REGION MAP GENERATION OF EYE PUPIL MOVEMENTS TO PRESCRIBE CUSTOMISED PROGRESSIVE LENS

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Abstract—**Losing the normal vision is the common problem facing by human beings in this present world. These problems occur when the image is not properly focused on retina. These problems are usually corrected by using spectacles or contact lens. To test the eye sight of the patient in the present system, we have manual testing and computerized or Tablet based eye testing. By using any of these techniques eye sight of the patient is determined. In these type of traditional methods users are just choosing the spectacles that is of stylish and suits them, even if wearing of such spectacles is of no use to them. So once as it is found that whether the patient is having the eye sight or not, even if there is no eye sight and patient is interested to wear the spectacles to protect his eyes while reading or watching the screen then there should be an approach using which we can suggest the person with customized progressive lens by monitoring their observations whether a person is moving his head or just eye to see object or screen.**

This project is done by Digital Image processing and Computer Vision based techniques and algorithms in a practical approach. The main objective of this project is to design algorithm for eye and head movement tracking device. Firstly that device is made learnt about what does eye looks like and where it is located on face by using some eye and head movement tracking algorithms. Then patient is made to sit comfortably in the chair in front of that device, such that the patient's eyes are visible from the camera and sensors view and he is made to wear some trial frame which emits radiation from LED's and then patient is allowed to observe the LED light that are mounted on the screen and they are designed to glow in some specific pattern. The motion of the patient's eye and head while observing the LED pattern is continuously monitored by camera and sensors that are present on the device and information is stored and processed. Based on this information Eye Movements Region map is generated. Once the eye and head movements region map is generated they are combined to form a generalized region map. This map is then used to suggest the patient with the customized progressive lens.

Keywords— **Vision, Eye Tracking , Head Tracking, Lens Design, Vision comfort, Eye Pupil Movements, Head Movements, Cascade Classifiers, Detect Eye, Detect Head , Motion Estimation, Customized Progressive Lens , Motion Detection.**

I. INTRODUCTION

There are many conventional methods for designing Spectacles lens in which they develop theoretical Target values by obtaining Subjective Patient feedback using objective testing methods to design lens.

Drawback back of Conventional methods for designing spectacle lenses are:

- They do not correlate patient feedback and objective testing to precise locations on lens.
- Do not account the parameters such as : Optimal visual comfort, Clarity of vision, Ease of changing focus, distant, intermediate, near channel width, Amount of head and eye movements required , by the lens wearer.

Additionally, it is known that certain parameters control optimal visual comfort for the lens wearer. These parameters include, without limitation, clarity of vision, comfort over sustained periods of use, ease of changing focus, and the amount of head and eye movement required by the lens wearer. Conventional design methods do not account for these parameters with any precision and provide little to no guidance for design optimization processes requiring definition of merit functions incorporating one or more of these parameters. Therefore, a method for designing lenses that overcomes this disadvantages is needed.

A. Overview

In order to provide visual comfort to the lens wearer by considering the amount of head and eye movements made by lens wearer is considered by conducting a simple experiment using the Eye and Head Tracking device. Then patient is made to sit comfortably in the chair in front of that device, such that the patient's eyes are visible from the camera and sensors view and he is made to wear some trial frame which emits radiation from LED's and then patient is allowed to observe the LED light that are mounted on the screen and they are designed to glow in some specific pattern. The motion of the patient's eye and head while observing the LED pattern is continuously monitored by camera and sensors that are present on the device

and information is stored and processed. Based on this information Eye Movements Region map is generated. Once the eye and head movements' region map is generated they are combined to form a generalized region map. This map is then used to suggest the patient with the customized progressive lens.

B. Motivation

The motivation behind this project is to develop an application that can be used for vision analysis to suggest patient with customized progressive lens in order to provide vision comfort to the lens wearer.

C. Problem statement

Track the eye movements of a person while observing the glowing LED patterns and generate the eye movement's region map based on the tracked movements and then suggest the Customized progressive lens based on the shape of the eye movements region map that has been generated.

D. Objective

The main objective of this project is to recommend customized progressive lens which are useful to the user while choosing lens and minimize user's effort to choose the suitable glasses and provide the visual comfort to lens wearer.

E. Modules

This project is divided into two modules .
1. Eye movements Tracking and Generation of Eye Movements Region Map.
2. Head movements Tracking and Generation of Head Movement Region Map

F. Required Specifications

Hardware Requirements are:
- LED's
- Camera
- Sensor
- Processing unit(PC)

Software Requirement are:
- Operating System : Linux
- Simulation Tools : OpenCV
- Coding Language : CPP
- IDE : Qt Creator

II. PROPOSED SYSTEM DESIGN

A. Introduction

The objective of a eye and head tracking system is to track the focus of the user's vision. So it is necessary to be able to track the eye and Head in an image. For this objective more information on the relevant biology and behavior of the eye is required. To this end, this chapter will present some background knowledge required for the creation of a eye and head tracking system and will describe some techniques used within the proposed system.

1) Description of the Eye and Head Tracking Device

Array of LED's arranged in the semi circle pattern shown in the diagram below. Same pattern on the upper screen and also with that it completes the circle. Two sensors arranged both sides of the upper screen, they sense the motion of the head trail frame which has four led's. Head and eyes movement is tracked by observing the light glowing along the LED's line.
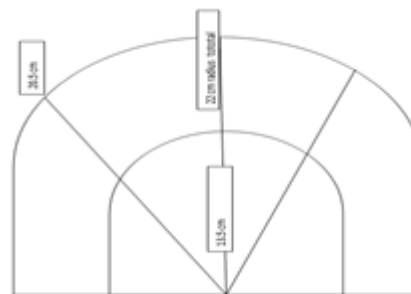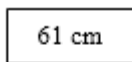

fig: 1 Screen Design Pattern

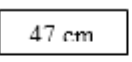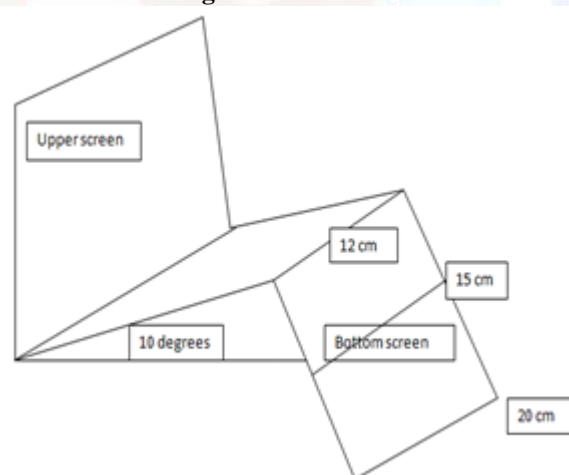**fig: 2 Upper Screen**

fig:3 Lower Screen

fig: 4 Bottom Screen

First we start finding the center of the upper screen and fix the person position normal center position is 510 mm distance. Camera snapshot is taken to fix the eye balls position. And can interactively fix the center of eye ball. These coordinates and the trail frame LED's position is noted down and saved. As the LED's pattern is glowing person may move only the eyes to see the light on the screen or person can move head to see the light on screen. If the person moves the head only then it can

be detected by the movement of led's on the trial frame and store the coordinates. If the eyes are only moving with the light movement that time head not moved then eyes are following the light, then we required to suggest more wider glasses along the eyes movement. This can be plotted as a pattern of eye and head movement.

At first stage of this project is to generate this pattern accordingly next stage we can convert the pattern into suitable customized glass prescription.

III. EXPERIMENTAL RESULTS

A. *Design of Eye and Head movements Tracking Device or System*

We have prepared the model of the Eye and head movement tracking device by making use of charts and made a set up. We have fixed the pattern in which the Led lights should glow by giving the numbering such that there is minimum possible repetition of same led glowing. We made a person to sit comfortably on chair in front of this setup at a distance of 50mm and made a person to watch the screen while the Laser Light is being passed through the screen holes in a specified fixed pattern. Then we have captured the different videos and images of person while watching the set up screen to find that whether the person is moving his head to follow the light pattern or just moving his eyes to follow the pattern.
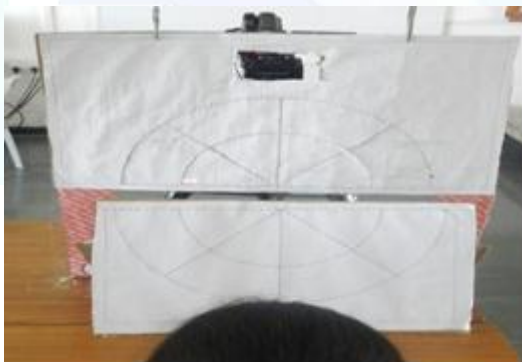

fig: 5 Sample Model of Eye and Head Movement Tracking Device

B. *Proposed Algorithm Steps*

The Steps that are followed to achieve the required result are:

1. Make The Patient to sit in front of Eye and Head Movement Device and make patient to watch at the center of screen.
2. Start the Device which will glow the LED lights in fixed specified pattern, Store the coordinates of LED and the time at which it glows in Excel File known as Static Excel File.
3. Start capturing the videos when the patient is watching the screen during the experiment.
4. Give Captured video as an input and click on the eye pupil to fix it as a reference point to find the eye pupil movements in next frames with respect to this reference point.
5. Similarly click on the center of the face that is nose to detect head movements made in sequence of frames.
6. Compute the Distance between two points that the reference point in first frame and current point in second frame to find the number of pixels that eye pupil has moved with respect to reference point. Then for next iteration reference point is the current point in second frame compared with the point in third frame and so on the process is repeated to find the number of pixels the eye pupil has moved in current frame with respect to previous frame.
7. Store the Movement made in terms of pixels separately for eye movements and Head movements in two different files.
8. Generate the Dynamic Excel Sheet that contain frame number, motion ,X and y points, movements made in pixels i,e Distance, Angle, Direction, time and frequency count.
9. Consider the frame number where there is motion from Dynamic Excel sheet generated above.
10. Select the record from Dynamic Excel file which has entry as 1 in motion field. From that record get the coordinate by choosing the X and Y fields of that record.

11. Plot that X and Y pupil coordinates, for both eye and head movements separately.
12. Draw an Enclosure including all points in it. This map is referred as Eye Movement Region Map or Head Movements Region Map respectively.
13. Based on the shape of this map Suggest the patient with Customized progressive lens to provide visual comfort.

C. Fixing LED Position and Direction of Glowing pattern

LED screen design is drawn on the Graph sheet and we have fixed the pattern in which the LED should glow based on minimum repetition of the line segments. once we have assign the numbering to each of the line segment present in the screen design we have fixed the positions of the LED's on this graph sheet such that there is a distance of 2mm between one LED to another. Then for each of the LED coordinate or position is noted in an Excel file and the count of total number of LED's is found.
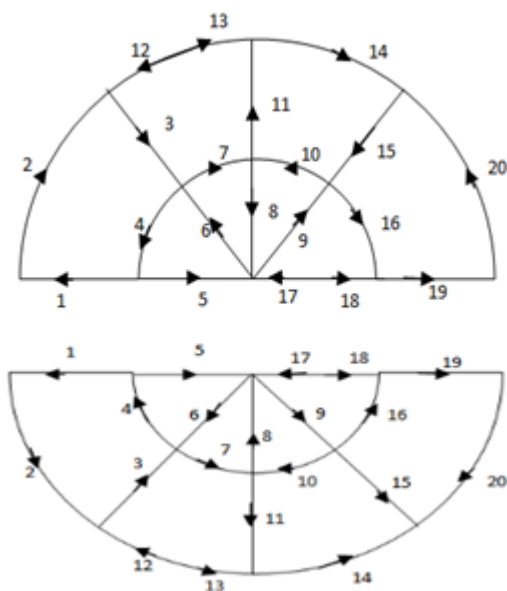

fig: 6 (a) showing LED glowing Pattern

fig: 6 (b) showing LED position and its glowing pattern in Graph sheet

D. Time Calculation

In order to Calculate the time or duration for which one LED glows and the total time taken to glow all the LED's on the screen in the fixed pattern is computed as:

Total Number of LED's including both the screens are 1486.

 Number of Frames per second = 24
 Assuming that 1 Led will glow per Frame.
 So for 24 LED's to glow it takes 1 second.
[24 LED's   ------------------> 1 sec
    1486 LED's ------------------> ?
   (1486*1)/24 = 61.92 sec
  ]

Therefore to glow 1486 LED's total time taken is 61.92 sec. i.e 1min3msec
[60sec-----------> 1min
    61.92sec--------> ?
    61.92/60=1.032 (1minute 3milli seconds)
  ]
 Duration for which 1 LED glow is: 0.0416sec
[24 LED's----□ 1sec
    1LED-----□?
   (1/24)= 0.04166sec   // i.e 41.66 msec
]

Therefore Total time to glow 1486 LED's in seconds is: 61.92sec

And Total time to glow 1486LED's in milli seconds is : 61920msec

E. Storing LED Coordinates and Time into a Excel File   (Static Excel File)

Based on the above calculation we store the following fields:

- Screen either upper or lower
- Flow which refer to the number assigned to line segment
- Position of LED and
- LED Glowing Time

SCREEN	FLOW	X	Y	TIME(msec)
UPPER	1	-274	0	41.66
UPPER	1	-276	0	83.32
UPPER	1	-279	0	124.98
UPPER	1	-282	0	166.64
UPPER	1	-285	0	208.3
UPPER	1	-288	0	249.96
UPPER	1	-276	0	291.62
UPPER	1	-279	0	333.28
UPPER	1	-282	0	374.94
UPPER	1	-285	0	416.6
UPPER	1	-288	0	458.26
UPPER	1	-276	0	499.92
UPPER	1	-279	0	541.58
UPPER	1	-282	0	583.24
UPPER	1	-282	0	624.9
UPPER	1	-288	0	666.56
UPPER	1	-276	0	708.22
UPPER	1	-279	0	749.88
UPPER	1	-282	0	791.54
UPPER	1	-285	0	833.2
UPPER	1	-288	0	874.86
UPPER	1	-276	0	916.52
UPPER	1	-279	0	958.18

fig: 7 Screen shot of storing LED coordinates and Time at which it glows referred as Static Excel File

This File is referred as Static Excel File since this data remains same for all patients because the Duration and the Pattern in which LED should Glow is fixed during the Design of the Eye and Head Movements Tracking device. This file is Later used to retrieve the LED coordinate.

F. Capturing the Video

We made different persons to sit comfortably on chair in front of this setup (i.e Eye and Head Tracking Device) at a distance of 50mm and made a person to watch the screen while the Laser Light is being passed through the screen holes in a specified fixed pattern. Then we have captured the different videos and images of person while watching the set up screen to find that whether the person is moving his head to follow the light pattern or just moving his eyes to follow the pattern. This videos we have used as input which needs to processed to meet our objective.

fig : 8 Videos Captured During Experiment

G. Eye Pupil Movement Tracking In Live Video

In order to detect pupil first we need to locate the face in caputred frame then locate the possible position of the eye window in the detected face, to do this we use Haarcascade_frontalface classifier and Haarcascade_eye classifier. Once as we obtain the region of interest i.e eyes position the we use houghcircle method to detect the circle of specified radius in eye window region and detected circles are displayed.
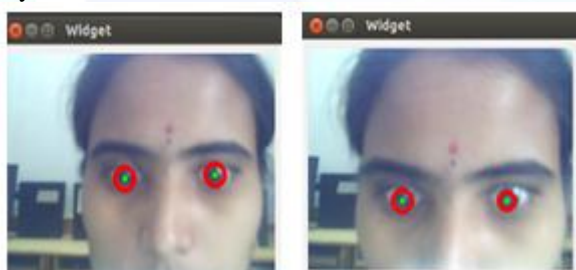

fig: 9 Pupil Tracking Live Video

H. Pupil Detection and pupil movement Trace graph generation

In order to detect pupil first we need to locate the face in caputred frame then locate the possible position of the eye window in the detected face, to do this we use Haarcascade_frontalface classifier and Haarcascade_eye classifier. Once as we obtain the region of interest i.e eyes

position the we use houghcircle method to detect the circle of specified radius in eye window region and detected circles are and generate the trace graph of both left and right eye movements made thereafter.
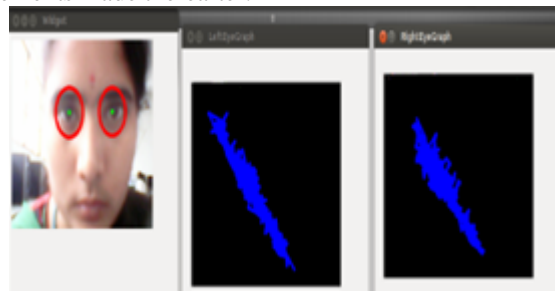

fig: 10 Eye movements Trace Graph generation

In order to generate the graph we have taken a structure which use two points at a time i.e first point in first frame and second point from second frame if there is a movement then draw a line segment using cvLine() function and the processes is continued till the program is exited and if there is no eye movements then no line will be drawn. This is done for both the left and right eye and graph is as shown in the above figure.

I. Head Detection and head movement Trace graph generation

In the given input video detect the Face or Head using Haarcascade_frontalface classifier and indicate the detected face with a rectangle bounding box.

fig: 11 Head movements Trace Graph generation

In order to generate the trace graph of Head Movements we have taken a structure which use two points at a time i.e first point in first frame and second point from second frame if there is a movement then draw a line segment using cvLine() function and the processes is continued till the program is exited and if there is no Head movements then no line will be drawn

J. Eye Pupil Motion Detection In sequence of Frames

The Videos that we have captured when the experiment is being conducted is given as input to detect eye pupil motion. The procedure used detect the motion in sequence of frames is as described below:

Give video captured during the experiment as input and as soon as the first frame of the video get displayed on the screen then to fix reference point as the eye pupil then we want to detect motion in sequence of frames with respect to this reference point Then in next frames if the eye pupil is moved the that motion is detected., Then To find is there any motion or not we find the distance between two points that is reference

point in first frame and current pupil point in second frame. This distance is in terms of pixels that is the eye pupil has moved, how many pixel compared to first frame reference point. Then for next iteration current cursor point in second frame becomes the reference point and the point in third frame becomes the current point and this process continues till last frame of the video.

Similarly above procedure is also repeated to detect head movement by by fixing the center of head that is on nose as reference point. Then after detecting the motion we store the results in Excel sheet which is named as Dynamic Excel sheet(which will be different for different videos or users)..

fig: 12 Eye Pupil movements detection in video

K. Generation Dynamic Excel sheet

Dynamic Excel sheet contains the following fields in excel sheet:

Frame number: Display the frame number on which the processing is done at particular Time.

Motion: This field contain the two values either 0 or 1 that is if this field contains 0 then it means that there is no motion is detected in current frame and if this field contains 1 then it means that the motion is detected in current frame number.

X and Y: This field contains the coordinates of the point in frame with respect to which motion is found.

Movement in pixels: this field contains some numeric value which represents the movement made by reference point in terms of pixels.(that is the distance moved by reference point of first frame in next frame).

Angle : This field display the angle moved by the eye pupil or reference point.

$$((angle>=-23)\&\&(angle<23)) \quad direction=1;$$
$$((angle>=23)\&\&(angle<68)) \quad direction=2;$$
$$((angle>=68)\&\&(angle<113)) \quad direction=3;$$
$$((angle>=113)\&\&(angle<158)) \quad direction=4;$$
$$((angle>=158)\&\&(angle<=180))||(angle<-157))$$
$$direction=5;$$
$$((angle>=-157)\&\&(angle<-112)) \quad direction=6;$$
$$((angle>=-112)\&\&(angle<-67)) \quad direction=7;$$
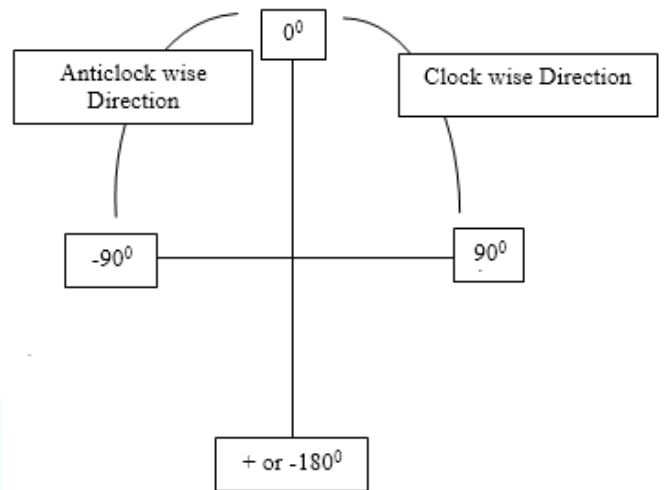$$((angle>=-67)\&\&(angle<-22)) \quad direction=8;$$

fig: 13 (a) Angle Representation used to Fix the Direction

Direction : This field represents some numeric value between 1 to 8 which represents the direction of motion.There are 8 possible directions that is Upper, Lower, Right, Left, UpperLeft, UpperRight, LowerLeft and LowerRight.we fix for what range of angle what direction should be given.
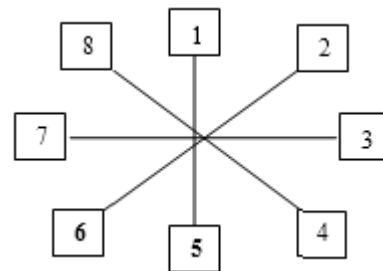

fig: 13 (b) Direction specification

Frequency Count: This represents the count of number of frames in which the movement has not been detected till current frame.


frameid	moved	x	y	distance	angle	direction	frequency	elapsed time in msec
1	0	0	0	0	0			
2	1	1024	523	30	-33	8	0	165
3	1	1061	524	37	-2	1	0	66
4	1	1074	539	20	-49	8	0	96
5	1	1045	548	30	-163	5	0	98
6	1	1056	556	14	-36	8	0	101
7	1	1046	566	14	-135	6	0	99
8	1	1041	591	25	-101	7	0	100
9	1	1026	595	16	-165	5	0	137
10	1	1038	599	13	-18	1	0	70
11	1	1046	580	21	67	2	0	95
12	1	1070	546	42	55	2	0	100
13	1	1053	539	18	158	5	0	99
14	1	1084	540	31	-2	1	0	101
15	1	1090	546	8	-45	8	0	119
16	1	1075	576	34	-117	6	0	80
17	1	1061	608	35	-114	6	0	100
18	1	1077	617	18	-29	8	0	102
19	1	1052	634	30	-146	6	0	101
20	1	1059	648	16	-63	8	0	97
21	1	1058	657	9	-96	7	0	130
22	1	1061	670	13	-77	7	0	73
23	1	1045	639	35	117	4	0	98
24	1	1052	585	54	83	3	0	128

fig: 13 (c) Dynamic Excel Sheet

L. Plotting of Eye Movement Region Map

In order to plot the Eye pupil Movement Region Map steps are:

- From the Dynamic Excel Sheet Take the choose the records in which motion field is 1.
- From the selected record choose the movement Coordinates that is X and Y fields and plot it.
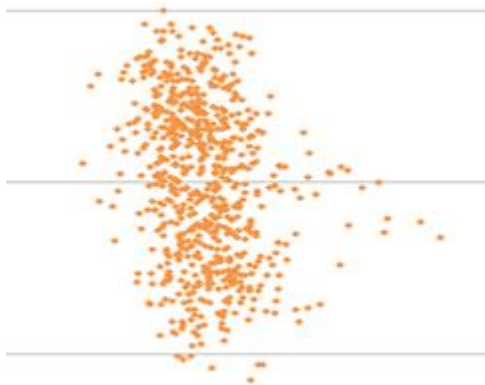
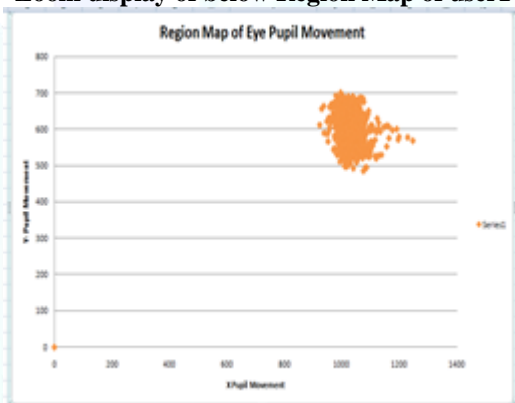**Zoom display of below Region Map of user1**

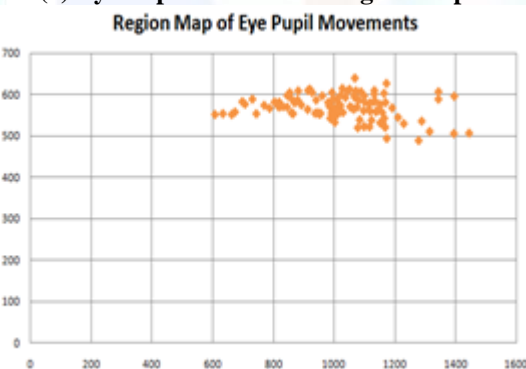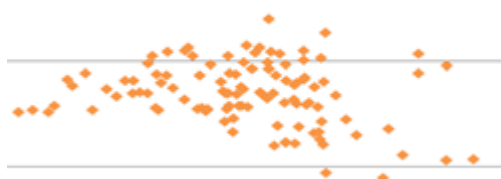**fig: 14 (a) Eye Pupil Movements Region Map of user 1**

fig: 14 (b) Eye Pupil Movements Region Map of user 2

Zoom display of Above Region Map of user2

M. Enclosing the Plot with Curves

Draw a enclosure curve such that all points are inside the curve combine the Eye Movement region Map and Head movement Region Map to get one single generalized map referred as Eye and Head movement Region Map. Based on the shape of this Eye and Head Movement Region Map suggest the shape of the lens that a patient has to wear to get comfort vision.

IV. CONCLUSION

The main objective of this project is to generate the Eye Movement Region Map based on the eye movements made the person while observing the glowing LED pattern. This map information is then used to suggest the person with the customized progressive lens and provide vision comfort to the lens wearer.

V. FUTURE WORK

This Experimental idea or proposed system can be implemented in the design of real time Eye and Head Movement Tracking Device which can be used in the Eye sight testing centers to prescribe the patient with the appropriate shape of the lens which best fits the patient according to his or her eye and head movements made to look at particular object.

VI. ACKNOWLEDGEMENT

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