

# Extending the SHOEBOX Audiometry mobile audiometer with an automated audiogram classification system



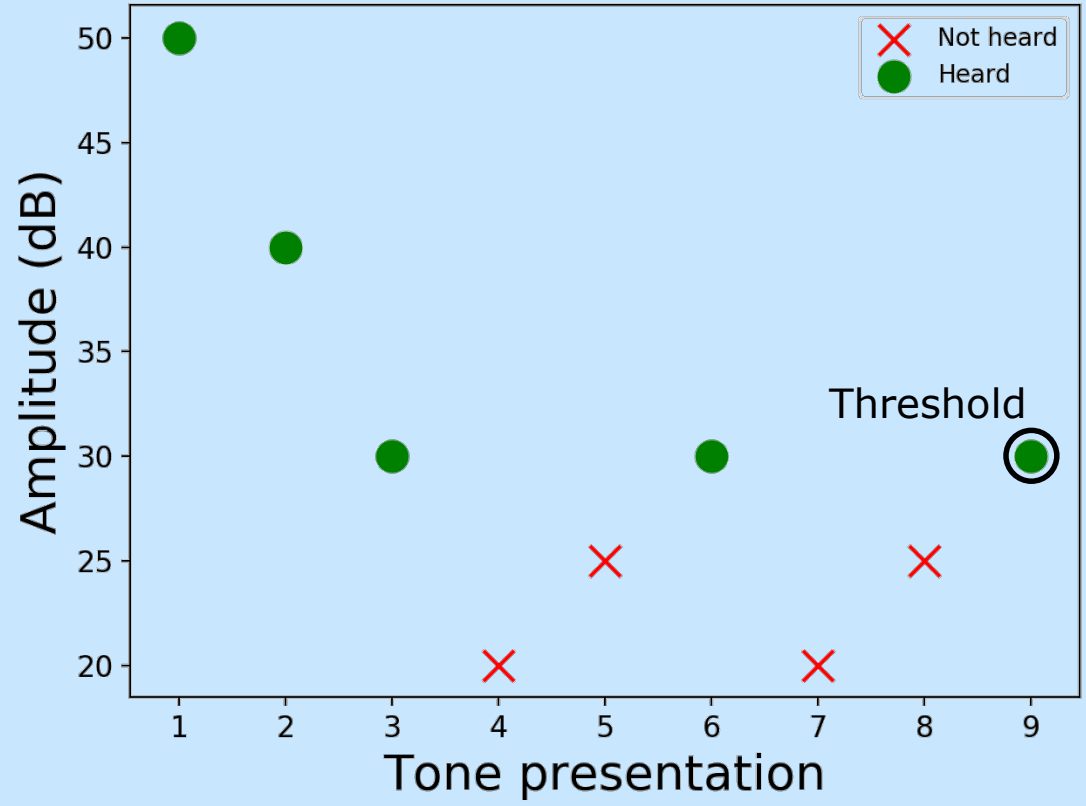
François Charhi<sup>1</sup>, Matthew Bromwich<sup>2,3,4</sup>, Renée Lefrançois<sup>2</sup>, James R. Green<sup>1</sup>  
<sup>1</sup> Department of Systems and Computer Engineering, Carleton University, Ottawa, ON <sup>2</sup> Clearwater Clinical Limited, Ottawa, ON  
<sup>3</sup> Department of Otolaryngology, Children's Hospital of Eastern Ontario (CHEO), Ottawa, ON <sup>4</sup> Faculty of Medicine, University of Ottawa, Ottawa, ON

## Abstract

The SHOEBOX Audiometry mobile audiometer application for iPad co-developed by Clearwater Clinical Ltd. and CHEO enables audiologists, ENTs and other healthcare providers to generate reliable audiograms outside of a conventional sound booth. While SHOEBOX Audiometry can automate the delivery of a standard hearing test for non-expert users, the issue of audiometric data interpretability has remained an important challenge that limits the reach of the application. In this project, we aim to develop an audiogram classification system capable of generating standardized audiogram annotations describing, among others, the configuration and severity of the hearing loss. A semi-automated system that enables users to review and optimize automated annotations will be built and assessed in a user study. Ultimately, this project will enhance the interpretability of SHOEBOX-generated audiograms, and tighten the gap between the audiogram and the final diagnosis.

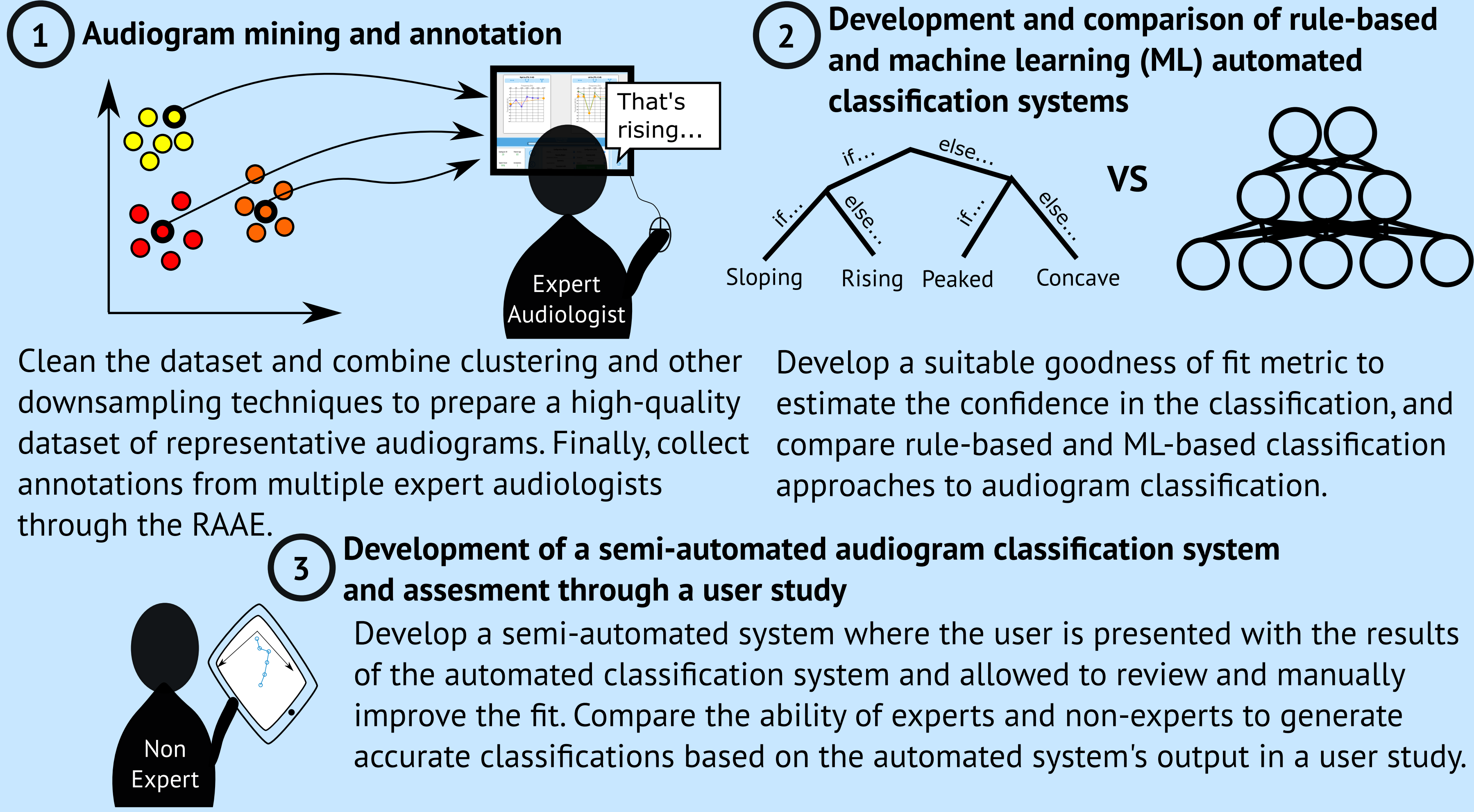
## Introduction

- Pure-tone audiometry is a psychophysical procedure where a series of pure tones are delivered to a patient. The tester estimates hearing thresholds based on the amplitude required to elicit a consistent and reliable positive response to the stimulus from the patient [1].
- SHOEBOX Audiometry automates threshold estimation by means of a modified Hughson-Westlake down-up procedure [2] which can be delivered manually or automatically.



- Figure 1.** SHOEBOX Audiometry's interface in manual mode
- Figure 2.** Threshold determination via a modified Hughson-Westlake procedure
- A considerable proportion of SHOEBOX's users are not trained to interpret audiograms, which hold a wealth of information regarding the patient's hearing. Such users would greatly benefit from a clinical decision support system that assists them with audiogram interpretation.
  - This project aims to overcome limitations of existing rule-based classification systems [3] which are rigid, do not improve with increasing amounts of data, do not provide an estimate of the classification accuracy, and, finally, do not attempt to establish a mapping between the audiogram and etiologies consistent with it.

## Automated and semi-automated audiogram classification systems



## The Rapid Audiogram Annotation Environment (RAAE)

- A responsive web application**
- The RAAE allows for the rapid generation of ground-truth annotations for thousands of anonymized SHOEBOX-generated audiograms.
  - The layout adapts to PCs and tablets.
  - Annotations by authenticated annotators are stored in an AWS database.
- An easy-to-use data collection tool**
- The annotator selects the most appropriate descriptors from standardized lists for configuration, severity, symmetry, ambiguity and etiology consistent with the available data.
  - Mathematical models are manually fit to the audiogram by dragging control points to capture the annotator's intuition.



Figure 3. The Rapid Audiogram Annotation Environment dashboard

**The RAAE is powered by**

React UI

Redux State management

amazon web services Web server/database

express Web server

Data-Driven Documents Plotting/Manual curve fitting

## References

[1] Schlauch, R. S., & Nelson, P. (2015). Puretone Evaluation. In J. Katz, M. Chasin, K. English, L. J. Hood, & K. L. Tillery (Eds.), Handbook of Clinical Audiology (Seventh Ed., pp. 29–47). Wolters Kluwer.  
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## Acknowledgments

We would like to extend our gratitude to Clearwater Clinical Ltd., our industrial partner, and to the funding agencies supporting this project.

