. Finding online 3d printing sites that cost lower in difference up to 1500 riyals, however, due to a lot of hard work we in the end cater all these factors to make our project better.

5.4.1 Equipment and Device Problems

There comes a lot of challenges in order to make this project successfully happened. One of them is the use of 3D printing to make our small and complex parts. Lack of lazers and specialized stores in microscope lenses and many more things ordered online but shipment was lost. Another main issue regarding equipment was fixing the lens in to lens plate. But with the help of seniors, supervisor and by doing some research analysis we came to find the solution of it and we ended up on the manufacturing of the subsystems of our design with 3D printing so that it can remain cost-effective. Moreover, in order to manufacture a device which is user friendly and easy to use is again a challenging task.

5.4.2 Testing and Safety Issues

Our setup would have been successful only if it was tested and proved to be safe at all conditions. We did not face and testing and safety issue as such because our project is safe and

secured. But only one this should be kept in mind that the prototype should be away of sunlight and should be of room temperature and also kept away from children below 5 years old.

5.4.3: Design Problems

The manufacturing and the assembly phase were a bit difficult task for us. But with the constant efforts and the regular check by our faculty and advisory we managed to complete this phase. The parts like pinion stand and focus knobs are constructed with high defined settings using Polylactic Acid (PLA). Since it is eco-friendly, recyclable, fire resistant and uses less energy while working on this material

5.5 Project Bill of Materials & Budget

The following table illustrates the materials that we purchased and their costs in Riyal (SAR)

Table #5.5 Project Bill of Materials

Material	Cost (SAR)
3D printing	1650 (online printers estimated 450 SAR)
3D printing (including VAT tax)	1732.5
Lens extracted from Lazer	5
Sample plate	20

Chapter # 6: Project Analysis

6.1 Life-long learning:

We aim to complete all the targets that have been set way before the selection of that project. So, we strictly firm our minds to keep an eye on the targets. We want to get software and hardware skills with the hands-on experience as well. In order to achieve these tasks, we need an assistance. So, we have appointed one of the team members as a group leader who has an additional duty to supervise the project and to keep on supporting the other group mates during the hard times. We have also worked on our communication and interpersonal skills to get the maximum outcome of the project. We start this chapter by highlighting few soft skills that we have achieved during this project.

6.1.1 Software skills:

In the successful completion of the project, the software that plays an important role is SolidWorks. One of our group members was proficient in it. So, we couldn't find that much difficulty in the development of 3D models. We keep on learning these skills from our group mate and the online learning platforms as well. Software like Autodesk Fusion and Free CAD takes a lot more time. We have started learning this software from Lynda. And with the passage of time and proper practicing we get expertise in these software's.

6.1.2 Hardware Skills:

Our project depends in many items of hardware that should be tested and fixed before the complete manufacturing. We have learned a lot of hardware skills while doing that project. Mostly, after the codes generated for 3D printing, there comes the phase of manufacturing and assembly of the project which requires skills.

6.1.3 Time Management:

Time management is the key part in the continuation and the succession of any task, group and project. We have set a group leader in order to keep an eye on time as well as the progress of the project and the contribution of the team members. He always keeps on motivating about the end goal of our project and ultimately, we all take it by heart and keep on doing our best to make it happen. We have divided the whole task into the sub parts in order to keep focus on each and everything and in order to allocate specified time to each portion. We, in order to cope up with the project arrange daily team meetings. We have divided the complete task into group according to the expertise of the individual ones. We also made project management analysis and use those tools in order to complete the project within allocated time and the resources available.

6.1.4: Project Management

To accomplish a project successfully on time is an art, this just not happens one have to make efforts to do so. For this purpose, we managed our project beforehand by developing a Gantt chart, which acted as project management plan. In Gantt chart everything was specified in advance for example all the tasks, their due dates, and who was responsible for doing particular tasks. Each group member assigned with number of different tasks had the responsibility of their completion on time. This effective and efficient teamwork led us to successful completion of our project on time.

6.2 Impact of Engineering Solutions:

6.2.1 Society

Social impact is the biggest target of the project manager, since they are looking for how their project is going to affect the surrounding community. So, as far as this project is concerned, we decided to market our project as much as we can so that it can affect masses. Since most of the individuals are spending their lives under the poverty So, we decided to keep the price low so that it can impact a lot of personals. It will improve the level of education as well as people's livelihood by creating an opportunity.

6.2.2 Economy

To make a project economically suitable, a person should wise estimates, allocate and control the cost of the project. We decided to choose a unique approach to reduce the price of the components used. As the title of our project tells us that we are going to design a low-cost 3D printed microscope. One of the intents to keep the price low is, to market it for the 3rd world countries and its use in practical laboratories by students.

6.2.3 Environment

In this era, environmental effects are of great concerns. Environmental concerns are those in which you carry out the study of renewable resources use, pollution creation and the diminishes of the non- renewable sources. So, we decided in our future work that we can able to charge our batteries of the power light with renewable sources such as solar and wind powered. By doing this we can accomplish pollution prevention, waste reduction, resource conservation and carbon emission free environment.

6.3 Contemporary Issues Addressed

In order to make our project and reach a final stage of manufacturing, we have faced some problems which affect the progress of our project and acted as obstacle to overcome. Rack fixing need more fixing to assure that the rack stays vertical and on the other hand sample slider did not perfectly fit with rack positions. Finding online 3d printing sites that cost lower in difference up to 1500 riyals, however, due to a lot of hard work we in the end cater all these factors to make our project best out of others.

Chapter # 7: Conclusion & Future Recommendations

7.1Conclusion

To sum up all the calculations, methods, skills and expertise that we have use in that project, we came across with the only thing left behind that is conclusion, which is not only the requirement of the institution but also reflects them about the understandings, knowledge, research and the skills that we have learned through this tenure. During the interim of 04 years we had faced many ups and downs while doing the project. There comes a lot of skills and software that we didn't know but now I am pleased to tell you that we have gained enough expertise and skills in the hardware and the software section as well. While during our project, we had a portion related to programming which takes a lot of time and efforts because it's a totally new field for us. But we would to commemorate our group leader and the project advisor who keep on supporting and always telling us the ways to get through in. We have learned all those skills taking out some time for online course learning websites. We also faced some manufacturing defects in our project but as time passes, we finally made it happen and rectify all those mistakes and these mistakes play an important role in the leaning step towards our project. The overall aim of the project was to design low price microscope. The most part of the project was based on 3D printing exercise which we have learned and done successfully.

7.2 Future Recommendations

With the help of well-organized project plan and the contribution of teammates we managed to complete our project within time. There is no end to innovation if contemplation continues. The price factor can further be reduced by improving the design. The aspiration is to produce clean and useful energy from nature to use it and power our microscope. We would like to extend our project towards mass manufacturability and productivity. Moreover, we will try to replace our source with the renewable energy.

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