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A discrete, affordable, hands-free text reader for blind and visually impaired people

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Currently, the 2 billion blind and visually impaired people in the world have little to no independent access to written text. Existing smartphone reader apps are clunky and occupy one hand, and hands-free technologies are conspicuous and prohibitively expensive. This paper presents a prototype concept and plan for a hands-free, over ear device that allows users to read text while being discrete, affordable and reliable to use.

I. Introduction / Background

Blind and visually impaired people – an estimated 2.2 billion people worldwide [1] and more than 2 million people in the UK [2] – still encounter daily barriers to accessing printed and on screen text. While screen-reader software improves access to digital content, hard copy materials such as menus, mail and signs remain largely inaccessible without human assistance. [2]

Optical Character Recognition (OCR) is the process of translating images of text into an ASCII format recognisable by computers, often using AI deep learning methods such as Convolutional Neural Networks. These can be then converted to a natural language output – text to speech (TTS) [3]

Mobile OCR apps have demonstrated an ability for smartphones to read text aloud in real time, but they tie up one hand, demand precise aiming, and can attract unwanted attention [4]. Recent research and commercial ventures have brough about wearable OCR systems, using cameras embedded in glasses or clip ons and embedded AI models to capture text and synthesise speech hands-free, promoting independence in everyday tasks like reading post, shopping, and navigating unfamiliar spaces. Currently, such devices are prohibitively expensive [4], and not widely available. A 1992 US survey by Kapperman et al found price and lack of information to be the dominant barriers to purchasing assistive tech among 228 visually impaired respondents, with 65% quoting price as the main hurdle. [4] A 2023 US policy brief by Morris et al demonstrated the heavy financial implications of disability related goods and services on people who are blind or have low vision, finding 80% reporting out of pocket costs, 39% reporting challenges making ends meet because of disability related costs, and 25% cutting back on food due to their disability related costs. [4] Technology needs to do better by prioritising affordability to be accessible to the people who need it most.

Assistive tech also needs to be discrete and dignified. A 2019 Indian study by Sivakumaar et al found social stigma to be a major obstacle to the use of visual assistive tech. [5] Current OCR TTS devices are conspicuous, being often bulky and outputting text speech via loudspeakers. [4] As such, there is a market need for OCR devices that are discrete designed for user satisfaction and aesthetics

This paper presents a concept for a solution to both affordability and discreteness for OCR TTS devices. It utilises bone conduction and ergonomic over ear attachments to create a lightweight OCR device. A business plan for ensuring affordability and user centred design is also briefly proposed

II. Related Work

Early assistive OCR tools emerged in the form of mobile apps. K-NFB reading technologies' KNFB reader in 2008 was one of the first to offer a text readout from a smartphone photograph, and is available on the app/google play store for $99.99 as of May 2025 [6]. Shen at al's research in 2012 built on this creating a software that could read signs and offer tactile feedback to make it more applicable for blind and visually impaired users to navigate.[7] Today, Microsoft's seeing AI is a free smartphone alternative to KNFB reader with some object identification capability, though struggles with multi column text, curved surfaces, and expiration dates. It's also limited in that it requires smartphone use and is not discrete [4] [8]

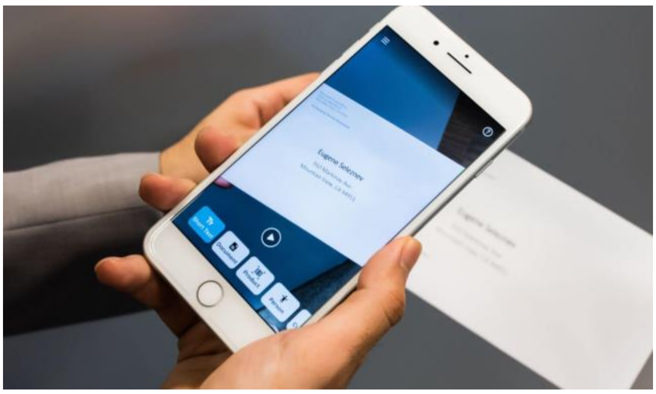


Figure 1: Microsoft's seeing AI app on an iPhone [9]

Orcam's MyEye is a well-known commercial example of visual assistive technology, offering hands-free TTS capabilities. User test studies by Amore et al [10] found the device easy to use and that daily living tasks improved for 87% of participants. However, participants in Nguyen et al's study [11] found the device to be useful in good lighting, but behave poorly in low light conditions, and had a short battery life limiting it's long term usefulness. They also found the device to be heavy and unbalanced when using in hands free mode. 85% of the participants did not continue to use the device after the study due to the high cost - £3,300 excluding VAT from the RNIB, UK [12]

Figure 2: Orcam MyEye [13]

Envision smart glasses are another commercial example of a hands free TTS device. Studies by Seipe et al found them to be more useful than the orcam for blind and visually impaired participants to complete searching and identifying tasks. [14] Envision glasses are also prohibitively expensive, ranging from £2,158.80 - £3,598.80 depending on specs [15]. They also do not satisfy the desire for a discrete device.

Figure 3: Envision glasses from their website [15]

These examples demonstrate a need for an offline, lightweight, ergonomic device that builds on the existing tech, utilising smart energy saving techniques and an affordable manufacture and/or sales structure. Notably, personalisation has not been considered, opening further options for novelty.

MIT's fingerreader is an innovative research solution, using a tiny camera and a speaker embedded into a finger wearable to read text highlighted by finger pointing. [16] The concept is a useful way to have more control over what text the device reads out, allowing users to read at their own pace, and reread sections if needs be. This gesture based control would be a useful addition to existing head mounted equipment, and is a future aim of the project described by this paper.

III. Imagined or Existing Prototype Sketches/Drawings/Photos

A. Breadboard prototype

The initial prototype will be built at a breadboard scale using off-the shelf modules to quickly demonstrate OCR and speech output. An Espressif ESP32-S3 DevKitC development board is currently being used as the microcontroller platform to develop and validate the code pipeline, and a V831 Dev Kit will be used to validate, train, and bug test the OCR software.

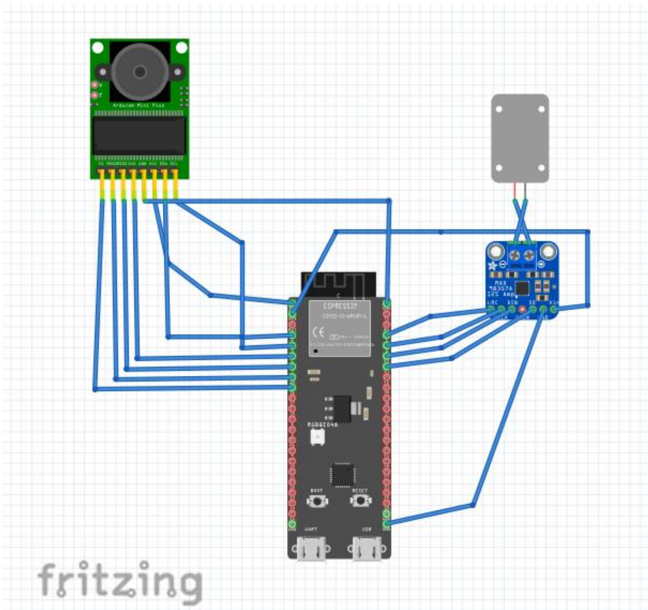


Figure 4: a very basic mockup of the circuit to test the code pipeline, fritzing

Figure 5: V853 devkit for testing the OCR, AliExpress.

An OV2640 camera, commonly used in IoT projects, will be interfaced to the ESP32-S3's digital camera port to capture images of text. Audio signals will be amplified by a MAX98357A amplifier.

Figure 6: OV2640 Camera from Arducam. The actual camera is about half the size of an average pinky fingernail.

For audio output, a GD14 bone conduction module is used

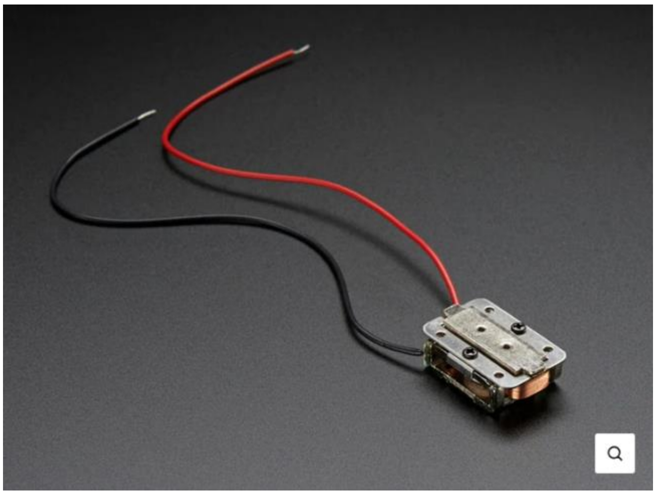


Figure 7: GD14 Bone conduction module from pihut

There are also passive through hole components that will be used. Pull up resistors at about 4.7kohms will be used to the I^2C camera inputs to prevent noise. Further passive components will be required in miniaturisation.

B. Miniaturisation plan

Miniaturisation is vital for the circuitry to fit in an over ear design. Miniaturisation consists of consolidating components from breakout boards into a custom PCB, designed on KiCAD. Surface mount components will be used wherever possible, such as for passive components, to save space.

The Allwinner V853 SoC chip is ideal for running the OCR model, as it features 128MB RAM, a 1GHz ARM A7 CPU, and a 0.6TOPS NPU for dedicated neural net processing. It can be obtained from LCSC electronics

MAX98357A amplifier chips and BQ25120A power management chips will be purchased from Digikey alongside their passive components according to the datasheet. The large scale GD14 Bone conduction module will be scaled down to a smaller GD02 module, to save space.

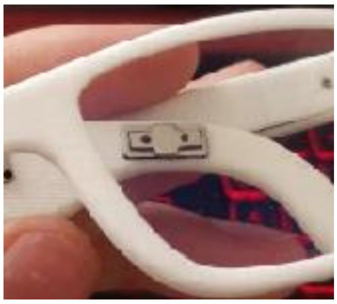


Figure 8: A GD02 embedded into a pair of glasses, next to a finger for comparison, from TheStaticTurtle [17]

Two 3.7V Li-Ion Varta CP1254 will be purchased from AliExpress and used in parallel to achieve a combined 140mAh in about mm^3. Assuming usage in small bursts for a total of 10 minutes a day (about 5mAh), interspersed with idling (about 3.6mAh, means a daily usage of about 10mAh. Allowing for error, this should allow for a full week of usage between charges. To guarantee safety, the steel can on the 1254 will be protective from thermal runaway, and individual PCMs and NTCs will be used to prevent this from happening. Capacitors will be used for stabilising input and output voltage. PMICs will be used to manage the charging of the batteries to prevent overcharging. These CP1254 batteries are commonly used in Apple and Bose in ear headphones, so they are a validated solution.

Figure 9: Varta CP1254 batteries from AliExpress

The first miniaturisation prototypes will be purchased from Eurocircuits or a similar supplier as their pay-for-square-footage model allows for a cheap prototyping cost.

Once the circuitry is tested and validated, a rigid-flex PCB will be used to allow the PCB to conform to the around the ear shape. The camera and bone conduction modules will be separated from the rest of the PCB by the flexible circuitry material. This also allows some movement in the circuit for the bone conduction module, which combined with a spring system will allow it to sit tight against the skin of the user - important for good audio quality.

C. Ergonomics

Concept sketches are seen below. The device hooks over the ear, similar to sports headphones or a hearing aid. Depending on weight distribution, splitting the device across both ears might allow for a more even loading on the ears, allowing for more comfortable extended usage, and offering more space for batteries for battery life.

Figure 10: a placeholder for where the ear clip could sit. With a casing made of soft and flexible TPU or silicone, hooks could conform to the inside of the ear folds to hold the device in place without pain.

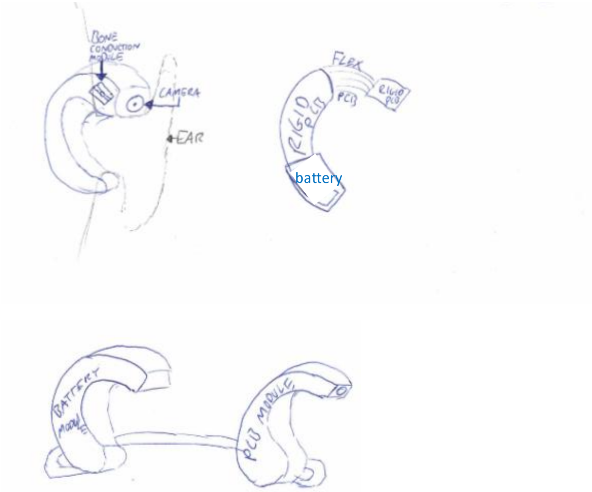


Figure 11: Concept sketches for the device. Top: a single ear design, with the circuitry all in one clip, Bottom: a double ear design closer to traditional bone conduction headphones, with the battery split into another module on the other ear. This would reduce weight and strain on one of the ears and allow more space for components. Design is dependant on outcome of miniaturisation

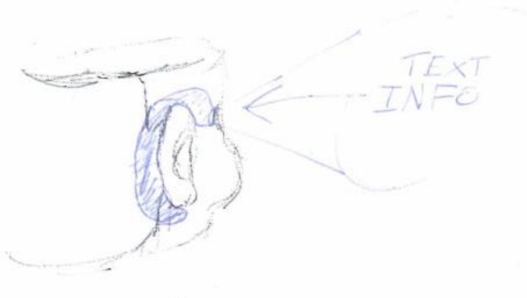


Figure 11b: A rough sketch showing operation from an over the shoulder perspective. A camera on the front of the device reads text info to output to user

To hold the device onto the ear, small hooks could be used

The casing will be designed in SolidWorks. 3D printing the device also allows for a wide variation in colour and texture. Fun or discrete colours can be selected, or interesting designs can be created. For example, a snake theme. This allows for users to express themselves with their device – a novel aspect which is lacking in conventional assistive devices

Figure 12: a basic CAD mockup in SolidWorks

D. Privacy

A key novel aspect of the design is use of bone conduction. Bone conduction headphones are commonly used by the blind and visually impaired community, to listen to music or hear navigation directions while leaving the ears free to perceive the environment. Use of bone conduction would fit seamlessly into many blind people's technology usage habits, and will allow them to hear their TTS privately rather than the convention of speaking the text out loud

Figure 13: Bone conduction headphones example, by RoadCC (https://road.cc/tags/bone-conduction-headphones)

In addition, the focus on an over ear design rather than glasses lends itself to a more understated, discrete presentation.

E. Software

To interpret the images, a CRNN will be used. This consists of a convolutional neural network to interpret letters as combinations of shapes, a recurring neural network to have memory of letters as it goes, and a CTC to string together words and sentences. PaddlePaddle OCR [18] is an open source, multilingual Optical Character Recognition (OCR) software that requires only 2.8MB of storage space and supports quantisation, making it perfect for this application. It has some training on handwriting, and it can be trained further on more handwriting data.

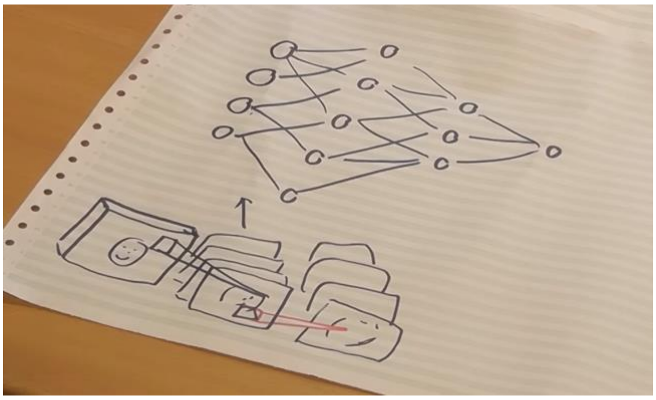


Figure 14: CNN Diagram – Computerphile [https://www.youtube.com/watch?v=py5byOOHZM8&ab_channel=Computerphile

Quantising the OCR to int8 will allow for much less power drain and faster operation by doing the minimum number of operations required to achieve an output. This is important for users to have minimal delay when reading and to maximise on battery life. The system will also be programmed to be idle when not in use to save battery. Minimising battery usage of components will allow for a smaller battery to be used, minimising weight and device footprint.

Augmenting the OCR training further with handwriting data, such as the IAM benchmark or EMNIST dataset will allow it to better identify handwriting or unique typographies. This is important for reading letters or unique fonts. In addition, having an on board dictionary to cross reference words against will ease processing demands and allow for secondary checking.

Future iterations aim to use gesture based commands, identifying a finger point to decide which word to read to the user. This allows a direct control of the system, allowing for more user autonomy and preventing the system from picking up unneeded or uninteresting data (for example page numbers, footnotes etc)

F. User validation

Speaking to my friend who is blind, and browsing online blindness communities such as r/blind on reddit.com stressed the need for a device like this. There is desire in the blind and visually impaired community for TTS devices, but financial barriers, a lack of knowledge and device abandonment are obstacles towards this. To ensure that my design is useable, I intend to reach out to blindness related organisations such as RNIB, and Royal national college for the blind to share my prototype for user surveys, iterating based on their feedback..

G. Affordability

The first prototypes of the device will be made out of 3D printed plastic from my in house 3D printer. Assuming TPU and a standard Prusa Mk4 printer, this comes to max £1 per unit including all running costs. At scale, polyurethane vacuum casting or even injection moulding might be a more effective option. Future iterations of the design using high quality manufacturing could result in a waterproof design, allowing for use in the rain or in the shower.

The electronics are also affordable, coming in at about £42 per unit

- V853 module ≈ £6
- BQ25120A PMIC ≈ £2
- MAX98357A Amplifier ≈ £1
- 2x Li-Ion CP1254 ≈ £7
- GD02 Bone conduction module ≈ £8
- Misc passives + PCB ≈ £8

Which is significantly cheaper than £3,300 for the Orcam

However UKCA certification and MHRA regulatory costs would make up the bulk of the upfront costs to produce a marketable device. Should the prototype be validated as useful and effective, investment from institutions or angel investors could enable the progression through regulations. Ultimately, the design is simple and uses widely available components, so could be produced with far less cost than currently marketed solutions.

If the device is marketable, it could be sold via a subscription model, allowing users to purchase by paying monthly/annually, similar to whoop. This will hopefully allow for more accessible pricing rather than a large upfront sum of money.

The details of the imagined or existing prototype should be described in body text. Explain what components and materials you have used or intend to use, including part numbers where possible. If the components are hard to source explain where you got them from. Explain how you built or intend to build the prototype.

IV. Responsible innovation

The potential for positive impact on people's lives with this device is significant. With the aim of accessibility as a driving force, getting the device functioning well in the hands of blind and visually impaired people could really help improve their independence and freedom to navigate society. I aim to make the designs open source, so users can easily print or repair their own parts should they become damaged. If I was to sell the devices, I aim to keep costs low with a subscription model service, where users can pay a small amount monthly amount to use the devices, and a free repair service where users can send back broken devices to be repaired.

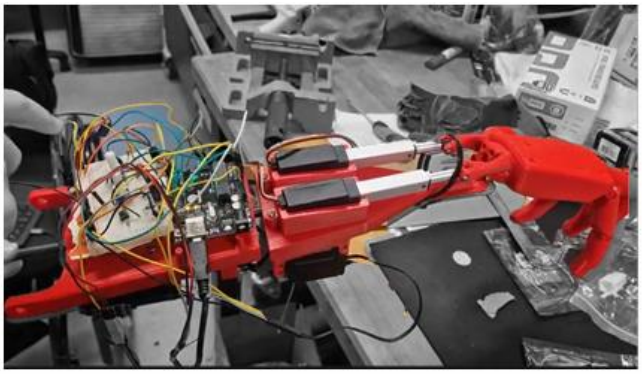
V. Author bio(s) / experiences

I'm a materials science and engineering undergraduate student going a bit rogue in the pursuit of devices that can help bring people freedom. My undergraduate dissertation was helping characterise novel shape shifting liquid crystal elastomers (publication submitted). I've moved from micro scale exploration to macro scale, currently completing an internship at Siemens Healthineers' MRI magnet factory to learn design and mechanical engineering in a medical devices context.

I'm motivated by the desire to level the playing field of disability – those statistics about the financial burden of blindness make me viscerally angry, and I want to help tackle them. I was inspired to work on this prototype particularly after meeting my friend Noah, and seeing his braille labels on his spice jars. I wanted to make something that would make his life that little bit easier, and not have to print labels or ask someone else to read everything

My work so far has focussed on the space of tackling obstacles imposed by medical conditions. At university, I led a volunteer project creating a myoelectric transhumeral bionic arm for a real patient and designed toys for toddlers with Osteogenesis Imperfecta (OI)

My teammate (anonymised for privacy) and I delivering the toys for OI at the hospital.



Prototype bionic arm developed with Bionics Society at my university

After attending pro2 last year and loving it, I'd love the chance to join again, reconnecting with and meeting new changemakers and innovators in the electronic device prototyping space. I'd like to take these learnings further with masters studies that I am about to begin in Innovation Design Engineering at RCA/Imperial College London

VI. Acknowledgements

Thanks to my friend Noah who shared his perspective of living with blindness, it has guided my efforts in this work and inspires me to want to contribute to the field of assistive tech. Thanks to my mentor Charlie Oulton for encouraging me to develop this idea further and proposing ways to market the device and get users to test it. Thanks to the Royal Academy of Engineering for their Engineering Leaders Scholarship, as it provided me funding to create initial prototypes and buy a 3D printer to explore my ideas

VII. Refernces

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