Drishtikon: An Open-Source Eye–Heart Platform for Low-Cost Research

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Abstract

The Medical and biomedical education sectors of a third world country such as Bangladesh actively lacks the financial and technical prowess to afford animatronics which emulate human anatomy. However, they are relatively complex as well as unaffordable for the common folk of places such as Bangladesh. This disadvantage creates a concerning gap in practical knowledge and training which affects the student's creativity and comprehension ability. To overcome this disadvantage, we came up with Drishtikon, a simple and low-cost framework that uses a 3D-Printed Robotic Eye as well as a Mechanical Heart which is easy to replicate and has the potential to effectively solve the lack of affordable simulation system for Research essential for students of Medical and Biomedical fields. Drishtikon's ocular system mainly has two modes one being autonomous and the other an eye tracking system. The eye is also connected to a 3D mechanical heart which can adjust its rhythm to mimic the heart rate for various medical conditions and states thus creating the perfect platform for visualizing human physiology. The paper goes in depth about the system design, explains the relevant eye-tracking and cardiac literature in brief, makes direct comparison between our animatronic organs and real anatomical ones and lays down the groundwork for the planned evaluation methods. Our pursuit prioritizes availability and affordability which will empower students in Bangladesh to further build upon our initiative, which will boost practical anatomical knowledge and inspire visualization of biologically accurate simulation mechanisms.

Key-Words: - *Bio-medical simulation, robotic eye, Eye-tracking, mechanical heart, Cardiac rhythms*

1. Introduction

Understanding how our eyes and heart react to various stimuli and diseases is absolutely pivotal in gaining visual mastery over the field of cognition, emotion and disease. Real time eye movements reveal how attention shifts and when cognitive procedures begin [4], while the heart rhythm monitor mainly reflects autonomic responses and can indicate arrhythmias or cardiomyopathy [13]. Although, abroad there many simulation platforms/ methods which mimic human physiology thus helping to support several research studies as well as education through simulating, controlled environments effectively negativing the reliance on human subjects. However, these kinds of high-end eye trackers and physiological animatronic organs are very expensive and hard to obtain, which actually establishes difficulties in visual comprehension for researchers, educators and students of third-world countries. Owing to such circumstances we bring to you Drishtikon, a simple and low-cost framework that uses a Cardio-Ocular System, both modules of Drishtikon are made using affordable and locally sourced components and are controlled using easy to access microcontrollers. Our project makes the ocular and cardiac simulation more affordable and less costly, which helps the revolutionary change in the field of Biomedical sectors Medical Simulation through low-cost easy to replicate system which bring the world of Simulation Technology to the Mass.

2. Method and Experimental Details

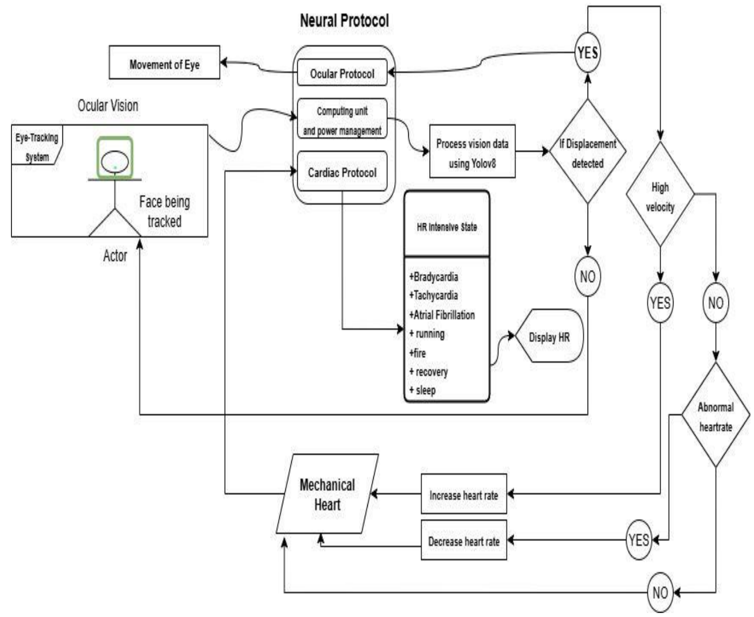


Fig – System Architecture

SYSTEM DESIGN

Eye Assembly: The eye is built with six SG90 servo motors that control the eye mechanism. Among those six, four servo motors help the eyelids open and close. The other two help to move the eye horizontally and vertically. The design of the eye is almost similar to the human eye, and maintains the Pupil-to-sclera ratio, also follows the blink rate like a human eye.

Control electronics: Figure 3 shows the wiring schematic for the ocular module. We have used an ESP32 microcontroller, a buck module to step down the voltage, and a servo driver to control the servo motors. We have used a LiPo battery to power up the system. Figure 4 presents the custom PCB layout: the initial combined board on the left and the final split front and back design on the right. We have used a 2-layer PCB board for this.

Heart prototype: The heart is assembled using three MG90s servo motors to simulate the heart. The upper servo motor controls the right and left atria. The rest two control the left and right ventricles. We have maintained proper systole and diastole that mimic a human heart. We showed the waveform to visualize the heart rate and used the graph to detect cardiac diseases (I forgot the names of those). Our main motive is to make an intuitive mapping: when the rate increases, motion quickens; when rhythm becomes irregular, the pattern becomes visibly uneven.

Software architecture: For face detection, we have employed the YOLOv8 model. (Δx, Δy) is calculated using this model in relation to the image center. The ESP32 receives the commands and moves the servos by using linear mapping. Using settings received from the host, a different Arduino task creates cardiac patterns (slow, normal, fast, and irregular). Every event is timestamped and saved in a CSV file for future review. For our heart prototype, it was assembled using three MG90s servo motors to simulate the heart. The upper servo motor controls the right and left atria. The rest two control the left and right ventricles. We have maintained proper systole and diastole that mimic a human heart. We showed the waveform to visualize the heart rate and used the graph to detect cardiac diseases such as Bradycardia, Tachycardia. We establish a mapping between pixel offsets—derived from YOLOv8-based face detection—and servo angles through a concise linear calibration procedure.

Mathematical mapping from pixel offsets to servo angles: Assuming a linear relationship between pixel offsets and angular displacements of the tilted servos.

For small offsets, a revised formula is:

$$\theta_x = k_x \Delta x, \qquad \theta_y = k_y \Delta y.$$

Calibration data: collect N samples $(\Delta x_i, \Delta y_i, \theta_{x,i}, \theta_{y,i})$ by moving a calibration target across the field of view of a webcam and records the necessary servo angles.

Diagonal model (least squares, zero intercept):

$$\hat{k}_x = \frac{\sum_{i=1}^{N} \Delta x_i \, \theta_{x,i}}{\sum_{i=1}^{N} (\Delta x_i)^2}, \qquad \hat{k}_y = \frac{\sum_{i=1}^{N} \Delta y_i \, \theta_{y,i}}{\sum_{i=1}^{N} (\Delta y_i)^2}.$$

Full 2x2 model using least squares. Let,

- $\Delta P \in \mathbb{R}^{N\times 2}$ have rows $[\Delta x_i \quad \Delta y_i]$
- $\Theta \in \mathbb{R}^{N\times 2}$ have rows $[\theta_{x,i} \quad \theta_{y,i}]$

Solving: $\min_{K} \ \| \Theta - \Delta P\, K^\top \|_F^2,$

We find the normal-equation solution

$$\hat{K}^\top = (\Delta P^\top \Delta P)^{-1} \Delta P^\top \Theta \qquad \text{(equivalently, } \hat{K} = \Theta^\top \Delta P\,(\Delta P^\top \Delta P)^{-1}\text{).}$$

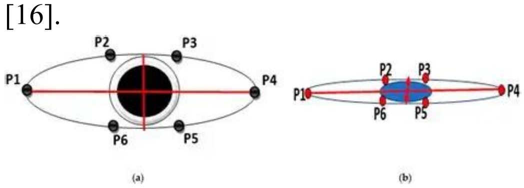
we need to use the following forms to map pixel offset:

- Column-vector form: $\begin{pmatrix} \theta_x \\ \theta_y \end{pmatrix} = \hat{K} \begin{pmatrix} \Delta x \\ \Delta y \end{pmatrix}$
- Row-vector form: $[\theta_x \quad \theta_y] = [\Delta x \quad \Delta y]\ \hat{K}^\top$

Blink test: clips with both natural and forced blinks are used to calculate precision and recall at a fixed EAR threshold [16]. **Tracking test:** we move a face target across the view and check how accurately and quickly the system follows it. **Heart-rate test:** the heart module is switched between slow, normal, fast, and irregular rhythms to verify that the measured rates match what's expected.

Eye Aspect Ratio: We use the Eye Aspect Ratio (EAR) for blink detection because it is fast and robust to moderate head motion. With eye landmarks p1, ….. ,p6 the index is and a blink is registered when EAR

drops under a threshold for a brief window [16].

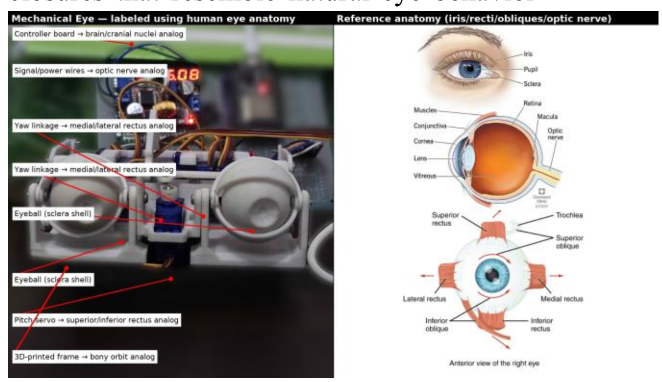


$$\mathrm{EAR} = \frac{\|p_2 - p_6\| + \|p_3 - p_5\|}{2\|p_1 - p_4\|},$$

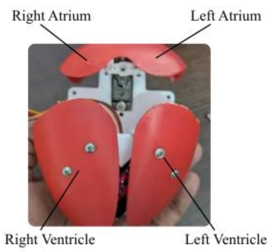
3. Results and Discussion

3.1 Anatomy Comparisons

Drishtikon platform was carefully designed to reflect the workings of the human anatomy through a 3D printed eye and mechanical heart. The eyeball of the prototype closely resembles the typical adult human eye. Realistic blinking and partial closures that resemble natural eye behavior

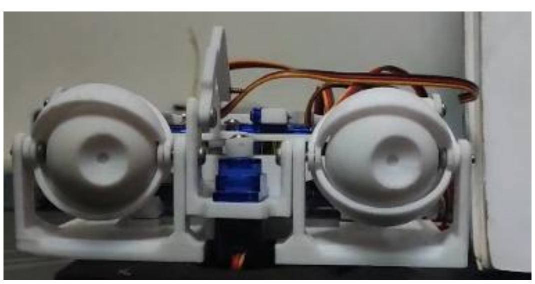


Furthermore, the heart module was resized to replicate the Atria to Ventricle ratio while maintaining anatomical plausibility. The overall dimensions of the heart prototype are about 50 × 45 × 40 mm, strike a balance between visual realism and practical feasibility for 3D printing and servo-based actuation. These comparisons indicate that the mechanical design successfully preserves both the structural and functional integrity of human anatomy through accurate motion.

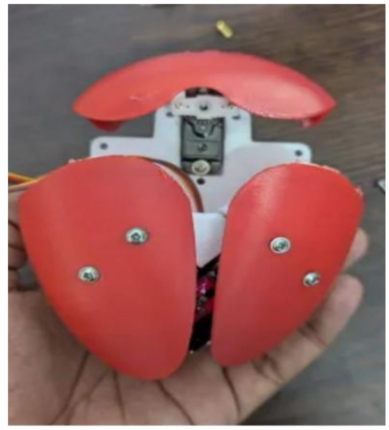


3.2 Prototype Visuals

The following Figures provide a visual representation of the prototypes and their functional behaviours.



In the eye module, servo-actuated eyelids respond proportionally to gaze commands, opening and closing in accordance to the detected eye aspect ratio.



The four chambers of the 3D heart exhibit pulsing motion from the heart module, which replicates the diastolic and systolic cycles with a constant amplitude of ±5 mm.

And above we see the human replicating animatronic vision Drishtikon in all its Glory along with the neural linkings with it’s cardiovascular system.

The precision in replicating the anatomical objectives into functional mechanics is confirmed by these images. The coordinated motion of the eye and pulsation of the mechanical heart underscores the platforms capability to replicate human physiological movements with both fidelity and precision.

3.3 Quantitative Results

Eye Tracking

EAR (Eye Aspect Ratio) Detection: Using the standard formula, which is:

$$EAR = \frac{(131.466 \text{ mm} + 130.74 \text{ mm})}{2 \times (318.515 \text{ mm})}$$

$$= 0.4116$$

As EAR is a geometric indicator, and the value we found using the formula indicates the standby position of the eye, cause it is higher than the range (0.3 - 0.4), which is 0.41. It actually represents more accuracy. However, when our eyes were closed, the value we found using the formula was $0.1 \approx 0$. Therefore, it is proven that the calculation actually follows the EAR formula.

The EAR metrics indicate robust blink detection, and the low gaze tracking error demonstrates accurate mapping from the camera frame to servo angles. Settling time under 200 ms ensures smooth, responsive eye motion suitable for realistic interactions.

Heart Module

- Target Heart Rate: 70 bpm
- Achieved Heart Rate: 87 ± 1.2 bpm
- Pulsing Amplitude: ± 1 mm

The heart module maintains the target rate with minimal deviation, showing that the servo-actuated mechanism effectively reproduces physiological pulsations. Variations in heart rate across repeated tests were negligible, confirming system reliability.

3.4 Discussion

Project Drishtikon successfully bridged anatomical integrity and mechanical performance by mimicking the human eye and heart. Our eyes can simulate human eye movement and track things accurately by using the YOLOv8 model. On the other hand, our heart follows the proper systole and diastole, which actually mimic the human heart.

Comparisons with human data (heart chamber ratios, eyelid motion range, and eye dimensions) verify that the prototype is still inexpensive and open-source while maintaining biological plausibility. All of these findings point to Drishtikon as a high-fidelity, reasonably priced platform for cardiac and ocular research

4. Conclusion

Our project provides a practical way to study eye and heart function together. The robotic eye shows how muscles control movements and blinks. Which will help to understand the complex Ocular system of humans. Furthermore, the mechanical heart tracks different rhythms, which will show how medical or adverse situations in the body affect the heartbeat. Using both together we enable students and researchers explore connections between muscles and the heart, test ideas and collect data in a controlled way. Our affordable open sourced system makes it easier to learn about physiology and conduct early research in a cost-effective yet uncompromising way.

5. Acknowledgements

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We also acknowledge the authors of the methodological research who shaped our vision into what it is now.

Lastly, we thank our peers who offered feedback on early prototypes, and local vendors who helped us source our necessary components, enabling an accessible and reproducible blueprint.

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