AI in Audiology

Leveraging technology to improve accessibility to healthcare

HLTH2001

Presented by
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clearwater

Quick introduction

- Ph.D. student in Electrical and Computer Engineering (Carleton, 2023)
- M.A.Sc. in Electrical and Computer Engineering (Carleton, 2018)
- B.A.Sc. in Chemical Engineering (Ottawa, 2016)
- B.Sc. in Biochemistry (Ottawa, 2016)

Research interests: Applied machine learning, computational biology, protein biochemistry, cancer
Hobbies: Songwriting, reading, drinking coffee (more than I should)

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Presentation Outline

Background

- Hearing loss and hearing
- Audiometry
- The SHOEBOX Audiometer, an assistive device
- The problem

Machine learning

- Machine learning v.s. AI
- Supervised learning

The SHOEBOX study

- Design requirements/research objectives
- Research and ethics
- Methodology
- Results
- Impact

Background

Prevalence of hearing loss

Approximately **1 out of 5 Canadian adults** suffer from **hearing loss that is at least mild**...

70% of them **do not know**...

Hearing Loss of Canadians 2012 and 2013, Statistics Canada, https://www.statcan.gc.ca/pub/82-625-x/2015001/article/14156-eng.htm. Accessed on October 16th, 2017.

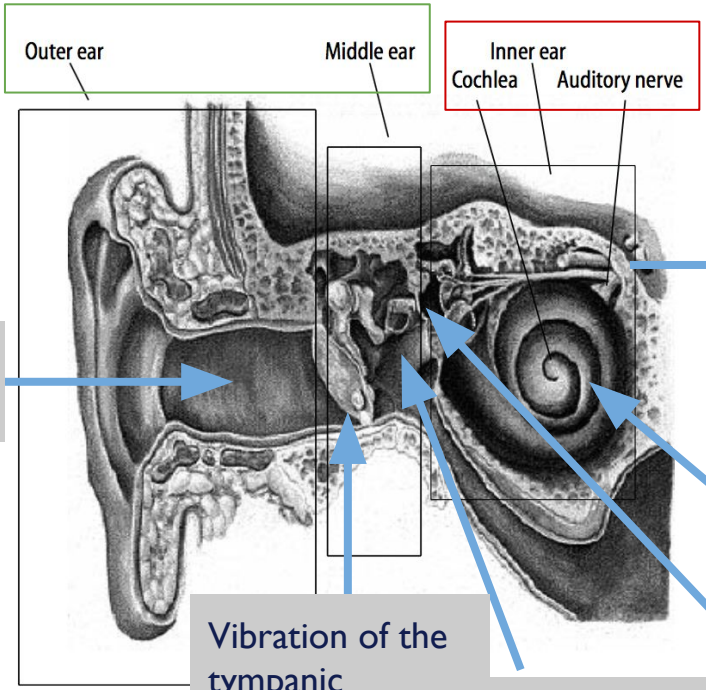
Consequences of hearing loss

The consequences of hearing loss are **economic**, **social** and **functional** in nature.

Deafness and Hearing Loss: Fact Sheet, World Health Organization, http://www.who.int/mediacentre/factsheets/fs300/en/. Accessed on October 16th, 2017.

Hearing: in a nutshell

Conductive hearing loss



Sensorineural hearing loss

Sound reaches ear canal

Vibration of the tympanic membrane

Sound transmission via the ossicular chain (impedance matching)

Vibration transmitted to the cochlea through the oval window opening

Stimulation of hair cells in the cochlea, sound becomes a nerve impulse

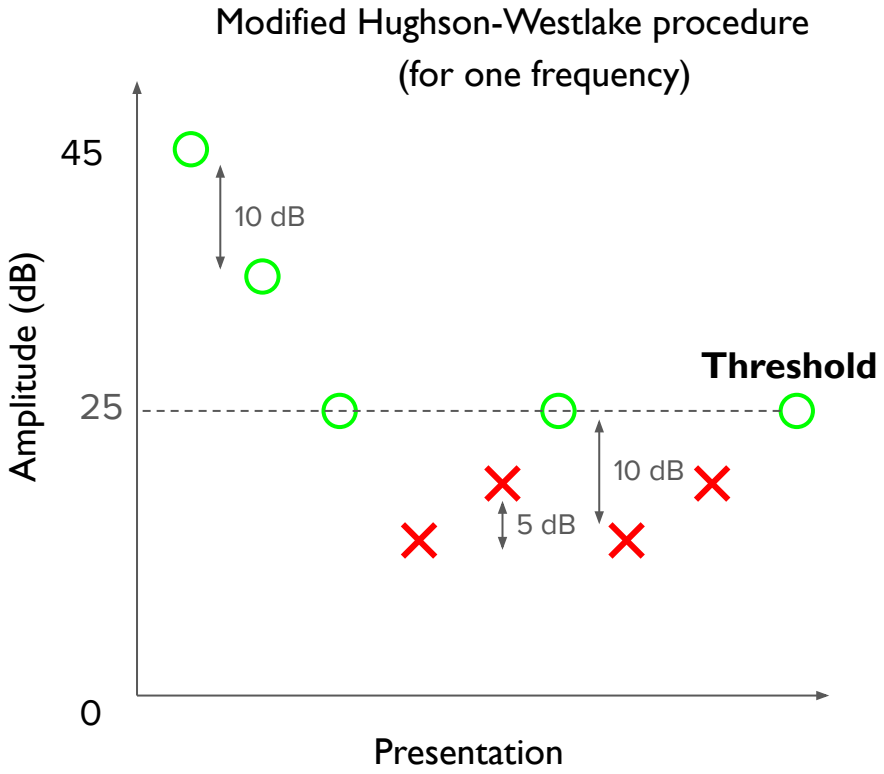
Nerve impulse is transmitted to the brain through nerve IIX

Hersh & Johnson (2003)

Hearing measurements: pure-tone audiometry

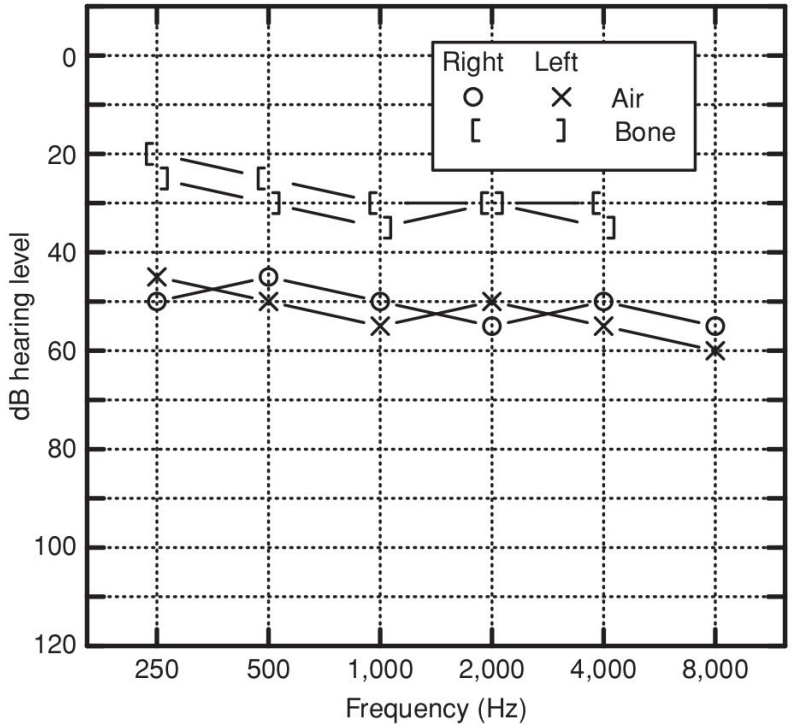
- **Gold standard** of hearing assessment
- Delivery of **pure tones** at **standard frequencies**
- Determines the **threshold of hearing** at frequencies delivered to the patient
  - Faintest amplitude at which a sound is heard
- Controlled environment (sound booth)
  - Acceptable background noise levels specified by ANSI standards

Threshold of hearing estimation



Carhart, R., & Jerger, J. F. (1959)

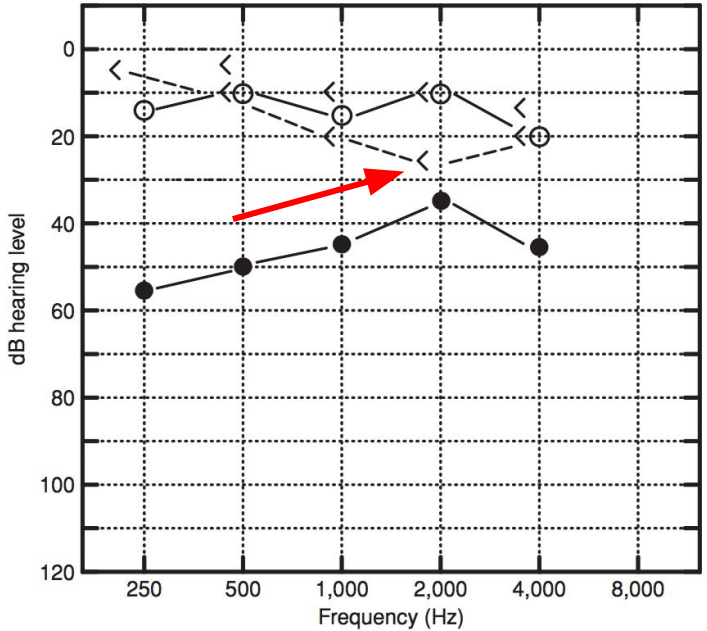
The audiogram



Schlauch and Nelson (2015)

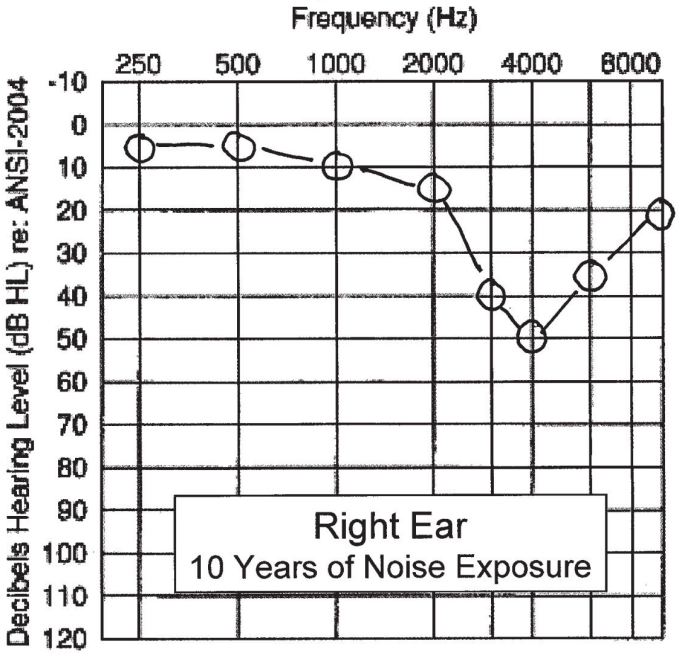
Audiograms and disease

Otosclerosis



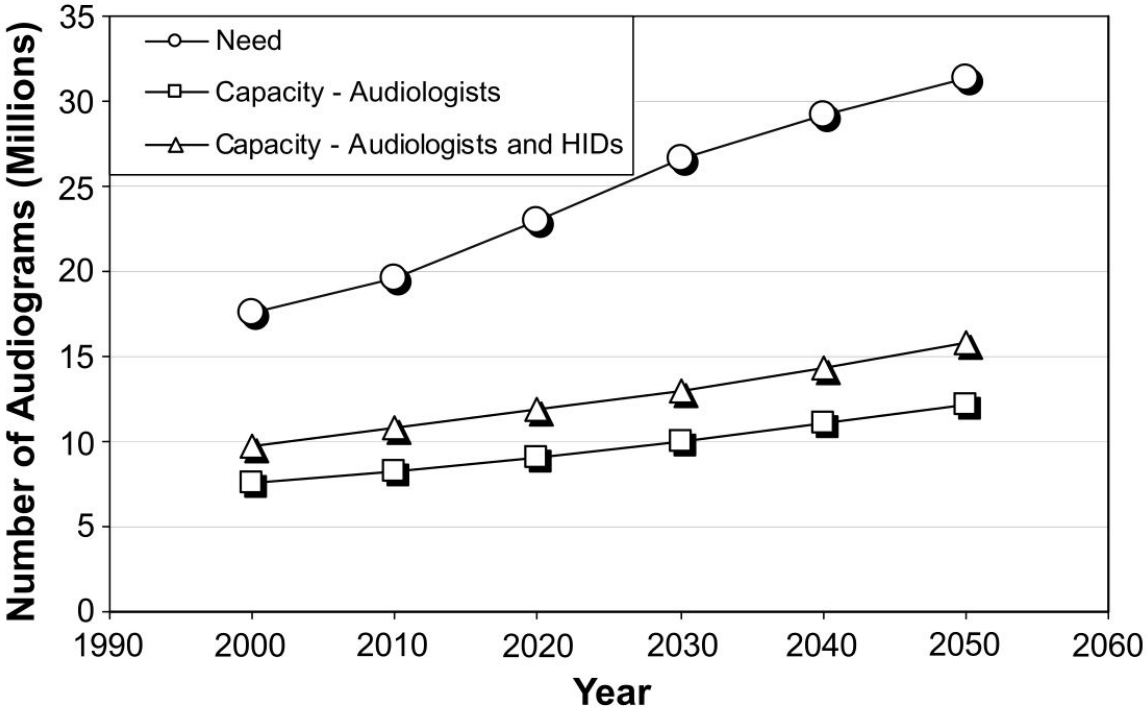
Schlauch and Nelson (2015)

Noise-induced hearing loss



Taylor and Mueller (2010)

Availability of hearing healthcare professionals

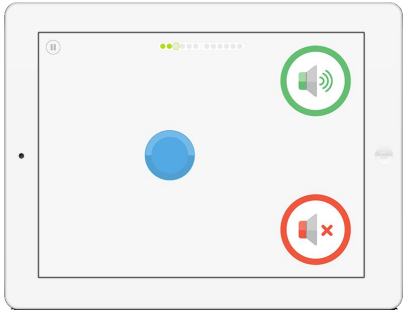


Margolis, R. H., & Morgan, D.E. (2008)

SHOEBOX Audiometry

What is it?

- Audiometry (hearing test) application for iPad
- Standard and Pro versions
- Clinically validated for use outside the sound booth



SHOEBOX Audiometry Interface

Applications

- Telemedicine applications
- Schools, hospitals, retirement homes, workplace, etc.

SHOEBOX Audiometry: an assistive device

Benefits:

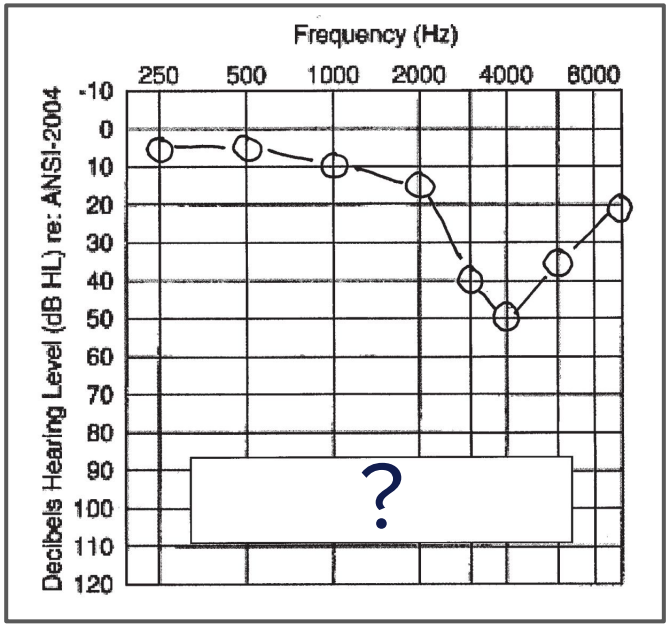
- Ability to bring healthcare to underserved communities
- Low cost
- Highly accessible

Risks/hazards:

- Misinterpretation of the device's output; false negatives
- Misuse of device (uncalibrated device, etc.)

The problem

Many non-specialist users of SHOEBOX Audiometry have **limited experience with audiogram interpretation**.

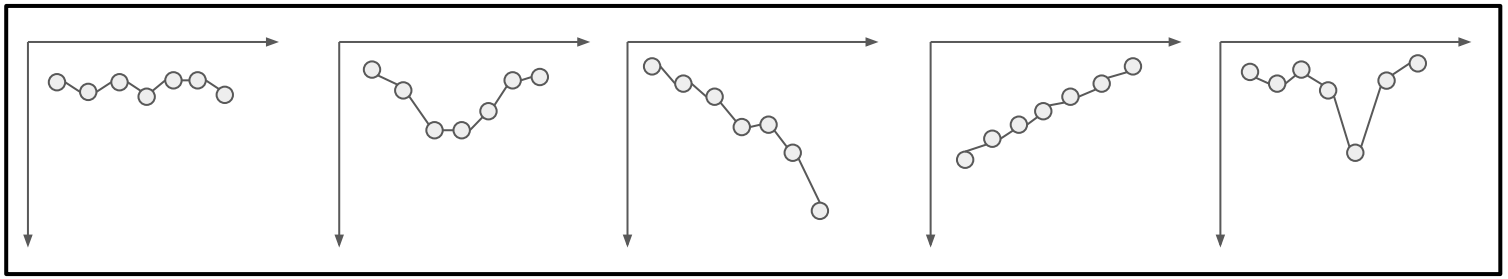


Taylor and Mueller (2010)

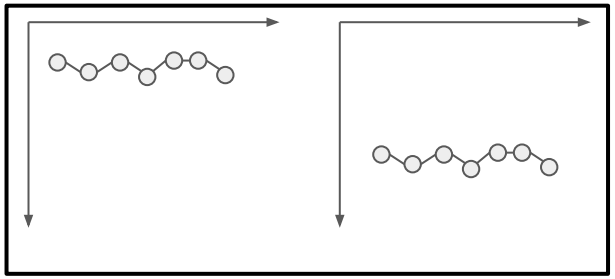
Categorizing audiograms for diagnosis

AMERICAN SPEECH-LANGUAGE-HEARING ASSOCIATION

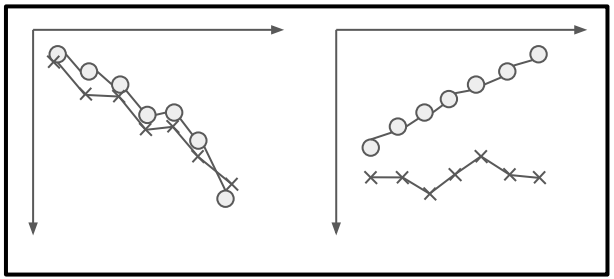
Configuration (or morphology)



Severity



Symmetry



The problem that needs solving

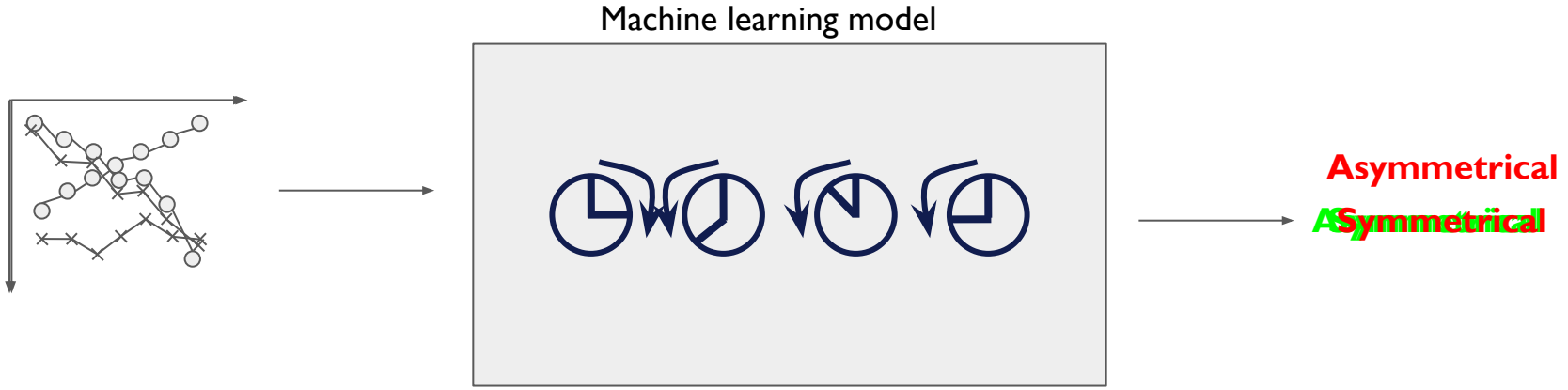
Can we automatically classify audiograms so that a non-expert can interpret it?

In the long term, we could establish a **differential diagnosis** ordered by probability and **integrate additional sources of data**.

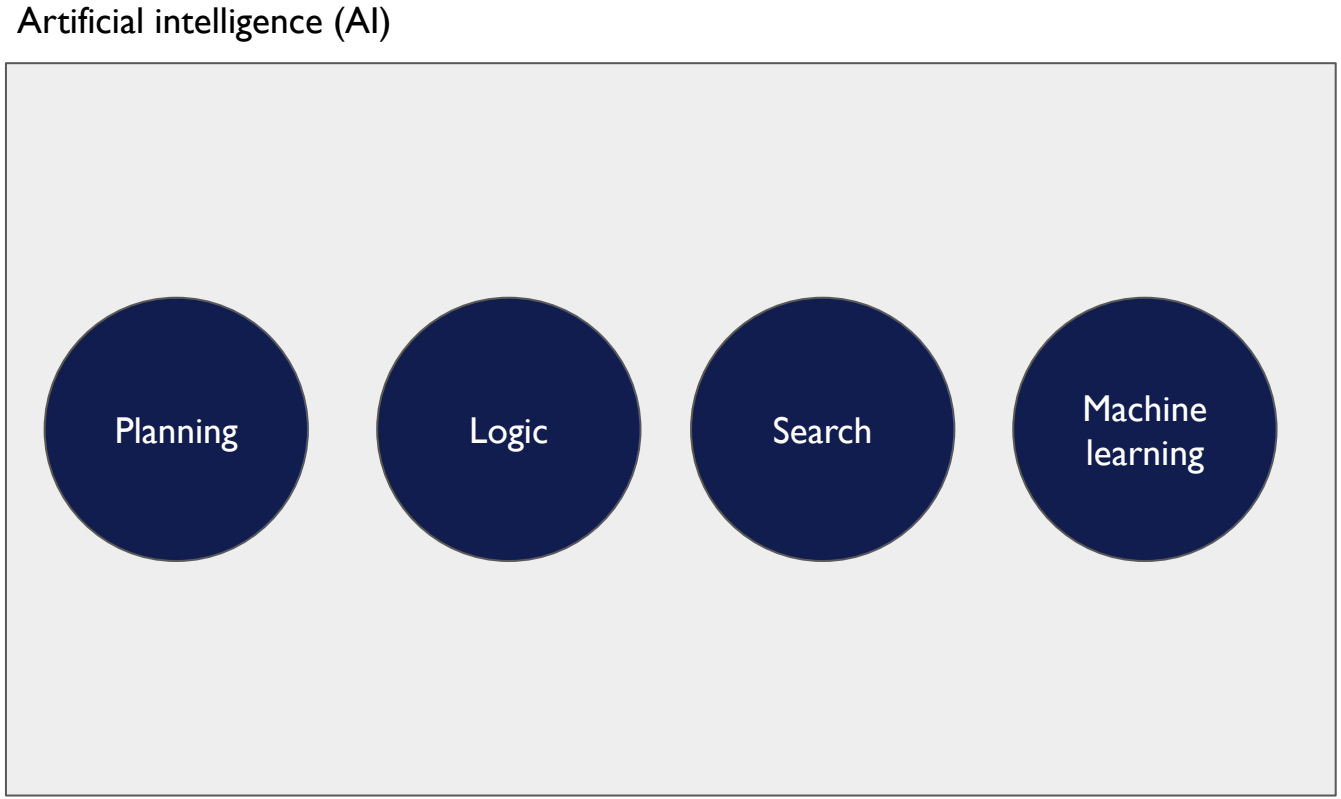
Generating **classifications/descriptions** can significantly improve the tester's **ability to make optimal decisions**.

Machine learning

Machine learning: the idea behind supervised learning



Machine learning: a speciality within AI



Supervised learning

- Very popular for healthcare applications
  - Predicting risk of diseases based on EHR
  - Distinguishing healthy sample/disease sample, etc.
- Model learns from exposure to data and the desired target variable
  - Adjust parameters so that model correctly predicts output for input data
  - Find the association between patterns in the data and the target variable value
- Requires labeled data
  - E.g. Audiograms that have already been reviewed by audiologists
- Assumption that there is a single right answer
  - Is there a single right answer in subjective tasks?

The SHOEBOX Study

Goals and design requirement

Goal: Develop machine learning models capable of classifying audiograms by configuration, symmetry and shape.

Design requirements:

- System should handle incomplete audiograms
- Should be able to return an estimate of confidence
- System should identify potentially unreliable audiograms

Research plan

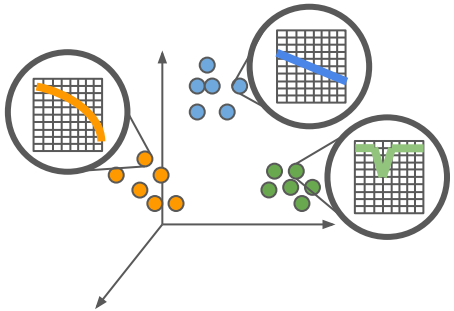
1. Assembling a dataset

2. "Ambiguity" labeling

Popular rule-based classification system

"Easy"/"challenging"

3. Mining (clustering & sampling)



4. Annotation

5. Train machine learning models

Getting ethics board approval

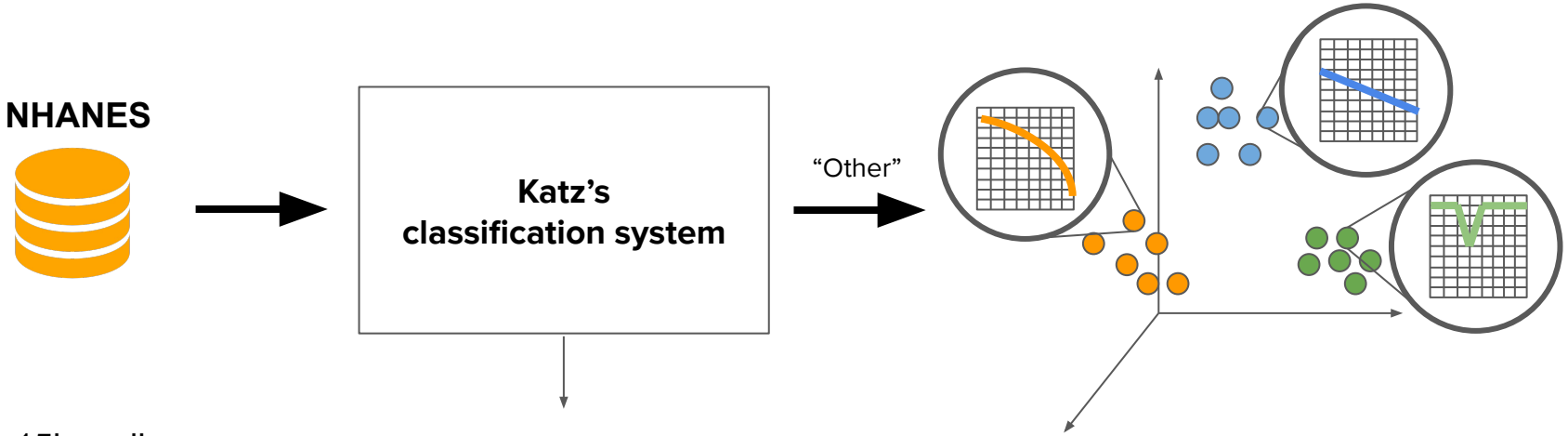
Research ethics board (REB) approval is required if research involves:

- Human participants
- Animals
- Biohazards and/or biological samples

What does an REB application entail?

- Rights of the participant (e.g. withdrawal)
- Detailed methodology
- Detailed analysis of risks, consequences, and means taken to mitigate them
- Data acquisition, storage, privacy, and destruction
- Participant compensation (if any)
- Conflicts of interest or relationship which may enable coercion

Preparing a dataset for annotation by audiologists



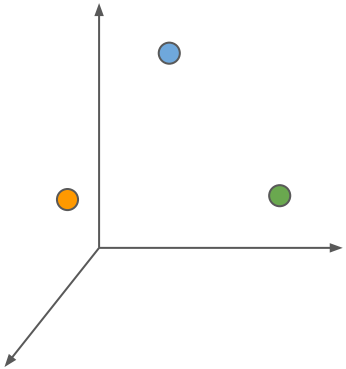
15k audios

Both ears classified as one of:
"Flat"
"Gradually sloping"
"Sloping"
"Rising"

9.8k audios

Preparing a dataset for annotation by audiologists (cont'd)

Pick a representative example of each cluster



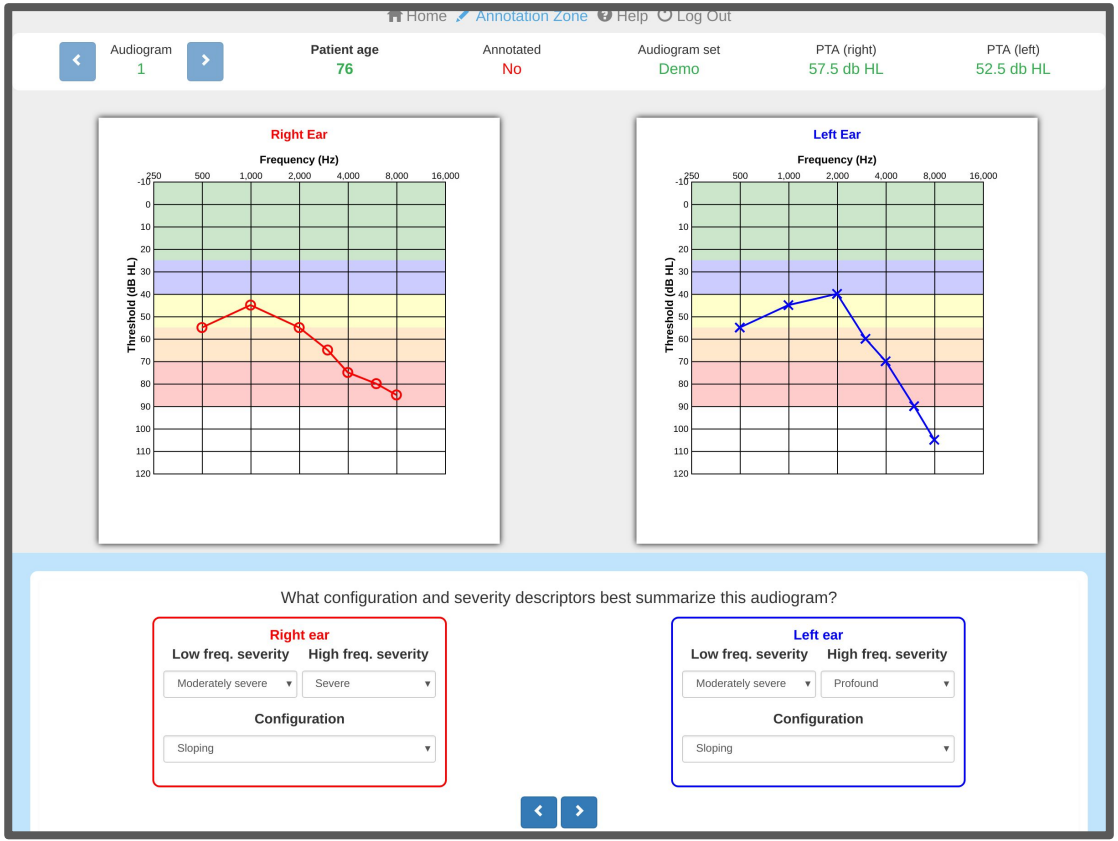
Assign a score that accounts for:

- Dissimilarity
- Cluster size

Audiogram	Score
#144	0.587
#977	0.582
#663	0.578
…	...

Pick top 270

Annotation with the Rapid Audiogram Annotation Environment



Results published in IEEE MeMeA

Mining Audiograms to Improve the Interpretability of Automated Audiometry Measurements

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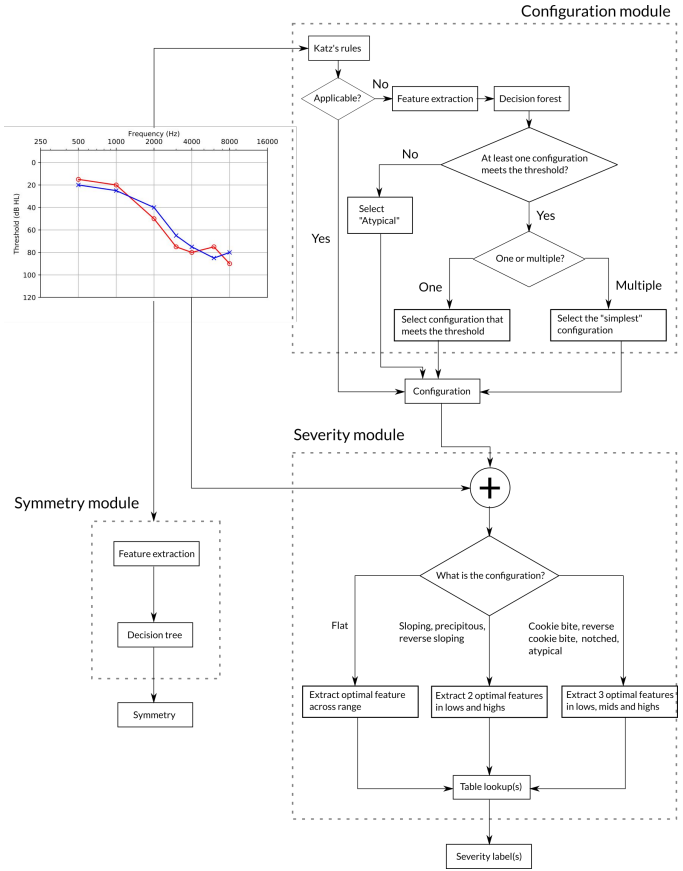
***Abstract*—Many people with hearing loss are unaware of it and do not seek benefit from available interventions such as hearing aids. This is in part due to the limited accessibility to qualified**

disabling hearing loss in adults is associated with higher risks of unemployment [4], lack of self-esteem [5] and accidents in the workplace [6], among others. Early detection and

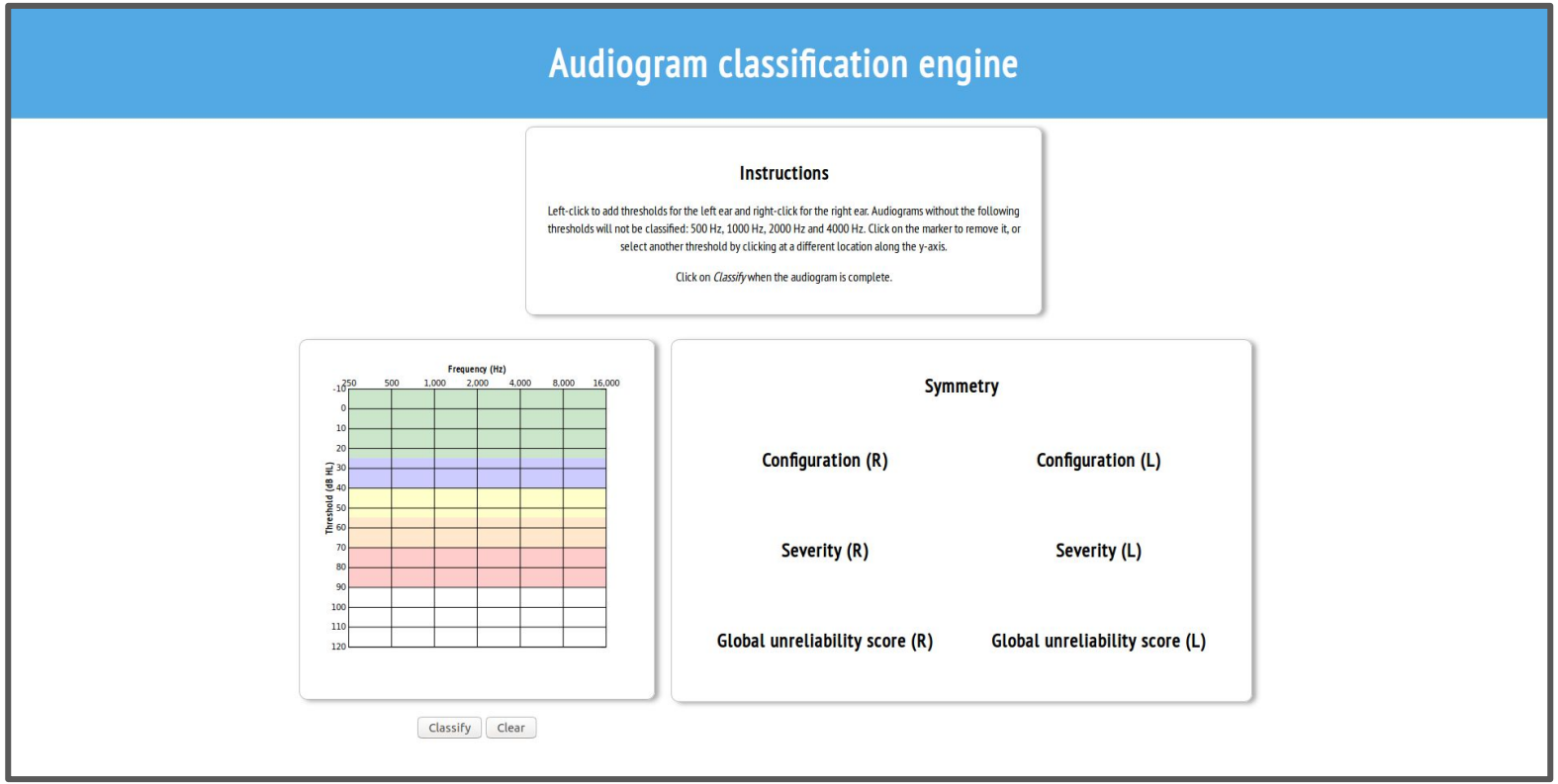
F. Charih, M. Bromwich, R. Lefrançois, A. E. Mark, and J. R. Green, "Mining Audiograms to Improve the Interpretability of Automated Audiometry Measurements," in *Proceedings of the 2018 IEEE International Symposium on Medical Measurements and Applications (MeMeA)*, Rome, Italy, 2018.

Topic of the paper: Presentation of an optimal sampling strategy for audiograms.

Trained machine learning models and integrated into a single system



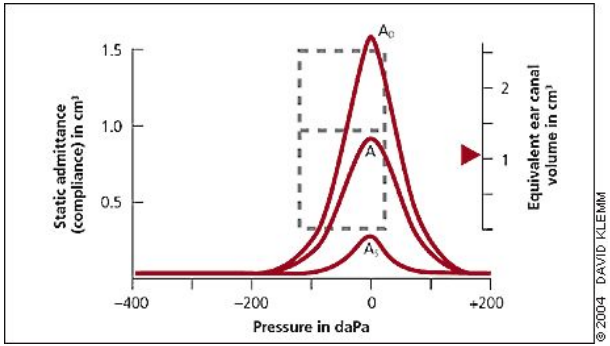
A demo of the classification system



What now?

- Currently integrating in the SHOEBOX
- Can we use otoscopy images and tympanogram data in addition to the audiogram?
- Can we integrate a diagnosis?
- Can we recommend the adequate type of referral
  - Physician
  - ENT surgeon
  - Audiologist
  - Hearing aid specialist

An otoscopy image



A tympanogram

Thank you! :)