Bionic Eye: Towards an Inclusive, Low-Cost Retinal Prosthesis for Adaptive Visual Restoration

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Abstract. This is a single paragraph overview of your prototype electronic device (or your idea for one) and the problem it aims to solve. (Style: Paper Abstract.)

Abstract. An estimated 43 million people live with blindness worldwide, yet the most advanced retinal prostheses remain prohibitively expensive and are designed around a narrow demographic of clinical trial participants. This paper proposes a low-cost, open-hardware bionic eye prototype, specifically an externally worn camera module coupled with a microcontroller-driven electrode array, capable of delivering spatially mapped electrical stimulation to the visual cortex. The proposed device targets underserved populations including elderly users, people in low- and middle-income countries, and those excluded from current clinical trials due to demographic homogeneity in testing. Drawing on inclusive engineering design principles, the prototype is conceived as a modular system in which stimulation parameters can be personalised to the individual user's residual neural response.

I. Introduction

Vision loss is one of the most prevalent disabilities globally. The WHO estimates at least 2.2 billion people have vision impairment, of whom approximately 43 million are blind [1]. Conditions such as retinitis pigmentosa destroy photoreceptor cells while leaving neural pathways intact, creating a biological opportunity for electronic intervention.

Retinal prostheses bypass damaged photoreceptors by converting camera input into electrical pulses delivered to surviving neurons, producing light perceptions known as phosphenes [2]. Despite this promise, current devices such as the Argus II cost over $150,000 USD and have been developed using narrow demographic trial groups, meaning stimulation parameters are optimised for a limited user profile [3]. This paper proposes a low-cost prototype addressing both affordability and inclusivity.

II. Related Work

The Argus II retinal prosthesis uses a 60-electrode array and external camera-transmitter, demonstrating statistically significant improvements in object location for patients with retinitis pigmentosa [2]. At over $150,000 USD, access remains severely restricted. Bionic Vision Australia's suprachoroidal device demonstrated a less invasive surgical approach with potential to broaden the eligible patient population [4].

Dobelle demonstrated direct visual cortex stimulation can produce phosphene perception without an intact retina, expanding the treatable population [5]. Researchers have also explored microcontroller platforms for low-cost neural stimulation prototyping [6]. A consistent gap across this literature is the absence of adaptive personalised stimulation , the gap this prototype addresses.

III. Proposed Prototype

The proposed bionic eye prototype consists of four principal hardware subsystems: image acquisition, signal processing, wireless transmission, and neural stimulation delivery.

A. *Image acquisition*

A miniaturised OV2640 2MP CMOS camera module is mounted in a spectacle frame worn by the user, capturing 30 frames per second downsampled to 32×32 pixels. The spectacle-mounted form factor avoids surgical risk at the prototyping stage while enabling full signal pipeline testing.

B. Signal processing

An ESP32 microcontroller (dual-core Xtensa LX6, 240 MHz, ~£4) processes image frames using edge detection to extract perceptually relevant spatial information. Pixel intensity values are mapped to stimulation pulse amplitudes via an adjustable user-specific lookup table, enabling individual neural threshold calibration , a key differentiator from fixed-parameter commercial devices.

C. Wireless transmission

Stimulation commands are transmitted via Bluetooth Low Energy (BLE) to a receiver near the electrode array. Power is delivered via inductive coupling at 13.56 MHz, consistent with established medical implant methods used in cochlear implants and pacemakers.

D. Electrode array and adaptive stimulation

The complete signal chain is shown in Figure 1. Stimulation is demonstrated using a surface 4×4 platinum electrode array applied to the scalp over the visual cortex. A Howland pump current-source circuit delivers biphasic charge-balanced pulses of 10–500 µA with pulse widths of 100–500 µs, within established neural stimulation safety limits [6].

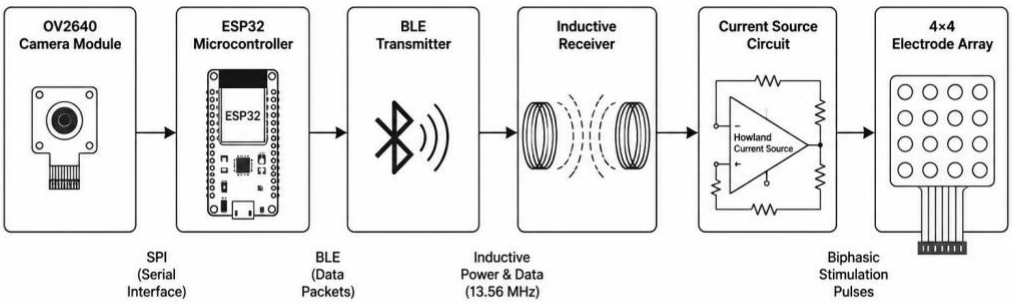

Figure 1.
System block diagram of the proposed low-cost bionic eye prototype showing the signal chain from image acquisition to neural stimulation.

Fig. 1. Figure 1. System block diagram of the proposed bionic eye prototype showing the signal chain from image acquisition to neural stimulation.

The key innovation is an adaptive calibration mode (Figure 4). On first use, the device cycles through stimulation amplitudes while the user provides binary feedback via a button, building a personalised threshold map , analogous to audiometric fitting in hearing aids, applied to visual prosthetics.

The wearable form factor and electrode array are shown in Figures 2 and 3. Estimated component cost is under £80, versus over £120,000 for current commercial systems.

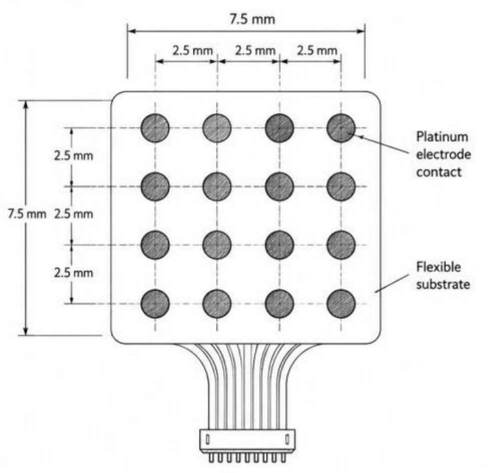

Figure 3.
4×4 Electrode Array Close-Up
Sixteen platinum electrode contacts arranged in a 4×4 grid on a flexible substrate. Inter-electrode spacing is 2.5 mm.

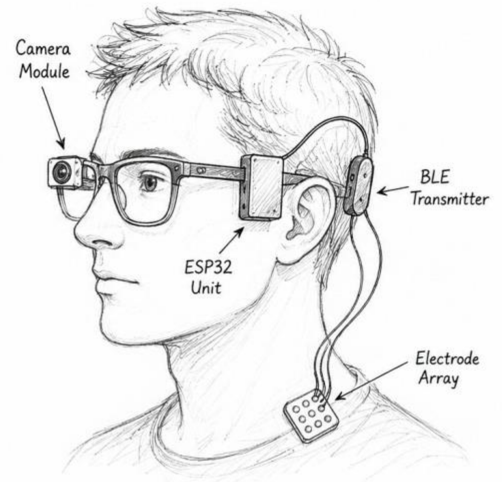

Figure 2.
Bionic Eye Device Concept (Worn by User)
Concept sketch showing the wearable components of the proposed bionic eye prototype.

Fig. 2. Figure 2 (right). Wearable bionic eye concept sketch. Figure 3 (left). 4×4 platinum electrode array with 2.5 mm inter-electrode spacing on flexible substrate.

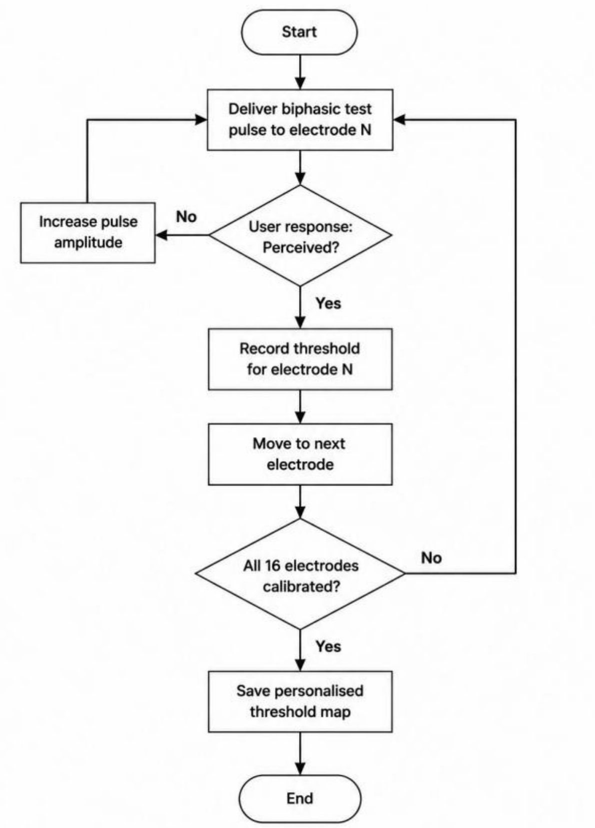

Figure 4. Adaptive calibration flowchart for personalised stimulation.

Fig. 3. Figure 4. Adaptive calibration flowchart for personalised stimulation threshold mapping.

IV. Responsible innovation

The most pressing concern is equitable access. Neural prosthetic technology has historically targeted high-income countries, with trial demographics failing to represent the global burden of blindness concentrated in South Asia, Sub-Saharan Africa, and East Asia [1]. Designing for cost reduction from the outset is therefore an ethical requirement, not merely a commercial decision.

The adaptive calibration system addresses a core diversity failure: the assumption that one stimulation profile serves all users. Neural threshold variation is significant across age groups, neurological conditions, and duration of visual deprivation [5]. Building personalisation into the hardware architecture enables the device to serve a broader population from inception.

The modular design minimises electronic waste by allowing independent subsystem replacement. Any implanted version would require MHRA or FDA regulatory approval. This paper describes a non-implanted prototype only. Clinical translation would require collaboration with neuroscientists, ophthalmologists, and ethicists.

V. Author biography

Joseph Collins Lumiinsa is a first-year undergraduate in Electrical and Electronic Engineering at the University of Nottingham. His practical experience includes embedded systems laboratory projects using the ESP32 microcontroller covering: combinational logic and seven-segment display control; autonomous maze navigation using IR sensors; wireless control via Bluetooth; line-following using IR reflectance sensors; and colour detection using RGB sensor modules , directly mirroring the architectures proposed in this prototype.

Joseph’s motivation stems from a long-standing interest in assistive technology and inclusive engineering design. The bionic eye concept embodies this: a device where inclusive design is a core engineering requirement, not an afterthought. The vision of sensors replacing switches , technology that adapts to the human rather than requiring the human to adapt , is the principle motivating this work.

VI. Acknowledgements

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VII. References

[1] [1] World Health Organisation, “Blindness and vision impairment,” WHO Fact Sheet, Oct. 2023.

[2] [2] M. S. Humayun et al., “Interim results from the international trial of Second Sight’s visual prosthesis,” Ophthalmology, vol. 119, no. 4, pp. 779–788, Apr. 2012.

[3] [3] L. da Cruz et al., “Five-year safety and performance results from the Argus II retinal prosthesis system clinical trial,” Ophthalmology, vol. 123, no. 10, pp. 2248–254, Oct. 2016.

[4] [4] L. N. Ayton et al., “First-in-human trial of a novel suprachoroidal retinal prosthesis,” PLOS ONE, vol. 9, no. 12, p. e115239, Dec. 2014.

[5] [5] W. H. Dobelle, “Artificial vision for the blind by connecting a television camera to the visual cortex,” ASAIO Journal, vol. 46, no. 1, pp. 3–9, Jan. 2000.

[6] [6] D. Ghezzi, “Retinal prostheses: progress toward the next generation implants,” Frontiers in Neuroscience, vol. 9, p. 290, Aug. 2015.

[7] [7] B. J. Pine II, Mass Customization: The New Frontier in Business Competition. Boston, MA: Harvard Business School Press, 1993.