Multisensory Navigational Aid for Visual Prosthesis Users

An Chi Chen

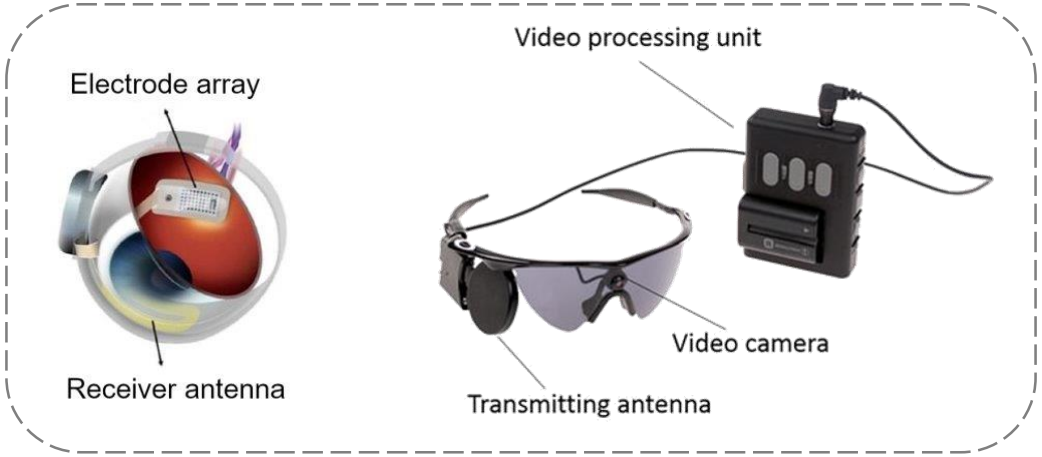
Mentors: Seth Billings, Chi Ewulum

APL JOHNS HOPKINS APPLIED PHYSICS LABORATORY

LABORATORY FOR Computational Sensing + Robotics

Background

- Argus II retinal prosthesis system is an artificial vision device for patients with end-stage Retinitis Pigmentosa
- Electrode array is implanted into patients' eye
- System accompanied with camera mounted on glasses and required processing system



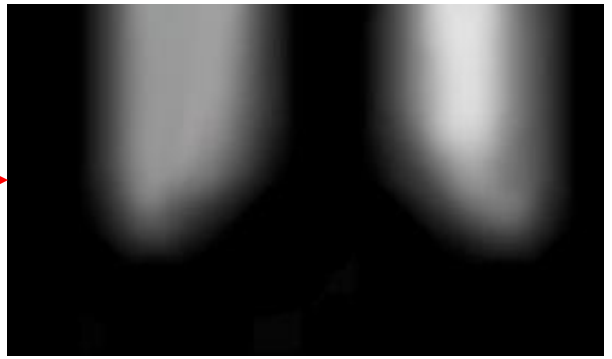
Argus II Retinal Prosthesis System

Background

- Camera input is used to stimulate retinal cells
- Perceived by user as light patterns

Camera Image

Output Stimulation Image



Perceived Image

Relevance

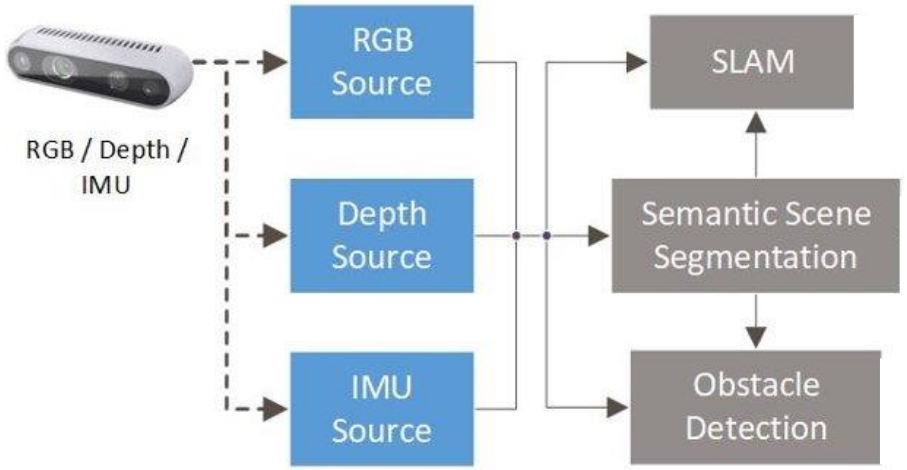
- Argus II visual feedback is limited
  - Some can distinguish limited light intensities
  - Others only distinguish on/off
  - Field of vision is limited

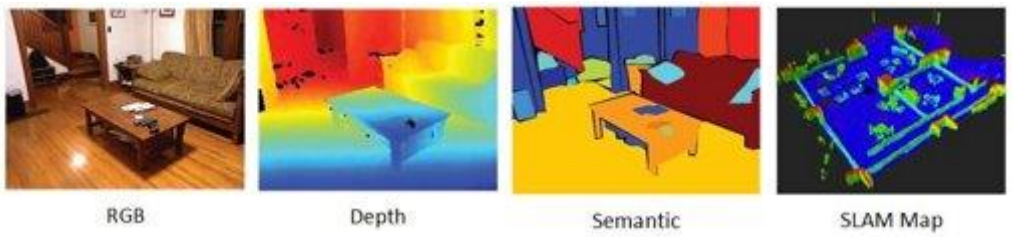
Goal

- Develop an haptic and auditory feedback system to supplement the Argus II retinal prosthesis system
- Assist with target navigation and object localisation
- Supplementary feedback systems should
  - Be intuitive for the user
  - Maintain low cognitive load

Project Background

- SLAM-based navigational aid using the Argus II developed by JHU/APL
- Can perform object detection

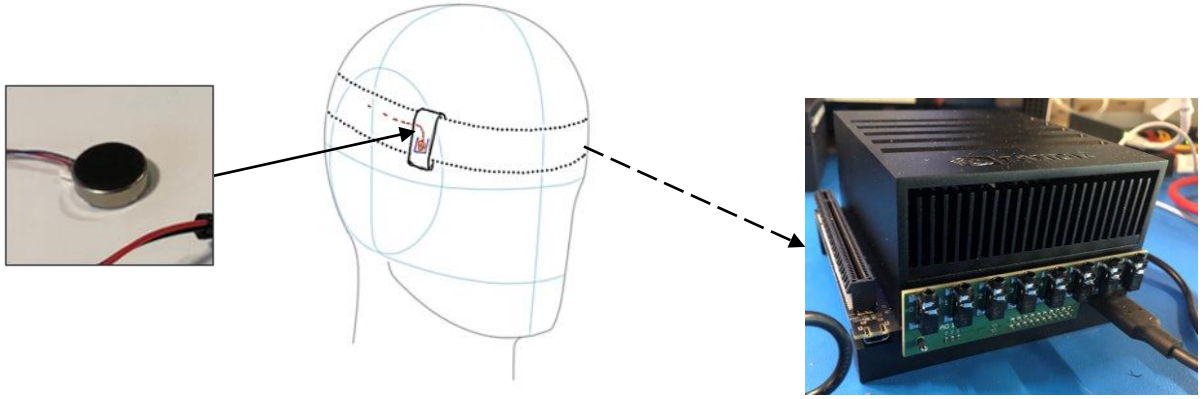




Technical Approach

- Haptic System

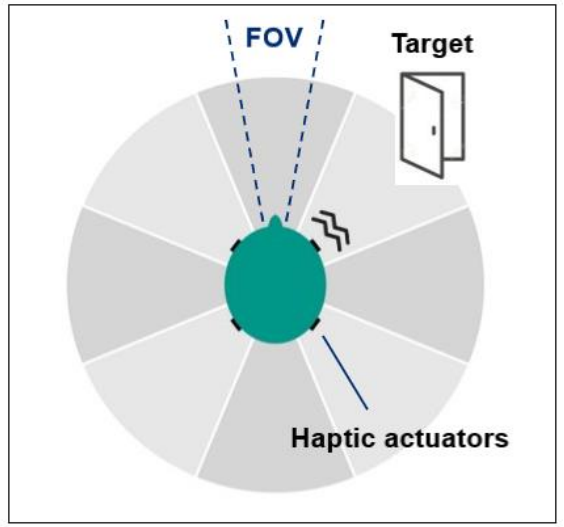
Hardware



Headband with 8 repositionable haptic actuators

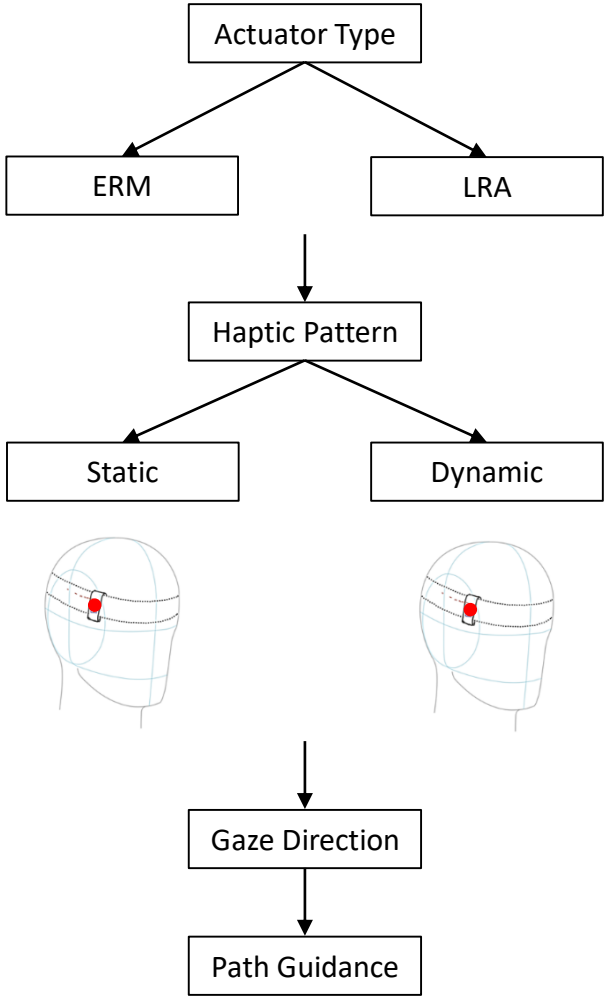
Custom 8-channel haptic driver

Functionality



Technical Approach

- Haptic System
  - Determine evaluation method and metrics
  - Investigate:
    - Actuator type (ERM vs LRA)
    - Haptic feedback pattern (static vs dynamic)
    - Gaze guidance and additional path guidance
  - Integrate with SLAM navigation and object detection



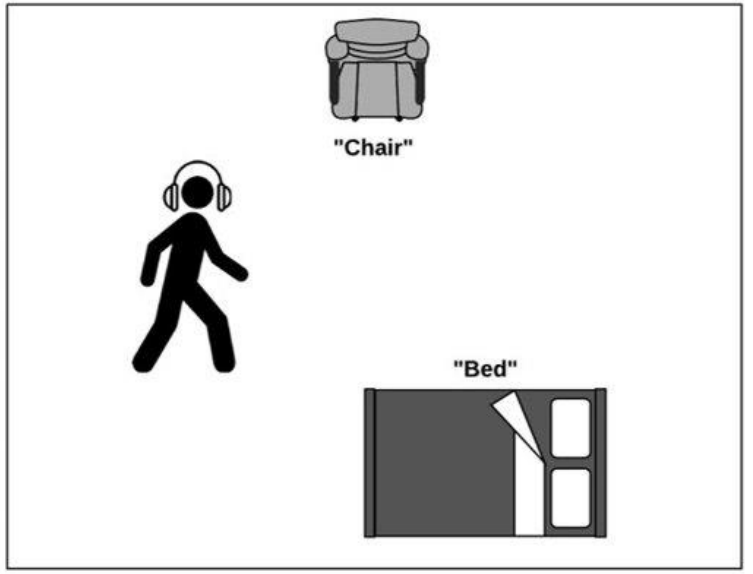
Technical Approach

- Auditory System

Hardware

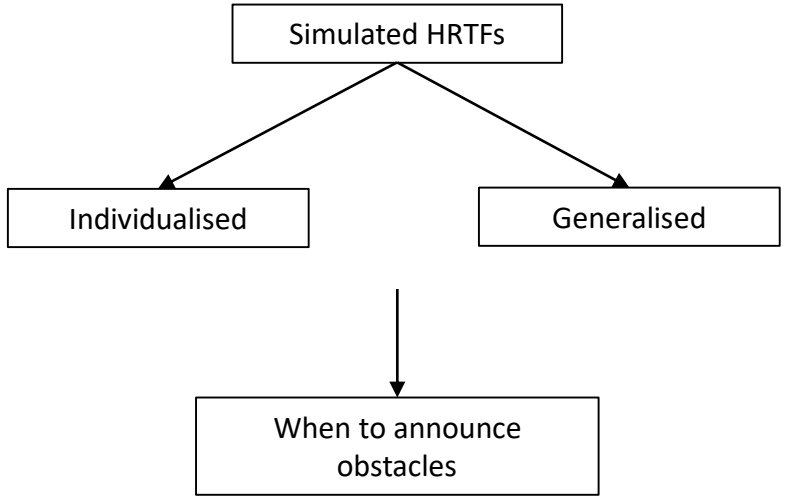
Open-ear bone conduction headphones

Functionality



Technical Approach

- Auditory System
  - Determine evaluation method and metrics
  - Investigate:
    - Simulated HRTFs
      - Individualise HRTFs or
      - Work around using generalised HRTFs
    - When to announce obstacles
  - Integrate with SLAM navigation and object detection



Technical Approach

- Participant Testing
  - Argus II users
  - Develop evaluation method
  - Determine evaluation metrics

Deliverables

- Minimum
  - Operational haptic feedback system with intuitive haptic patterns to guide users' gaze direction
- Expected
  - Haptic feedback system
  - Auditory feedback system for target and obstacle identification
- Maximum
  - Participant tested synergistic visual prosthesis system
    - Argus II system integrated with haptic and auditory feedback systems
  - Evaluation of integrated system's performance with target navigation and obstacle avoidance

Key Dates

		14-Feb-22	21-Feb-22	28-Feb-22	07-Mar-22	14-Mar-22	21-Mar-22	28-Mar-22	04-Apr-22	11-Apr-22	18-Apr-22	25-Apr-22	02-May-22	09-May-22
Haptic Feedback	Complete haptic headband													
	Chose actuator type													
	Determine evaluation method and metric													
	Investigate static vs dynamic pattern type													
	Consider path guidance													
	Project seminar													
Auditory Feedback	Research methods for implementing individualised HRTFs													
	Determine evaluation method and metric													
	Implement viable methods from research													
	Test and evaluate implemented methods													
	Project checkpoint													
Participant Testing	Start preparations (IRB, participant acquisition)													
	Determine evaluation method													
	Participant testing													
	Final report													
	Final presentation													

Dependencies

Dependency	Plan of Action	Fallback Plan	Effect if not achieved
Mapping, SLAM navigation (incl. required hardware)	Required parts are being made / ordered	Develop haptic and auditory system without SLAM navigation	No full integration with Argus II
IRB	Do the required training 2 weeks prior to planned participant testing		No participant testing
Participant availability	Start the participant recruitment 2 weeks prior to planned testing	Test system with seeing participants using VR headset	No participant testing

Key Dates

		14-Feb-22	21-Feb-22	28-Feb-22	07-Mar-22	14-Mar-22	21-Mar-22	28-Mar-22	04-Apr-22	11-Apr-22	18-Apr-22	25-Apr-22	02-May-22	09-May-22
Haptic Feedback	Complete haptic headband													
	Chose actuator type													
	Determine evaluation method and metric													
	Investigate static vs dynamic pattern type													
	Consider path guidance													
	Project seminar													
Auditory Feedback	Research methods for implementing individualised HRTFs													
	Determine evaluation method and metric													
	Implement viable methods from research													
	Test and evaluate implemented methods													
	Project checkpoint													
Participant Testing	Start preparations (IRB, participant acquisition)													
	Determine evaluation method													
	Participant testing													
	Final report													
	Final presentation													

Management Plan

- Mentors: Dr Seth Billings and Chi Ewulum
- Meet with mentors every Monday at 11am
- Email will be used as other means of communication when needed
- Shared online drive will be used for documentation
- Shared Github for code

Reading List

- 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
- 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
- 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.
- 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.
- Xu, S., Li, Z., & Salvendy, G. (2007). Individualization of Head-Related Transfer Function for Three-Dimensional Virtual Auditory Display: A Review. *HCI*.
- Iida, K. *Head-Related Transfer Function and Acoustic Virtual Reality.* 1st ed. 2019.
- 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*.