

CIS II: Project Proposal Plan
Multisensory Navigational Aid for Visual Prosthesis Users

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Objective

The goal for this research project is to develop haptic and auditory feedback systems that work cooperatively with the Argus II retinal prosthesis system to aid users in independent navigation. The supplementary systems are designed to assist with target navigation and object localisation. These additional systems should be intuitive, such as having a minimal learning curve, as well as maintain a low cognitive load.

Background and Relevance

The Argus II retinal prosthesis system is a system for patients with end stage Retinitis Pigmentosa [1] – a condition in which there is a loss or breakdown of retina cells. Many patients in the later stages of this condition are legally blind [2]. The Argus II is composed of an electrode array that is implanted into the back of the users' eye. This is accompanied by a camera built into a pair of glasses and along with the required processing unit.

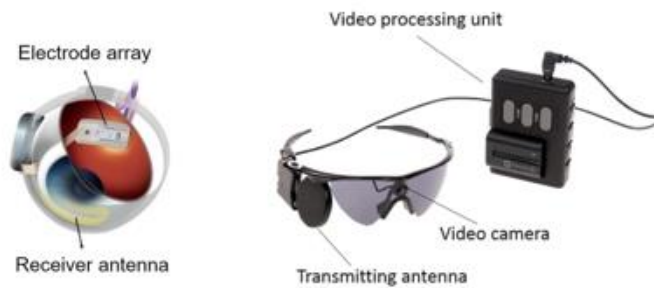


Figure 1: Argus II Retinal Prosthesis System

Information from the camera is used to create a stimulation image which is used to simulate the users' viable retinal cells, using the electrode array. This simulation is perceived by the user as light patterns. This process is illustrated in the figure below.

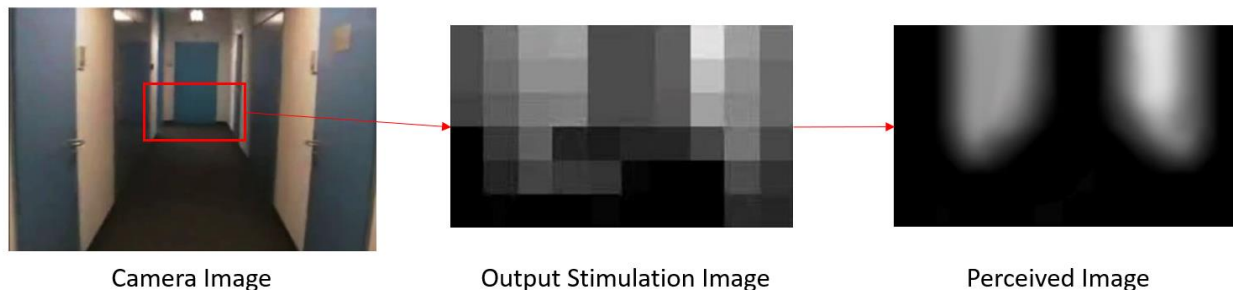


Figure 2: Imaging Process in Argus II System

There are limitations to this system that make it difficult for users to independently navigate a space. The artificial vision provided by the Argus II is not the same as actual sight as can be seen in Figure 2 above. In addition, the perception of this artificial vision varies between users. Some users are able to distinguish varying, though limited, light intensities whilst others can only discern the on/off

states. Furthermore, as what the users see is determined by the camera, the field of vision is severely limited – users can only see the scene at which the camera is directed. There is no peripheral vision which can be dangerous if the users turn their bodies before viewing the scene by turning their heads. This limitation also makes it challenging for users to find their targets as this requires physically moving their heads to scan their surroundings for their desired target.

Prior Work

The Applied Physics Lab (APL) at Johns Hopkins University has already developed a SLAM-based navigational system for the Argus II system. This system makes use of RGB and depth cameras to map a room and locate any obstacles. It is also able to determine the optimal route from the users' location to their target whilst avoiding the obstacles. For this project, the object detection capability will be of interest as it will be used for both the haptic and auditory feedback systems.

Technical Approach

Haptic Feedback System

The haptic feedback system's hardware consists of a headband fitted with 8 repositionable haptic actuators which connects to a custom 8-channel haptic driver. This is shown in Figure 3. The function and objective for this haptic system is to guide the users' gaze towards the direction of their target (e.g. a door). By doing so, this should assist the users in finding their targets and navigating to them more effectively.

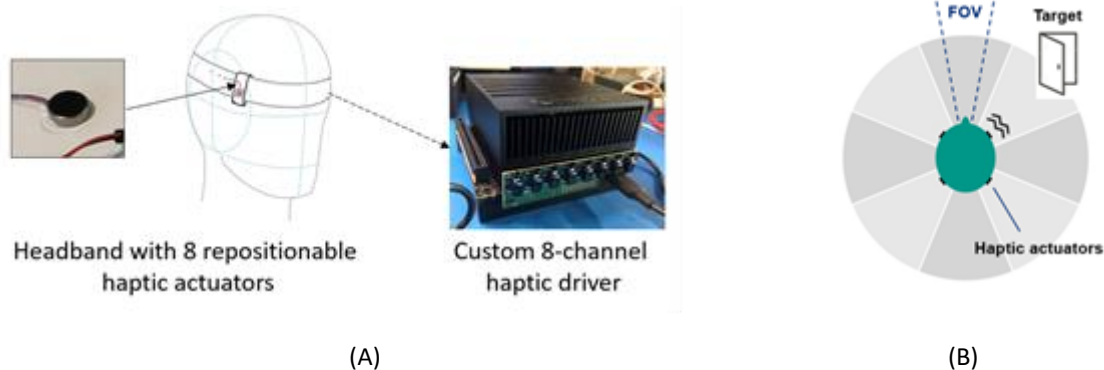


Figure 3: (A) Hardware and (B) Function and Objective of Haptic Feedback System

The first step in developing this system is to formulate an evaluation method and metrics. These will be used to determine if the system is intuitive and effective in relaying the directional instructions. Following so, there are a few options which need to be explored to develop the haptic feedback system. ERMs and LRAs are two common haptic actuators, thus, it must be determined which type is best suited for this application. Both have their advantages, and the choice will be dependent on which type provides a clearer, more distinct feedback. Furthermore, there are various haptic patterns which can be employed to relay a directional instruction. A static pattern involves only actuating motors on the side the users should direct their gaze. Whilst a dynamic pattern relays a direction by using perceived motion – the haptic motors are actuated in a specific order, such as right to left to relay a left direction. How intuitive these haptic patterns are to users will determine which one will be used. Figure 4 below illustrates the differences between these two pattern types. It is also worth considering the use of the haptic feedback system for path guidance, as opposed to just gaze direction guidance. For a path guidance objective, the haptic feedback will continually update as the users move their heads to

continually guide the users towards their target. After the haptic system is developed it will be integrated with the SLAM navigation system to test its real-world gaze direction and path guidance functionalities.



Figure 4: (A) Static and (B) Dynamic Haptic Pattern

Auditory Feedback System

The hardware for the auditory feedback system is a pair of open-ear bone conduction headphones. These headphones were chosen with the aim to not overwhelm the users' senses, due to the open-ear nature of these headphones they can still hear noises from the world. The function and objective for this system is to provide users with the location of potential obstacles using sound. The name of an obstacle will be played to the users through the headphones and sound like it is coming from the direction of the objects. This mitigates the need for users to manually scan their surroundings for obstacles before moving.

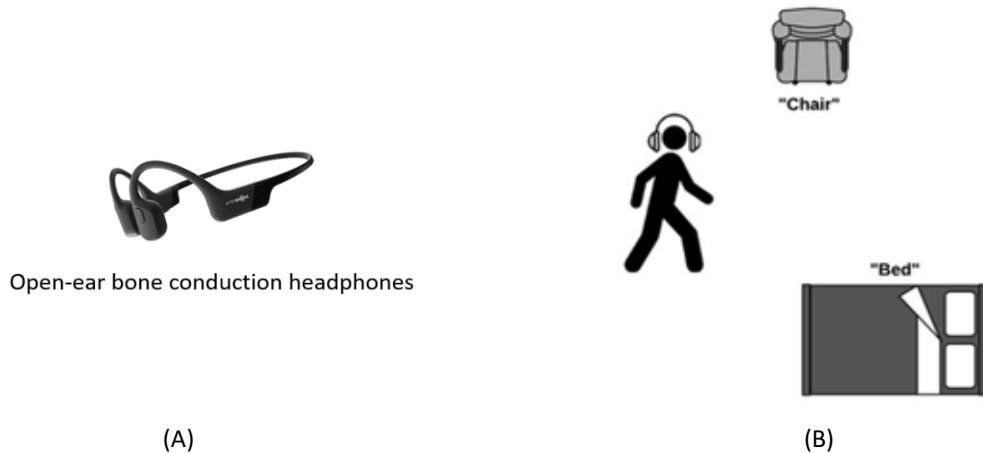


Figure 5: (A) Hardware and (B) Function and Objective of Auditory Feedback System

Similar to the development of the haptic system, the first step in developing the auditory feedback system will be to formulate an evaluation method and metrics which will be used to determine the accuracy and effectiveness of the system's localisation functionality. Following so, methods to individualise head related transfer functions (HRTFs) will be explored. HRTFs are what aids individuals in determining the location of a sound but are unique to each individual as they are dependent on various factors such as the shape of the head. Thus, generalized HRTFs do not translate well with everyone. There is especially a discrepancy between determining whether a simulated sound is coming from the front or back as well as up or down. Currently, individualised HRTFs are not well developed,

though there have been various methods suggested for creating personalization. Some of these methods will be explored as well as determining the possibility of using calibration to personalize a set of generalised HRTFs. Once the auditory feedback system has been developed it will also be integrated with the SLAM navigation system to test its real-world, real-time object localisation.

Participant Testing

Once both systems have been developed and integrated with the SLAM-based navigational system built by APL the system can be participant tested with Argus II users. Before testing can take place, an evaluation method and required metrics will be formulated. These will be used to evaluate the system's performance in terms of target navigation and obstacle avoidance.

Deliverables

The minimum, expected and maximum deliverables for this project are detailed below.

Minimum:

Operational haptic feedback system that can intuitively guide user's gaze direction

Expected:

Haptic feedback system and auditory feedback system that is able to assist users with obstacle localization

Maximum:

Integrated retinal prosthesis system with haptic and auditory feedback that has been user tested. Evaluation on the system's performance in terms of target navigation and obstacle avoidance as a result of the participant testing

Dependencies

There are not many dependencies for this project however they will affect the deliverables if they are not resolved in a timely manner. For both the haptic and auditory feedback systems the SLAM-based navigational system is required for full integration with the Argus II system. This also includes the necessary hardware such as cameras. The SLAM system itself has been developed and is currently in the refinement phase. The required cameras for the system have been obtained. The only outstanding hardware are the camera mounts – these are currently being 3D printed. If these mounts are not completed by 10 April 2022, then the subsequent tasks (testing of gaze and path guidance and object localisation in the real world and participant testing) will be delayed. If the delay is substantial (past 17 April 2022) it may not be possible to complete the participant testing in this timeframe as there should be at least two weeks of participant testing.

For the participant testing, the IRB training will need to be completed. Whether testing can take place also depends on participant availability. The IRB training can be completed in advance and thus will be done as soon as possible. A testing protocol currently exists, and the team members will simply need to be added to it to be able to perform participant testing. Furthermore, four weeks have been allocated to acquire participants. Ideally the testing will be done with Argus II users, however if they are not available it is possible to perform participant testing with seeing individuals. The system developed by APL does integrate with a VR headset which allows seeing individuals to see what Argus II users perceive. If it is still not possible to acquire the participants by 17 April 2022 then the allocated time for participant testing will be reduced and potentially may not be completed in this project timeline.

Table 1 summarises the dependencies mentioned above. The 'Latest Date' indicates the date after which a dependency is resolved the deliverables will be affected.

Dependency	Responsible Person	Plan of Action	Fallback Plan	Expected Date	Latest Date	Effect if not achieved
Mapping, SLAM navigation (incl. required hardware)	Mentors	Required parts have been made /ordered and delivered	Develop haptic and auditory system without SLAM navigation	28 Feb 2022	20 March 2022	No full integration with Argus II
IRB	An Chi	Do the required training as soon as possible		27 March 2022	17 April 2022	No participant testing
Participant availability	An Chi / Mentors	Start the participant recruitment 4 weeks prior to planned testing	Test system with seeing participants using VR headset	10 March 2022	17 April 2022	No participant testing

Table 1: Project Dependencies

Management plan

- Team members: An Chi
- Mentors: Dr Seth Billings and Chigozie Ewulum
- Weekly meetings are to be held on Mondays at 11am over zoom
- All other communication will be done via email
- Shared online drive for any documentation
- Shared Github for code

Key dates and Milestones

The milestones for the project as well as the anticipated completion dates are detailed in the tables below. The 'Latest Date to Be Completed By' provides the date after which if a task is still incomplete will result in delays in the planned schedule.

Haptic Feedback System

Milestone	Anticipated Completion Date	Latest Date to Be Completed By
Formulate evaluation method and metrics	27 February 2022	13 March 2022
Chose actuator type (ERM vs LRA)	27 February 2022	13 March 2022
Design and evaluate haptic feedback patterns	13 March 2022	27 March 2022
Investigate path guidance	20 March 2022	10 April 2022
Integrate with SLAM system	27 March 2022	17 April 2022

Table 2: Milestones for Haptic Feedback System

Auditory Feedback System

Milestone	Anticipated Completion Date	Latest Date to Be Completed By
Formulate evaluation method and metrics	27 February 2022	13 March 2022
Research methods to implement individualised HRTFs	13 March 2022	20 March 2022
Implement chosen methods	20 March 2022	27 March 2022
Test and evaluate implemented methods	3 April 2022	10 April 2022
Integrate with SLAM system	10 April 2022	17 April 2022

Table 3: Milestones for Auditory Feedback System

Participant Testing

Milestone	Anticipated Completion Date	Latest Date to Be Completed By
Formulate evaluation method and metrics	10 April 2022	17 April 2022
IRB training	27 March 2022	17 April 2022
Participant acquisition	10 April 2022	17 April 2022
Participant testing	1 May 2022	1 May 2022

Table 4: Milestones for Participant Testing

The figure on the following page is a Gantt chart illustrating the planned schedule. The anticipated start dates have been planned such that the tasks can be completed by the anticipated completion dates detailed above.

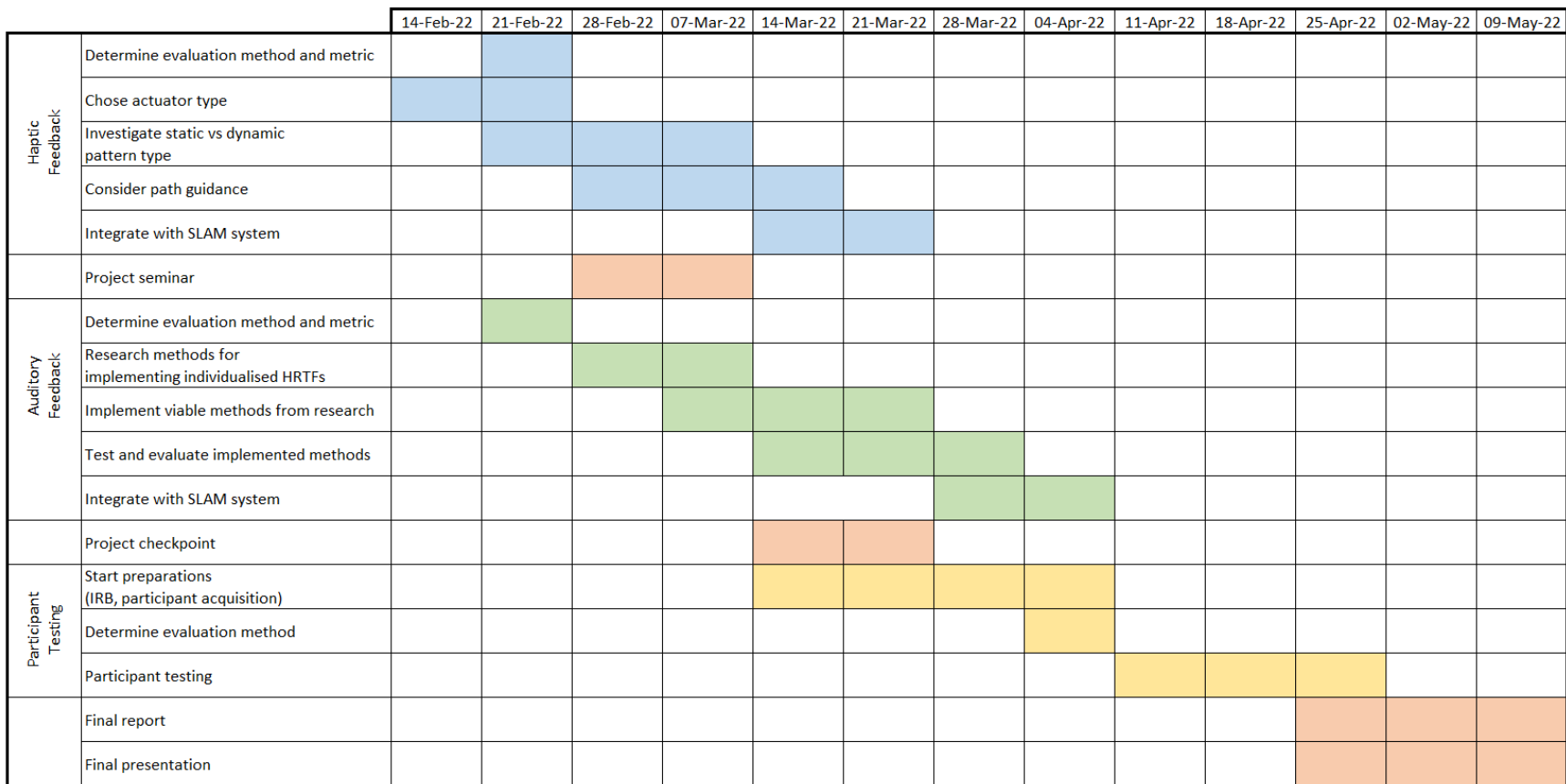


Figure 6: Gantt Chart for Planned Schedule

Reading List

- (1) Arevalo, J. F., Al Rashaed, S., Alhamad, T. A., Al Kahtani, E., Al-Dhibi, H. A., & KKESH Collaborative Retina Study Group (2021). Argus II retinal prosthesis for retinitis pigmentosa in the Middle East: The 2015 Pan-American Association of Ophthalmology Gradle Lecture. *International journal of retina and vitreous*, 7(1), 65. <https://doi.org/10.1186/s40942-021-00324-6>
- (2) U.S. Department of Health and Human Services. (n.d.). *Retinitis pigmentosa*. National Eye Institute. Retrieved February 28, 2022, from [https://www.nei.nih.gov/learn-about-eye-health/eye-conditions-and-diseases/retinitis-pigmentosa#:~:text=Retinitis%20pigmentosa%20\(RP\)%20is%20a,of%20side%20\(peripheral\)%20vision.](https://www.nei.nih.gov/learn-about-eye-health/eye-conditions-and-diseases/retinitis-pigmentosa#:~:text=Retinitis%20pigmentosa%20(RP)%20is%20a,of%20side%20(peripheral)%20vision.)
- (3) Farvardin M, Afarid M, Attarzadeh A, et al. The Argus-II Retinal Prosthesis Implantation; From the Global to Local Successful Experience. *Front Neurosci*. 2018;12:584. Published 2018 Sep 5. doi:10.3389/fnins.2018.00584
- (4) Kaul, O.B., Rohs, M., Mogalle, M., & Simon, B. (2021). Around-the-Head Tactile System for Supporting Micro Navigation of People with Visual Impairments. *ACM Transactions on Computer-Human Interaction (TOCHI)*, 28, 1 - 35.
- (5) Panëels, S.A., Anastassova, M., Strachan, S., Van, S.P., Sivacoumarane, S., & Bolzmacher, C. (2013). What's around me? Multi-actuator haptic feedback on the wrist. *2013 World Haptics Conference (WHC)*, 407-412.
- (6) Xu, S., Li, Z., & Salvendy, G. (2007). Individualization of Head-Related Transfer Function for Three-Dimensional Virtual Auditory Display: A Review. *HCI*.
- (7) Iida, K. *Head-Related Transfer Function and Acoustic Virtual Reality*. 1st ed. 2019.
- (8) Berger, C.C., González-Franco, M., Tajadura-Jiménez, A., Florêncio, D.A., & Zhang, Z. (2018). Generic HRTFs May be Good Enough in Virtual Reality. Improving Source Localization through Cross-Modal Plasticity. *Frontiers in Neuroscience*, 12.