HS202: Human Geography and Societal Needs

End Sem Report

Laser Integrated Navigator for Cataract Surgery (LINCS)

Department - Electrical Engineering

Submitted to: Dr. Devaraj

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Certificate

This is to certify that the B. Tech project titled " **Laser Integrated Navigator For Cataract Surgery (LINCS)** " prepared by (names of the students) is approved for submission for the course on Human Geography and Societal Needs in the Department of Humanities and Social Sciences, Indian Institute of Technology, Ropar. Department of Humanities and Social Sciences IIT Ropar.

Signature of Examiner/ Guide's

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Declaration

We hereby declare that the report entitled " **Laser Integrated Navigator For Cataract Surgery (LINCS)** " submitted by us, for the partial fulfilment of the course on Human Geography and Societal Needs (HS 202) in the second year of the B. Tech programme in IIT, Ropar. The work carried out by us under the supervision of Dr. Devaraj. P, Assistant Professor, Department of Humanities and Social Sciences. We further declare that this written submission represents our ideas and other's ideas or words have been included. We also have adequately cited and referenced the original sources in the case of other's ideas or words. We have not misrepresented any idea/data/fact/source to the best of our knowledge. Therefore, we affirm that our group has adhered to all principles of academic honesty and integrity.

Date : 17-05-2021 Signature of Candidates

Acknowledgment

The satisfaction and euphoria that accompany the successful completion of any task would be incomplete without the mention of the people, who made it possible, whose constant guidance and encouragement aided us in the completion of this project. Presentation, inspiration, knowledge, and hard work are the key components of this report. We would also like to express our heartfelt gratitude to **Dr Devraj** sir for providing us with an in-depth knowledge of how to collect and analyze our data which gave us a direction to work effectively. We also want to thank **Dr. Ravinder Goud** for providing a detailed view on the current method employed in cataract and the problems faced during surgery. Further on, we want to thank our group members:- **Aditya Bharuntia , Ankur Kumar , Challa Brahmani , Kashish Jain , Manav Mago**

for working hard on this report whether it is the content or the presentation, everyone has given their best.

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Abbreviations:

1. **LINCS** : Laser Integrated Navigator for Cataract Surgery
2. **IOL : Intraocular Lens** is an artificial lens implanted in the eye as part of a treatment for cataracts **.**
3. **TC:** It stands for Traditional Cataract surgery.Surgery in which entire procedure is Done manually including the initial surgical cut.
4. **PE :** It stands for Phacoemulsification, which is another form of cataract surgery in In which the cataract layer is removed with the help of ultrasound energy and Suction.
5. **BP :** Blood pressure
6. **HP :** Hypertension
7. **WHO** : World Health Organization

1.Introduction and Objectives

1.1 Introduction

India was the first country to launch the National Programme for Control of Blindness in 1976 to reduce blindness prevalence to 0.3 percent by 2020. But, the estimated prevalence of blindness still stands at 1.99 percent, severe visual impairment at 1.96 percent, moderate visual impairment at 9.81 percent, and moderate-severe visual impairment at 11.77 per cent, according to the *National Blindness and Visual Impairment Survey India 2015-19*, released on October 10, 2019.
Bijnor in Uttar Pradesh has the highest population suffering from blindness (3.67 per cent) and visual impairment (21.82 per cent), found the survey. It was followed by Warangal and Nalbari with differences of less than one per cent point.
According to the survey Cataract-related surgical complications was the second-highest causable factor for blindness with 7.2 per cent cases in people above 50 years. Also, refractive errors (near or farsightedness) was found to be responsible for 70.6 per cases of early visual impairment.
The *World Vision Report* released by the World Health Organization (WHO) on October 8, 2019 also pointed out that high costs involved in accessing eye care, especially, for rural populations was a major driver of visual impairment.

A recent WHO report mentions that India needs at least 1.8 million doctors, nurses and midwives to achieve the minimum threshold of 44.5 health workers per 10,000 population. This drives the need to improve surgical procedures in such a way that needs less human interference.

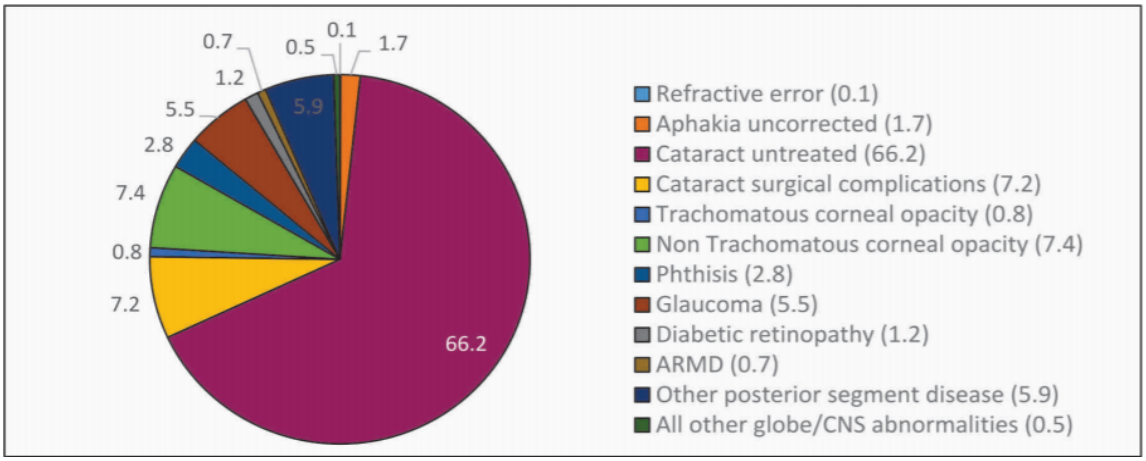


Fig 1: ***Pie chart showing Causes of blindness in population aged≥50 years***

The pie chart clearly shows that among other eye related problems leading to blindness, untreated cataract occupies a very large proportion , which is cause of grave concern. Therefore,

Not only treating cataract should be our priority but also treating it with accuracy and precision should be our goal as cataract related surgical complications sweep out 7.2% of area among other causes leading to blindness.

Current Cataract Surgery Procedure:

Laser based cataract surgery which is done presently involves following steps:-

1) Femtosecond laser (Unguided laser) is used ONLY to make a small incision in the front of the eye, which creates a small opening in the capsule of the eye, allowing access to the cataract. Some surgeons still use a scalpel for the incision. But more and more, surgeons have started using a Femtosecond laser.
2) Once we have got access to the cataract the next step is to remove the cloudy layer, essentially the cataract made up of the proteins.
3) To remove the cataract, the surgeon makes an incision around the eye's lens.Removal of this layer is done with the help of an ultrasound probe. Ultrasound energy is used to break up and remove the cloudy lens.The probe breaks up the cataract with vibration and removes the fragments with suction.
4) After that, a new lens is slipped into the eye.
5) Finally the incision is closed.

1.2 Objective

Our objective is to aid the conventional process of cataract surgery with technological advancements by taking in account the socio-economic impact, thus automating the process at various levels and help in improving the accuracy and reducing time. We aim to achieve this by combining the latest advancements in Medical Sciences, Computer Science, Electrical Engineering and Optics to develop LINCS.

Our final product will use a navigation system in combination with an algorithm guided feedback system which takes input as a scan for the eye (which will detect the refractive properties as well as the dimensions of the eye) in continuous domain and gives output in the form of maximum accuracy incision along with IOL (Intraocular lens) placement by avoiding post-surgical errors.

The whole main idea is around the fact that innovation happens when **Technology meets human needs.**

2.Theoretical and Conceptual Aspects of Problem Selected

Even with technical advancement in cataract, Cataract is the leading cause of blindness in people above 50 years. According to the National Blindness and Visual Impairment Survey India 2015-19 conducted by AIIMS Delhi, cataract is behind 66.2 percent blindness cases, 80.7 percent severe visual impairment cases and 70.2 percent moderate visual impairment cases in the age group. There are still several areas in cataract where there is a need of improvement and according to a survey it has also been seen that the cataract cases have been increasing as 7.75 million cases were reported in 2001 and 8.25 million cases were reported in 2020 in India for people aged above 50 yrs. That's why there is much need to address the issue.

Principle Cause	Blindness(%)
Cataract Untreated	**66.2**
Cataract Surgical Complications	**7.2**
Refractive error	0.1
Aphakia uncorrected	1.7
Trachomatous corneal opacity	0.8
Non trachomatous corneal opacity	7.4
Phthisis	2.8
Glaucoma	5.5
Diabetic retinopathy	1.2
ARMD	0.7
Other posterior segment diseases	5.9
All other globes/CNS abnormalities	0.6

Table 1: Showing the percentage of blindness due to treated and untreated cataract.

2.1 Main Problem Statement

The main problems that we found through our intensive research in current cataract surgery are as follows:-

(i) Low accuracy of Incision: In many cases of cataract surgery, the incision done has a noticeable error which can lead to conjunctival redness, capsular complications (anterior & posterior tears), posterior lens dislocation.
(ii) Burns caused due to excessive ultrasound energy: In Phacoemulsification, the ultrasound device that breaks up the cataract is inserted into the incision. Ultrasound energy in few cases leads to heat buildup in the incision, which sometimes can burn the incision and negatively affect the visual outcome by actually inducing astigmatism.
(iii) Improper selection of lens: One of the most prevalent errors during cataract surgery remains the insertion of the wrong intraocular lens. IOL implantation error results in an unexpected postoperative refractive outcome. Improper lens selection occurs due to errors in preoperative assessment of the eye and Poor management of Intraoperative complications such as Astigmatism, which may require an alteration to the surgical plan and different lens because of which an additional situation for incorrect lens insertion arises.
(iv) Incapable of curing astigmatism during surgery: In the current cataract procedure, surgeons neglect the pre-check for astigmatism as it requires much time.

Apart from these, complications such as severe vision loss, bleeding, and infection can occur. Although, they are extremely rare, and most of the time Doctors are able to evade this situation or minimize these complications.

Our Inspiration for the Research Topic Cataract:

Our inspiration for opting for Cataract Treatment as a problem statement arose from the experience of one of our group member's grandmother's cataract surgery. She had surgery done for both of her eyes. Despite the fact of having a good experience with one of the eyes, it was not upto the mark for the second one. As a result, her eyes got puffy and there was redness and pain which stayed for quite a few months. Though the medical aid was taken from a very renowned and experienced eye surgeon, she still faced these problems. Having seen this in the past motivated us to work on this issue.

2.2 Theoretical Aspect

In our **Engineering Problem**, we tend to make a conceptual understanding of the problem from the theoretical point of view and also analyze its usability from a practical perspective through various interviews and surveys.

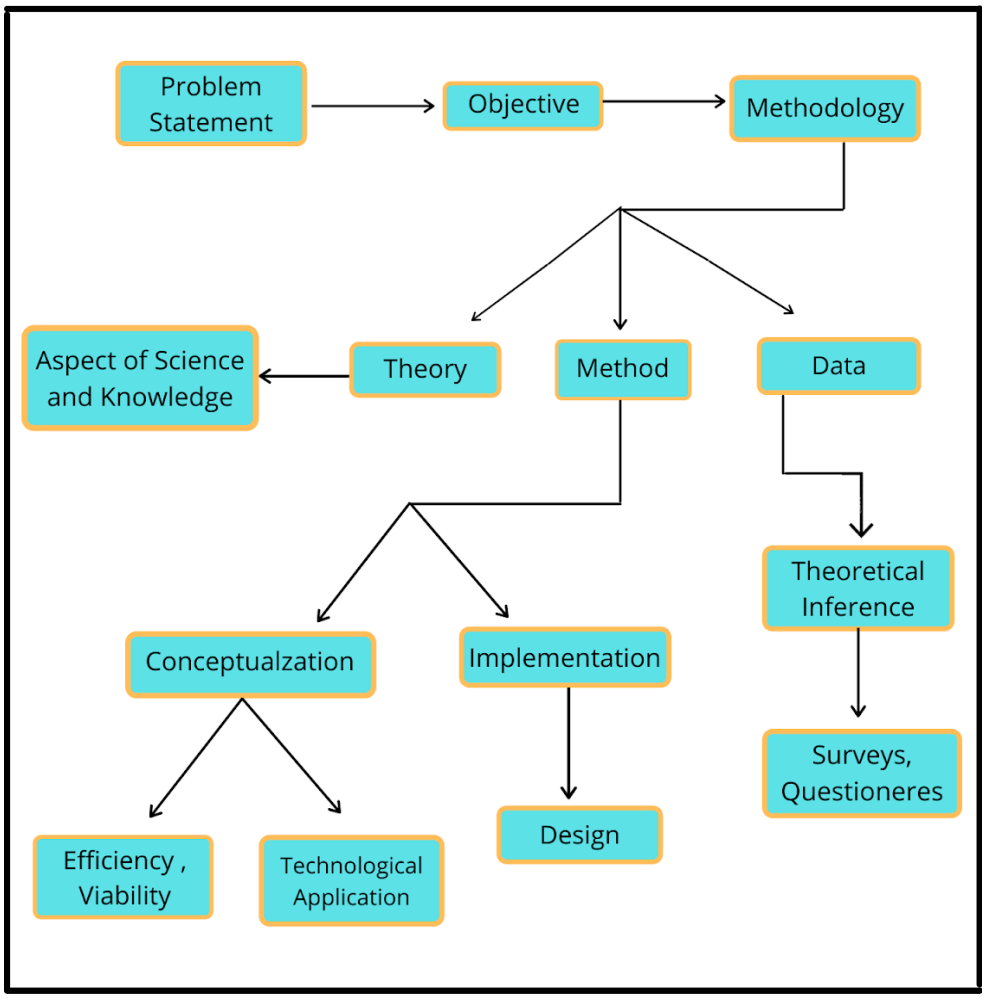


Fig 2: Workflow of our project

We would also like to concentrate our efforts on trying to achieve maximum efficiency from the perspective of the user based on usability and real-time constraints along with the engineering designs perspective.

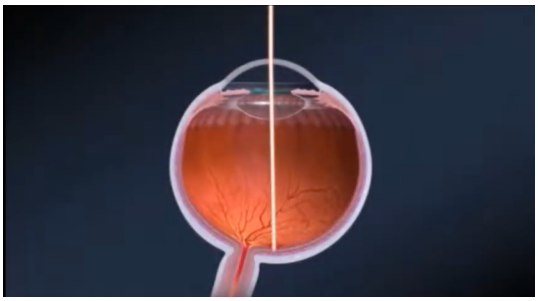
2.3 Main Working Idea

To solve this problem we introduced a LINCS (Laser integrated Navigation System for Cataract Surgery) system which provides continuous assessment of the patient's eye allowing for highly accurate refractive measurements.

Working Principle:-

1. Along with performing scans to determine the grade of cataract, a **low-intensity laser** is also directed into the patient's eye and is reflected off the retina.
2. The reflected light passes back and is processed by LINCS to calculate **refractive values** and different characteristics of the eye (**Depth**, **Thickness, Power, etc.**)
3. The **refractive properties like refractive index** calculated from the reflected ray are used **to calculate the exact point of incision**.
4. For the entire duration of surgery, until the IOL lens is placed, **feedback** is passed through the laser to the LINCS to guide the exact position and intensity of the Laser by giving a continuous real-time assessment.
5. After the incision LINCS extracts the cataract abstract from the eye by using ultrasound energy in case of maturation grades, while in case of lesser grades the laser is sufficient enough to break the proteins.
6. Then LINCS checks refractive information to help **determine cylindrical and spherical power** magnitude. (As in most of the cases after surgery there is loss of natural power of the eye, which is replaced by introducing artificial lenses).
7. After checking for IOL (Intraocular Lens) which determines the nature of the lens to be placed, LINCS places the lens with the help of an in-built navigation system which helps to determine the exact position for placement.
8. After that, the incision is closed.

What is this low-intensity laser and how would we be determining a suitable one.? (As mentioned above)



A suitable light would be the one that would be able to **penetrate the cornea** and reach the retina as shown in the image. At the same, it should **possess enough energy** so that even if the coefficient of reflection of the retina is such that there is some amount of energy lost, it can **travel back** to LINCS passing from the cornea for processing to extract and gather suitable information.

(Light coming from LINCS would always be **perpendicular** to the surface of the eye so that **multiple reflections do not occur** and enough energy is preserved(i.e. characteristics) such that relevant information can be extracted.**)**

2.4 Conceptualization

1. **Aspects of Science -** Cataract is a dense, cloudy area that forms in the lens of the eye. A cataract begins when proteins in the eye form clumps that prevent the lens from sending

clear images to the retina. The retina works by converting the light that comes through the lens into signals. It sends the signals to the optic nerve, which carries them to the brain. It develops slowly and eventually interferes with the vision.

2. **Aspects of Knowledge and Observation -**

Cataract blindness is a public health problem of major proportion. Therefore it is important to realize the aspect of knowledge, awareness, and observation in cataract and its surgery. The main reasons analyzed by us in regards to cataract leading to blindness include ignorance regarding the disease, lack of awareness on the possibilities of getting eyesight restored through operation, economic constraints, myths among people towards surgery, etc. Thus to make cataract surgery more socially acceptable, accessible, and economically affordable, a definite plan which can make more people aware is necessary so that ever-increasing cataract blindness can be cured.

cured.

Awareness and knowledge programs need to be devised to educate especially the rural population on the importance of curable blindness and advanced surgery solutions.

To carry out such programs, Anganwadi, specially organized eye camps, radio sessions can be really beneficial.

3. **Aspect of Technology -**

Technology - the application of scientific experiments and results obtained from them also has a part in the conceptualization stage as the implementation and application of technology should be efficient and at the same time prioritizes cheaper design. With cataract surgery regarded as the most widely performed surgical procedure, a demand exists for continued innovation and technology. Latest advances evolved through the application of well-defined principles to current surgical goals and patient expectations include advances in preoperative and intraoperative diagnostics, femtosecond laser-assisted cataract surgery (FLACS), and a new generation of intraocular lenses (IOLs).

Patients with a history of corneal refractive problems like astigmatism expect reduced dependence on spectacles after cataract surgery. To remove both anterior and posterior corneal astigmatism and prevent it from occurring post-surgery it is important to make surgical incisions more predictable and accurate along with the goal of appropriate IOL selection to provide the best visual outcome that meets a patient's individualized goals and expectations.

Therefore it is very crucial to consider variability in materials, optical properties, and designs to achieve a patient-specific selection of an IOL. Thus a new paradigm in IOL manufacturing is to bring further advancements in IOL technology with an aim to improve visual functionality by creating customized IOLs or modifying optical power

postoperatively. The concept of adjustable IOLs involves the correction of residual refractive error postoperatively or customization after lens implantation.
With refinements of the latest technology, Systems such as LINCS and other parallel advances will provide surgeons with the potential to perform an even safer, predictable, and effective surgery. Hence, The future of refractive cataract surgery would be very exciting.

4. **Aspects of Economics and Industry -**
One of the major parts of understanding involves the knowledge of the affordability of the product which we are designing because if the target population is not able to afford the same then it would be rendered useless. The *World Vision Report* released by the World Health Organization (WHO) on October 8, 2019, also pointed out that high costs involved in accessing eye care, especially for rural populations, were a major driver of visual impairment.
To help us understand patient's affordability, we interviewed some patients from Sarojini Devi Hospital, Telangana (as described earlier) and also got to know about the general cost structure from the doctor's point of view. In the information collected, we took the patients as constants and their social and economic status as variables which would help us in developing indicators to understand the cost feature of our product by comparing it with the current amount spent on current surgery.

5. **Aspects of Experimentation -**
One major part of our problem statement is understanding the different variables involved and their characteristics. The types of variables which are identified in our project are:-

1) **Dependent variables -** They are dependent on some other variables and changes in those variables will cause some changes in these variables. The dependent variables in our project are the Amount of Ultrasound & Laser energy that is used in breaking & removing the cataract, measures taken to cure other eye problems like Astigmatism, Type, and power of IOL used, Cost of treatment, Post-surgical complications.
2) **Independent variables -** These variables do not depend on other variables of our experiment and their values are independent of values of other variables of our study. The independent variable in our project is Age, Socioeconomic Status, Medical history and Cataract grade of patients.

We studied these variables to identify the causal hypothesis and relationships between them and to determine how one variable affects the outcome of the other variables and in what sense and manner.

3.Methodology

For the purpose to obtain more information in a versatile way and be able to use it in a generalized form for the whole population, hence we chose Sarojini Devi eye hospital, Hyderabad. Sarojini Devi eye hospital is a government hospital and it's a specialized hospital for eye surgeries.

3.1 Site Description:-

The reason for us selecting the particular hospital is because

1. It is a Govt hospital, therefore helps in reflecting the political side or the Govt role in healthcare. It is the primary hospital for eye treatment for the poor and underprivileged in and around Hyderabad. It has been treating many patients for free since its inception.
2. All types of cataract surgeries are done here.
3. The institute has "State of the Art" equipment and technology to treat diseases in general ophthalmology and specialties. People from all Telangana and neighboring states come for treatment at the hospital.
4. On average 40,000 -50,000 surgeries are performed at the hospital per year.
5. The hospital bed capacity is 550 beds which are enough for accommodation.
6. Also, it is a medical institution(with 450 students training under 9 professors,6 Associate Professors, and 33 Assistant professors) which helps us further understand the way technology is taught and used.

Therefore it was justifiable to choose such a hospital from where we can get a vast view of overall cataract surgery conditions.

3.2 Selection of respondents:

This can be divided into two parts based on the doctor's and the patient's perspective.

Doctor:

We met Dr. Ravinder Goud, Superintendent, Professor, and Attending Surgeon who gave us information regarding the exact process and complications in cataract surgery. He has more than 20 years of experience and has done hundreds of surgeries. He mainly gave us the information regarding the primary understanding of our problem. Also, we got to know the problems or errors caused during the surgery. By seeing the surgery room we got to know about the technologies used during surgery.

Patient:

Sampling methods

A patient survey was done using the sampling method. The sampling done was probabilistic which focuses on Quantitative research. The total population of the Sarojini Devi eye hospital is 550 The **sample size** was 20 (a survey of 20 cataract patients was done). The **population** was a

part of The Sarojini Devi eye hospital. The **elements** chosen were age, gender, income, type of surgery conducted based on the complexity of cataract, medical history.
Sampling units were divided based on the level of cataract and type of surgery conducted to cover a wide range in the **sampling frame**. **Probabilistic sampling** is done to avoid biasing and to ensure that each individual has equal probability. As the **subset** is chosen as a part of the government hospital it can be treated as a representative sample of other government hospitals in the country.

3.3 Methods of Data Collection

Methods employed by us to collect data are:
Primary Data Collection:

(a) **Interview:** To know the exact process and complications of cataract surgery, one of our group members visited the 'Sarojini Devi Eye Hospital', Hyderabad. We interviewed Dr. Ravinder Goud, Superintendent, Professor, and Attending Surgeon. He gave us insight into cataract treatment which helped us to understand our problem with deeper clarity.
(b) **Surveys:** We conducted a direct survey with patients who had undergone cataract treatment. The patients were selected using probabilistic sampling and a survey of 20 cataract patients was conducted. The survey was based on their satisfaction from cataract treatment, previous health issues, post-surgery complications, etc. A survey form in Telugu was distributed among patients in the hospital. Along with this we also interacted directly with patients in order to understand various issues in cataract surgery and learn about their experiences during the treatment.
(c) **Focus Group**: We gathered opinions about our research topic from various students, doctors, and professors in the hospital. Through this discussion, we were able to identify common patterns among cataract patients. We discussed our proposed engineering solution with professors & doctors and made changes in our engineering solution as per the feedback.
(d) **Observation**: We observed cataract surgeries in the hospital so that we can determine the dynamics of cataract surgery. We studied different aspects of cataract surgery to make certain conclusions and to design our solution.

Secondary Data collection: For statistical data, we referred to the National Blindness & Visual Impairment Survey India 2015-19 conducted by AIIMS Delhi, Reports of Ministry of Health & Family Welfare (Government of India), and other assessments by the World Health Organisation because this gave us a more versatile view of the situation.
These will help us in generating data for statistical inferences and designing LINCS.

Analysis of Collected Data: It involves the interpretation of data collected through the use of analytical and logical reasoning to determine patterns along with breaking down of complex data

structures into smaller understandable components to derive meanings from data.The two major forms of analysis are:

(a) Quantitative: The data collected from our surveys and various other reports are in tabular form which we will give a pictorial representation through histograms, bar graphs, and pie charts. This will help us in providing appropriate input to our system which will enhance its performance. For visualization, we are using histograms and pie charts which along with our predicted result will be used to describe the pattern and variability in the data to improve our output and arrive at a conclusion.

(b) Qualitative: Qualitative analysis refers to the analysis of non-numerical data which we collected from the interview, surveys, observation, and focus groups. From the data, we concluded that guided lasers can help us to fix corneal irregularities like astigmatism. From the conversation with the doctor, we got to know about the error doctors generally make regarding the input intensity of ultrasound. As a consequence, this helped us in formulating the idea of imaging software and thus making required enhancements in the LINCS system.

Analysis of collected data helped us in the identification of the role of variables, relationships, and their impacts. It also helped us in building a better understanding to devise our system and further pipeline the additional features to our model.

4.Findings

The main aim is to collect the data that gives us insights to find the engineering problem and propose the solution. The first step was to select the field which can provide information in all aspects. We chose Sarojini Devi eye hospital, Hyderabad.

4.1 Doctor Interview

Dr. Ravinder Goud, Superintendent, Professor, and Attending Surgeon gave us information that helped us to understand our problem with deeper clarity. The major discussions with him have been formulated.

*(*NOTE: All the below-given information is only in context with the visit to Sarojini Devi Hospital. It may vary from state to state and person to person.)*

1. Are there any classifications in cataracts?

   Ans: Initially the Grade is given to the patient based on the complexity of the cataract (Which is known through the protein thickness), the grade is from 1 to 5 with increasing complexity.

2. What are the treatment processes for the above mentioned classifications?

   Ans: For simple cataract like grade 1-3, SICS (Small incision cataract surgery) intraocular lens implantation is done. Whereas for Grades like 4,5 Phacoemulcificaton is done.

   SICS (Small incision cataract surgery) is done totally manually, an incision is made with a scalpel and protein is removed. Further the lens is placed.

   In Phacoemulsification, cataract is broken using Ultrasound energy. The fluid is extracted using a suction pipe.

3. What is the difference between above mentioned treatment processes in terms of end results?

   Ans: The precision in Phacoemulsification is more than normal SICS (Small incision cataract surgery) due to two reasons:

   a. SICS incision length is more than in phacoemulsification.
   b. SICS incision is done manually whereas Phacoemulsification incision is done with laser.

4. What is the cost of cataract surgery at this Hospital?

   Ans: In this hospital (Sarojini Devi Eye Hospital - A government Hospital) the complete treatment is done freely for the patients. It costs around 2500-5000 for the government for single eye treatment using SICS intraocular lens implantation and 10,000 for Phacoemulsification.

5. What tests are performed before surgery is done?

   Ans: Two types of scanning are done before surgery

   a. Scan A: IOL(Intraocular lens power) is calculated to select the lens.
   b. Scan B: Gives 2-D view of the eye with which we can know the positioning of the lens, choroid, retina etc.

6. What type of lenses are used for the Cataract Treatment?

   Ans: If we talk about the material used it is acrylic usually. If we talk about nature there are different types of lenses like monofocal, multifocal, toric etc. Usually monofocal and multifocal are used in India. There are some toric lenses which can correct astigmatism

and cylindrical correction but they are very costly. You have no chance of using them in hospitals like this (Government hospital).

Now if we speak about Phacoemulsification, we use a foldable lens as the incision is very small. We basically fold the lens and insert it and it opens and spreads. Whereas a normal lens is used in SICS as the incision is big enough to place it.

7. Is it currently possible to treat cataract without surgery in starting stages?

   Ans: Currently it's not possible, though at various research centres research is going on to remove early stage cataract with the help of eyedrops. If it is in starting stages we usually prescribe glasses and when the cataract becomes dense enough to remove surgery is done.

8. Can we cure astigmatism along with cataract surgery? How often do you cure astigmatism along with cataract surgery?

   Ans: Yes, if you know that the patient has astigmatism already we can give 2-3 small incisions on the cornea, it gets cured. We usually don't check whether the patient has astigmatism because we treat more patients in less time and don't want to increase the duration of patients' treatment. Astigmatism may arise after the surgery but we (doctors) recommend glasses for it.

9. What are the challenges faced during the cataract surgery and what type of cases require the surgery to be done again?

   Ans: Sometimes the lens placement may be wrong or it does not adjust to the eye then we have to remove it and place it again but this process is very difficult. Repeated incisions mean more errors. Especially in the case of Phacoemulsification the lens is placed folded through small incisions but if you want to replace it you need to make the incision large to remove the lens.

   Sometimes there may be a recurrence of a cataract called After cataract surgery in which the layer of protein is formed again, and the surgery is done again.

10. Is it possible that astigmatism is induced after cataract surgery?

    Ans: Yes, It may be due to incorrect placement of the lens, while using the lasers and ultrasound energy burns may happen near the incision which may cause astigmatism.

11. What are the postoperative complications?

    Ans: There are many postoperative complications like

    - Hyphema(internal bleeding)
    - Iris collapse

- Sunset sunrise syndrome or null position(caused due to lens misplacement)
- Infections

  These are usually caused due to the errors during the surgery. Patients with diabetes and hypertension may have retinal damage after the surgery.

From the interview, the below inferences were made

4.2 INFERENCES FROM INTERVIEW:

Our field investigation mainly concentrated on Surgical imperfections and their results. It helped us understand our engineering problem.

The main problems which are highlighted in the interview are

- Accuracy of incision
- Burns due to ultrasound energy
- Lens placement
- Incisions to cure astigmatism during surgery
- Retinal damage
- IOL power inaccuracy
- Wound leakages

These inferences were used to design our LINCS system.

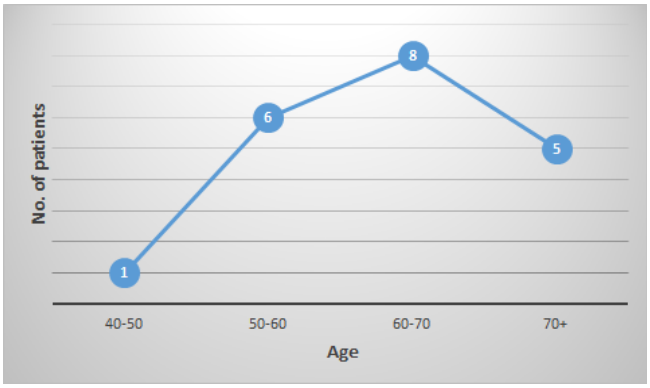
Patient survey

The below are the conclusions obtained from the survey conducted

S.No	Age	Stage	Type of cataract surgery	Lens used	Income	Medical history	Post Surgical Complications
1	62	1	TC*	L*	75	N*	N
2	70	5	PE*	M*	82	Diabetes	Burns
3	53	2	TC	L	62	N	N
4	62	2	TC	M	120	N	Wrong IOL
5	74	4	PE	M	450	N	Wound leakage
6	65	4	PE	L	100	Diabetes	N
7	49	1	TC	L	280	Obesity	N

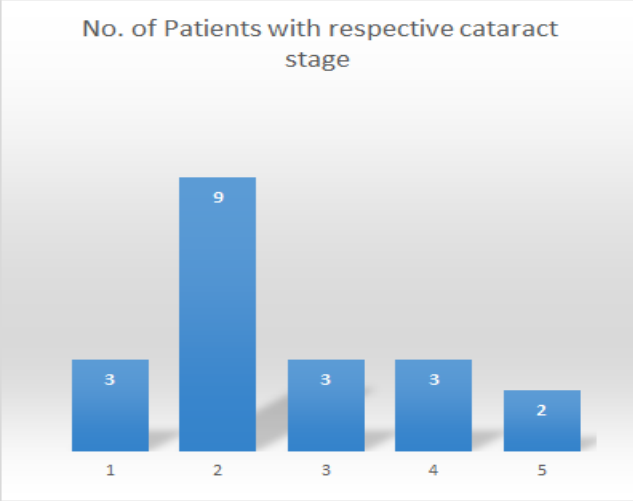
8	67	3	TC	M	175	N	N
9	57	2	TC	M	72	N	N
10	76	3	TC	M	62	N	High recovery time
11	66	2	TC	L	80	Diabetes, BP*, HP*	High recovery time
12	53	2	TC	L	90	N	N
13	56	2	TC	L	78	N	N
14	72	4	PE	M	100	N	N
15	48	1	TC	M	320	Diabetes	N
16	75	3	TC	L	98	Diabetes and obesity	Eye irritation
17	65	2	TC	L	150	Astigmatism	N
18	53	2	TC	M	180	N	N
19	42	5	PE	L	300	Obesity	N
20	58	2	TC	L	68	N	Astigmatism

Table 2: Different categories and data obtained in the survey (sample size = 20)
(* TC = Traditional cataract surgery, PE = Phacoemulsification, L = Normal lens, M = Multifocal lens, N = None, BP = Blood pressure, HP = Hypertension)

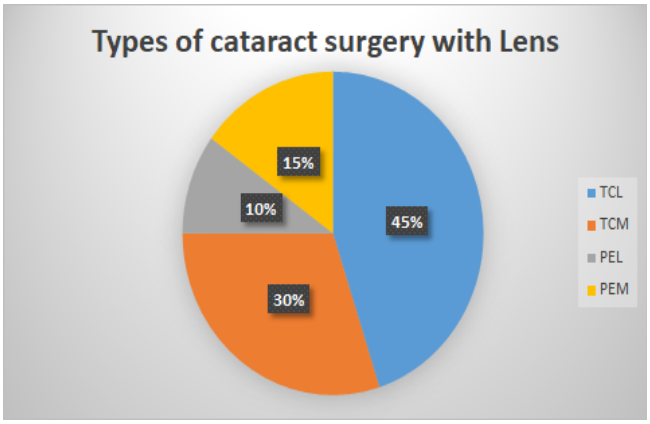


Graph no.1: No.of patients vs the age group

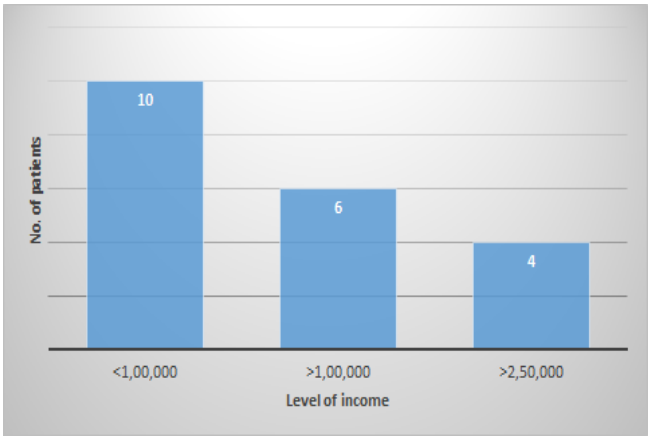
From the graph, we can understand that cataract is mostly age-dependent. It is mostly caused by people aged above 50 yrs.



Graph no.2: Patients division according to the stages. In the interview, one of the things known is the division of cataract stages according to their level of protein formed. From the graph, it can be observed that most of the cases are less severe and are treated easily using traditional cataract surgery



Graph no.3: Different cataract surgeries. It is observed that most people get traditional cataract surgery although it has flaws when compared to Phacoemulsification. Also, a normal lens is placed although there is a possibility of placing a multifocal lens which helps to avoid usage of glasses after surgery.



Graph no.4: Income status of patients. It is observed that most of the people belong to the <1L PA category. This can be understood from graph no.1 as most of the people are above 50 years of age which means either they depend on their pensions or allowances from their children. Another approach can be that people getting operated in government hospitals are from poor backgrounds and have less income.

5.Discussion

The following points describe the strategy employed by our group to integrate different aspects of this project and to solve the problem referred in here with its various social-economic aspects with maximum efficiency. Here we are employing the data to identify the engineering problem and suggest the design for the system.

5.1 Socio-economic aspects observed in the survey:

Social aspects:

The social aspect which plays a major role is illiteracy. Most of the patients who are getting treated are from rural areas and are not educated properly. Even during the survey people were unable to read our survey sheet and hence we obtained the information through verbal means. The problems caused due to this are people don't know the severity of cataracts and leave it untreated, which in turn causes blindness. Another aspect of this was discussed in the interview, which is that most people avoid surgery for the second eye even if they have cataracts for both eyes.

Even after surgery recovery will be slow if proper food is not taken. Also, people cannot travel alone to and from the hospital. A lot of people refrain from getting surgery done even if it is available free of cost, with the main reasons being lack of awareness about the free of cost surgeries in government hospitals, economic constraints, myths among people towards surgery, etc.

Many medical decisions are jointly taken by household members, especially in developing countries like India. Therefore, it is very crucial to educate people on the importance of cataracts and it's the surgical cure.

Economic aspects:

This part can easily be understood from the survey. In graph no.1 we can observe that most of the people are above 50years of age and hence we can know they depend on their pensions or allowance from their children. This is even observed in graph no.4 as 10 out of 20 people’s income is less than 1 lakh. Also, all the slots during the complete year for the surgery are filled as most people cannot afford the surgeries in private hospitals.

By analyzing these constraints, it motivated us to develop and suggest clinical changes which can be more acceptable to the masses and make people feel more safe and secure. Besides that to increase the willingness of people to undergo surgery, we emphasized providing a bladeless architecture with a personalized setting so that the surgery is less painful, and the entire process becomes swifter and seamless.

Exploratory:

For exploratory data, we interacted with Dr. Ravinder Goud and some of his patients in our first visit to the hospital to understand the prevailing methodology employed and the problems and challenges faced in cataract surgery.

1) The conclusion we could draw was that several patients complain of double vision (which is due to cylindrical vision i.e. astigmatism), burns due to ultrasound energy, redness, wound leakages, inappropriate placement, and power of the lens, etc.

We solved this problem by introducing a navigation system that helps in making precise cuts and customize the intensity of ultrasound to avoid any postoperative complications.

The interaction also provided us insights into the income of people generally visiting the Sarojini Devi Hospital. The doctor mentioned that several people who get their surgery done for the first eye do not come if cataracts develop in the other eye, though the treatment is done free of cost.

Since most of the patients visiting hospitals are daily wage workers they are reluctant in leaving their daily wage and spending money on travel. Furthermore, money is spent on their postoperative stay as they can't leave for their homes right after the surgery. Such negligence on the part of patients leads to blindness.

The other aspect of exploration was the identification of various factors associated with cataract treatment like cost, age & gender of patients, the severity of the cataract in the eye, medical history of patients, etc to gain an understanding of the unexplored aspect of cataract surgery. Collecting all this information was the stepping stone for us to come up with the better LINCS functions that were to be formulated.

Descriptive:

In our project, through the LINCS system, we will achieve a bladeless architecture that could facilitate customizable laser incisions. The idea is to make the incision more predictable for the surgeon hence increasing the accuracy. The guided system would cater to reducing corneal irregularities like astigmatism. LINCS provides safer surgery solutions by making input ultrasound energy more predictable for doctors and thereby reducing burns.

In our project, our aim is to improve cataract treatment, so as to avoid post-operative problems and improve the accuracy of cataract surgery. Therefore, we proposed the LINCS (Laser Integrated Navigator for Cataract Surgery) which allows surgeons to continuously assess a patient's eye and helps them in calculating the exact position of incision, provides refractive information and helps surgeons finalize lens choice and placement during surgery.

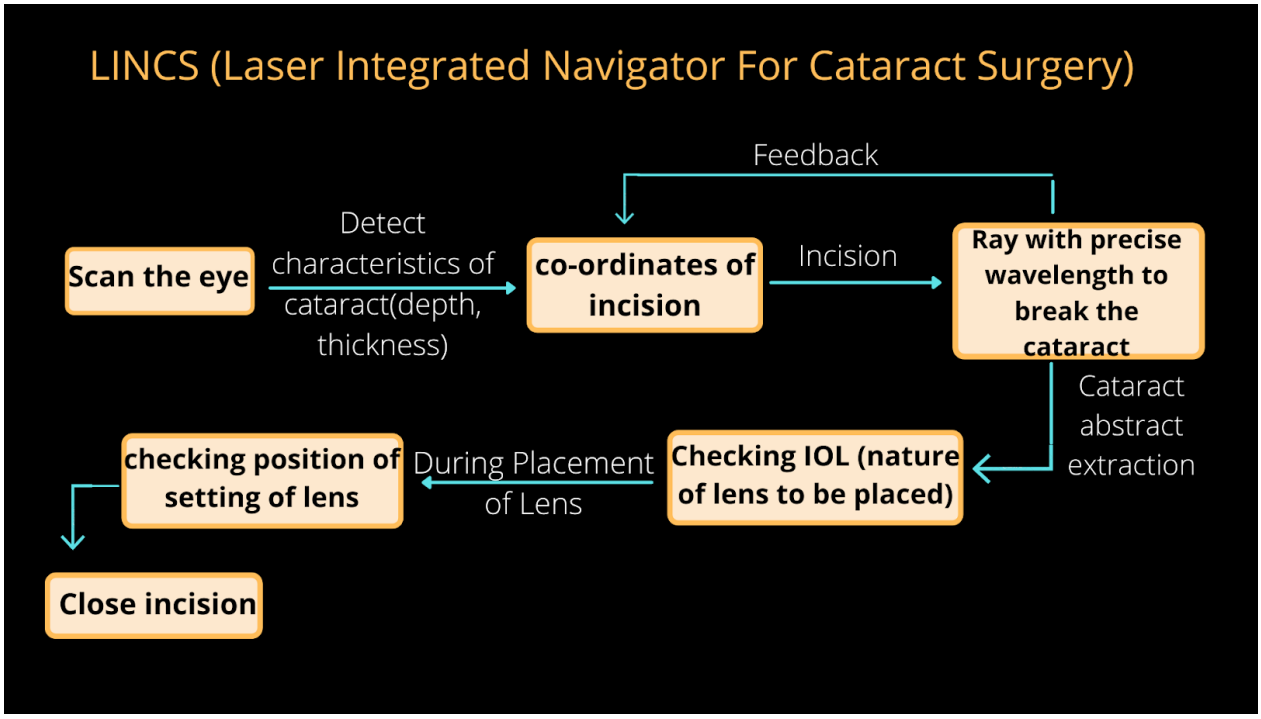


Fig 3: Schematic Flow of working of LINCS

5.2 How LINCS is useful:

1. LINCS provides continuous assessment of the patient's eye allowing for highly accurate refractive measurements. Working Principle behind this: Using a low powerful laser (different from a laser which is used for incision) guidance a narrow beam of light is directed into the patient's eye and is reflected off the retina. As the reflected light passes back it is processed by LINCS to calculate refractive values.
2. The LINCS system provides refractive information to help determine cylindrical power magnitude and access accounts for corneal astigmatism. Thus it will help doctors perform laser cuts keeping astigmatism in consideration so that if a patient has it from before it can be corrected after the surgery by making carefully placed laser incisions in the cornea to normalize its curvature.
3. Even if astigmatism still remains after the surgery it will help surgeons finalize lens choice and placement during surgery and reduce its risk of unexpected residual post-operative astigmatism.

5.3 How is LINCS innovative?

From the aspect of technology, our solution of LINCS is better than the conventional one because of the following advantages. It help us achieve following:-

1. Bladeless – Customizable laser incisionsas

2. Accuracy – Perfect cataract capsule openings to access the cataract
3. Astigmatism Reduction – Reshapes the surface of the eye
4. Predictable – Consistent, outstanding results
5. Safe – Enhanced safety profile especially for advanced and complex cataracts

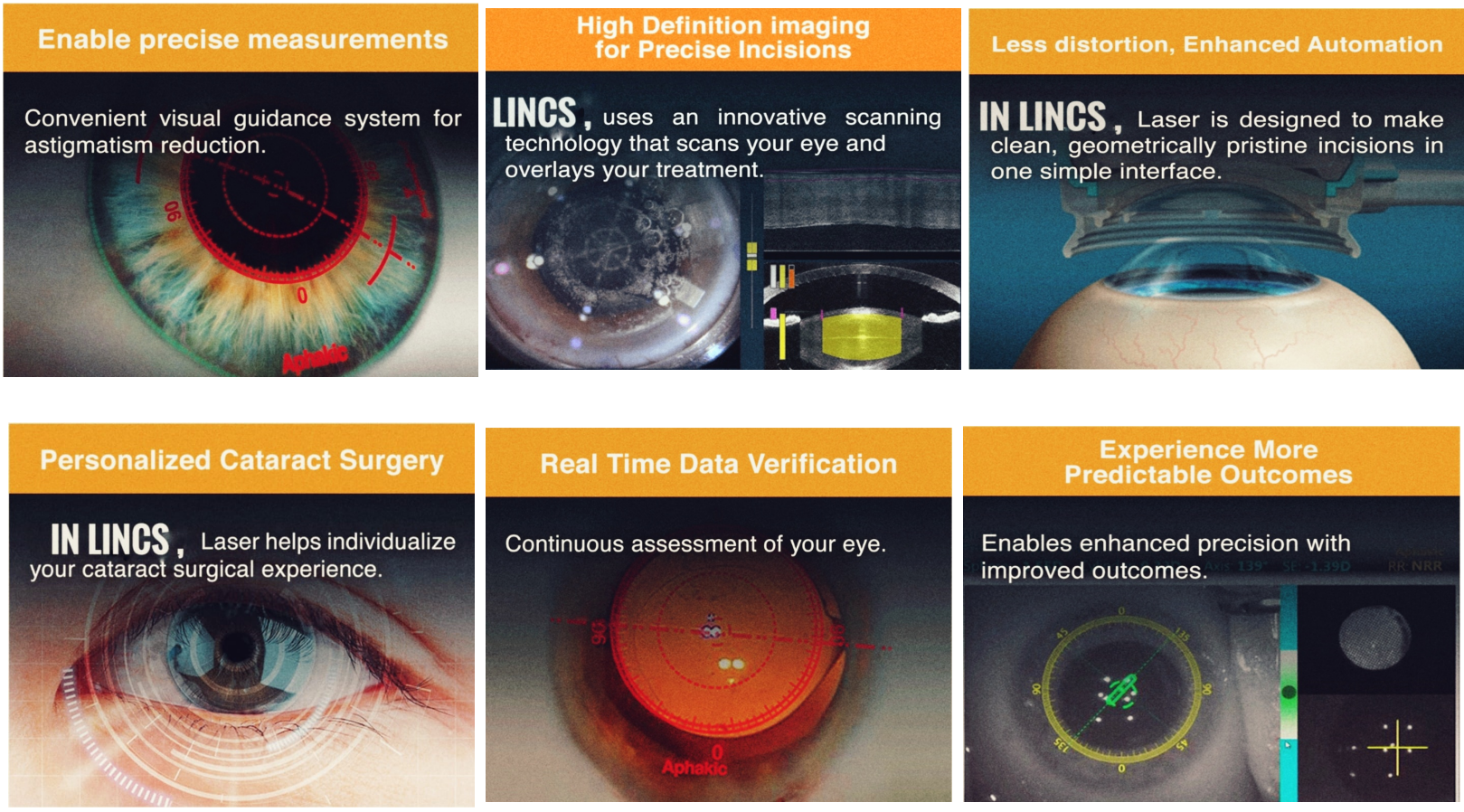


Fig 4: Advantages of LINCS

5.4 Tech Stack for LINCS:

1. Laser for incision.
2. Laser for phacoemulsification in case of less grade cataract while exact ultrasound energy input calculation in case of maturer cataract.
3. Live tracking system to assist doctors with surgical cuts to prevent postoperative astigmatism.
4. Guided beam of light to provide continuous monitoring of refractive power to the eye to avoid any problems related to shape.

With every field visit and subsequent use of data collection methods, we kept on exploring new aspects of the cataract treatment and getting one step closer to an engineering solution. With our inferences, theoretical understanding, and interaction with doctors & patients, we were able to conduct an in-depth analysis of the problem to arrive at an engineering solution.

Experimental:

The variables identified in our project can be categorized as :

Independent variables	**Dependent variables**
Age Socioeconomic status Medical history Grade of Cataract	Amount of Ultrasound & Laser energy Type & Power of IOL used Measures to cure other eye problems Cost of treatment Post-surgical complications

We started with categorizing different parameters as independent variables and dependent variables. This helped us to model them and then work on their optimizations.

Dependent variables are those variables whose output depends on some other variables.
For example: $z = x + y$. Here z value depends on x and y and thus z is a dependent variable.
Similarly, if x and y doesn't depend on any other variable and their value is completely arbitrary, then they are said to be Independent variables.

In our case,

- If someone has a high grade (maturer) cataract then we need high energy ultrasound to break the cataract.
- If someone is suffering from Astigmatism, then we have to make carefully placed laser incisions in the cornea to normalize its curvature.
- Medical history & Age of patient will also affect the type & power of IOL (Intraocular lens) implanted in the eye as part of cataract treatment.

In this process, we made sure that we are not double counting the variables. For example- $z = x + y$ and $y = x^2$. It might look that z is a dependent variable with two independent variables x and y. But actually y is a dependent variable and so, even though x and x^2 are different , just having one of them is sufficient. We avoided putting any variable which can be represented by any of the previously selected independent variables. By doing this we made sure that our model is not complex.

6. Conclusion

Problem

6.1 Abstract

India was the first country to launch the National Programme for Control of Blindness in 1976 to reduce blindness prevalence which was aimed at reducing blindness. Even with technical advancement in cataract, Cataract is still the leading cause of blindness in people above 50 years as concluded by the National Blindness and Visual Impairment Survey India 2015-19 conducted by AIIMS Delhi.Understanding the root cause of this problem along with researching on clinical aspects and proposing a solution was the main goal for our group. Our proposed idea aims at solving the most sensitive aspects of the surgery which otherwise cause a lot of problems.
(For eg Severe eye burns as a result of surgery).

6.2 Main engineering problem statement

Our interaction with Dr.Ravinder goud,patients including our own grandparents and other social and economic factors have led us to identify several problems in the current cataract surgery procedure done ,which has paved the way for us to define the engineering problem.
Exploring the possibility of employing guided laser instead of unguided one which can assist in surgeries in such a way that corneal irregularities can be treated appropriately.
Furthermore, exact prediction of the input Ultrasound energy by analysing cataract appropriately using computer vision or imaging software so that severe burns arising due to inappropriate input energy can be avoided.
Identifying the correct IOL lens to be placed depending on the needs and requirements of patients and ensuring its correct placement comprise of our engineering problem.

In **development engineering,** we intend to build a working prototype, which will include three of the **major aspects** of LINCS, which are:-
1) Firstly, a system that can accurately make real-time refractive measurements and assist lasers to perform surgical cuts more efficiently in order to remove preoperative astigmatism and simultaneously prevent postoperative astigmatism from arising.
2)Secondly, an architecture that can efficiently calculate the input ultrasound energy to be given in case of maturer cataracts and thereby preventing any serious burns.
3)Thirdly, suggesting the appropriate nature of IOL and ensuring its correct placement.

Design of the module

Though we have explained the main working principle above, here we try to answer some of the most challenging problems in designing LINCS.

Some of the problems and unexplained aspects associated with design are as follows, wherein we have tried to come up with some design improvements, which can help us get rid of them.

1)How exactly are we going to deal with providing real-time data to assist the surgeries?

Since the eye is very small and practically it is very difficult to map the eye into different axes, such that we can have accurate measurements to correct the corneal shape during the surgery, which in turn made us rethink, brainstorm again and redesign this aspect of our solution.
One thing which is always fixed is the center of the surgical portion of the eye(Which can be obtained after performing scans, which are done initially as mentioned in the flowchart)and though we may not able to define axes we can always define distances from this point(i.e the spherical coordinates). Since after each cut the refractive values of the eye will change, therefore to analyze the real-time refractive information LINCS will be capable to capture images at a frame rate of 100 images per second to predict these distances and position it's lasers accordingly to help perform laser cuts more efficiently.

2) Limitation of earlier said method of removing cataract with Ultrasound
In earlier reports and even in this report ,we have mentioned that in case of lesser grade cataracts laser power would be sufficient enough to break the cataract proteins and in case of maturer grades input energy calculated by LINCS will be used . But we identified a limitation of this proposal which is:- Initially we went along with the current strategy being used in the process ,that prior to the surgery by categorizing the cataract according to thickness and hardness of proteins, the grade is predicted and surgery is performed accordingly.However for example: in case of lesser grades the laser may not be able to break down the proteins completely or sometimes it may not be able to categorise those cataracts which are at the intersection of higher and lower grade which made us to ponder on this problem.

In the end ,we concluded that it is better if LINCS helps us out in this by following the below mentioned steps.

Let Eu **= be the amount of ultrasound energy to be given to break the proteins completely and** El **= be the safe limit of laser energy which can be given.**
1)LINCS calculates the amount of ultrasound energy to be given to break the proteins completely i.e Eu.
2) Now if $Eu <= El$ **then we can proceed with the surgery without use of ultrasound energy.**
3)Otherwise, if $Eu > El$ **then we provide optimum energy and break the proteins.**

In this way, rather than giving importance to grade, we give importance to input energy required to break it and thereby remove protein formation without minimal residual.

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8. Annexure

8.1 Research Questions

1. How long will it take for the Cataract surgery to be completed using our proposed LINCS system as compared to an average of 15 to 30 minutes in the current procedure?
2. How much time would it take for the technology to be acceptable by people and what are the best ways to create awareness?
3. How beneficial would it be for hospitals in terms of finances to accommodate the new technology LINCS into their system?

We put up a lot of questions to the doctor and the patients which helped us in getting deeper insights into the clinical principles involved as well as in designing LINCS.

8.2 Survey Questions:

1. What is your age?
2. What is your diagnosed Cataract Stage?
3. Which type of cataract surgery did you undergo?
4. Do you know the type of lens they placed in your eye?
5. What is your yearly income?
6. What is your medical history?
7. Did you face any postoperative complications?
8. How many times did you visit the hospital before surgery?

9. How much did you spend on cataract surgery? (This part was meant to be overall like travel charges etc.)
10. Who among the family members came with you to the hospital?
11. What was the overall experience of the surgery?