iTracker

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ECE 1778 - Creative Applications for Mobile Devices
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Introduction:

One of the most common basic physical examination skills that are expected of most primary care physicians is the examination of eye movements (or extraocular movements), and being able to determine whether there are any disorders in the movements. This examination is performed routinely during periodic/annual health examinations with ones family physician, and also in acute-care settings, such as in the context of an acute stroke or head injury.

The extraocular movement examination is performed by asking the patient to move their eyes (without moving their head) while following an object (e.g., a left index finger) in different directions – left, right, up-left, down-left, up-right, and down-right. This is termed the "six cardinal movements", and it provides a gross assessment of eye movements, also called the "extraocular" movements. As such, an assessment of the relevant (cranial) nerves, their associated muscles, and the muscle actions can be assessed for each eye. Any abnormalities detected in the coordinated movements of the eyes may suggest an underlying condition, such as a stroke, or brain tumor.

Unfortunately, like many examinations in medicine, and despite significant inter-observer reliability (e.g., most trained physicians will note the same gross abnormalities in movements), the examination of the extraocular movement is inherently subjective. Compared to other areas of medicine, such as the examination of the heart using a stethoscope, detecting abnormal heart sounds (or murmurs) is also analogously subjective. Consequently, patients are often sent for non-invasive, and relatively low-cost objective testing, namely a 2D-echocardiogram. However, for any eye movement disorders, patients are often referred to one of the few sub-specialists (e.g., Neuro-Ophthalmologists) across Canada, who may decide to do more specialized, and often time-consuming testing and investigations.

Accordingly, aside from the inherently subjective physical examination, there are no currently available low-cost, non-invasive tools available to objectively evaluate for disorders of eye movements. With the advent of the Apple iPhone in 2007, and Google Android platform in 2009, innovations in mobile phone, particularly video camera technology, have resulted in rapid advances and vast arrays of new tools available to healthcare professionals.

Consequently, our **goal** was to develop a novel application that augments the clinical eye examination using a mobile phone camera to detect and capture normal and abnormal eye movements – easily, accurately, in a low-cost and non-invasive manner.

Overall Design:

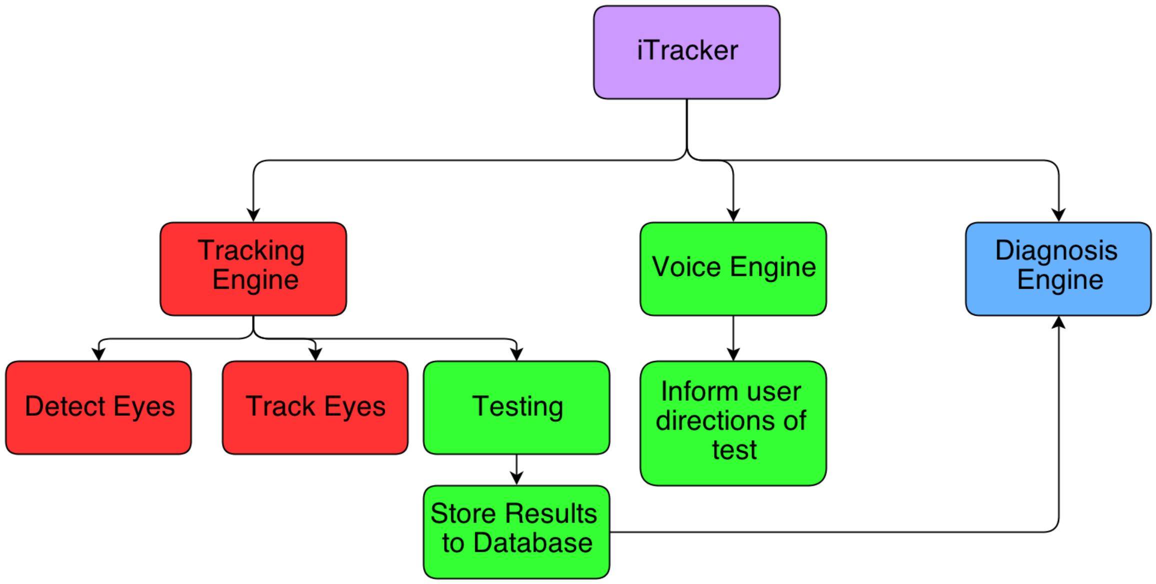


Figure 1. *Block diagram for iTracker Android mobile application.*

The overall block design is shown in Figure 1.

Functionalities of each component:

- Tracking Engine:
    - Utilizes OpenCV on Android to detect and track eyes using open-source algorithms based on Haar Classifiers.
- Voice Engine:
    - Utilizes the Google Android TTS Engine to provide computerized voice feedback during each step of testing
- Database:
    - SQLite database storing images and image processing data
- Diagnosis Engine:
    - Utilizes image processing data (e.g., eye coordinates) which are passed through physician designed algorithms (pending final implementation) to detect normal versus abnormal eye movements

Functionality and Screenshots:

iTracker was designed to have the following main functions:

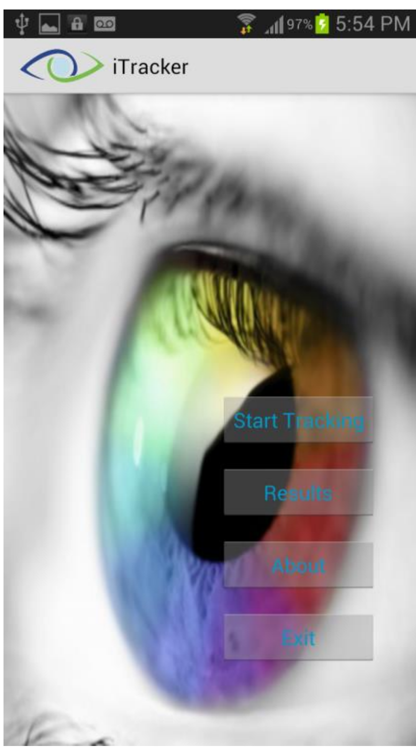
1. Eye Detection
2. Eye Movement Testing
3. Eye Position Review
4. Diagnosis Engine

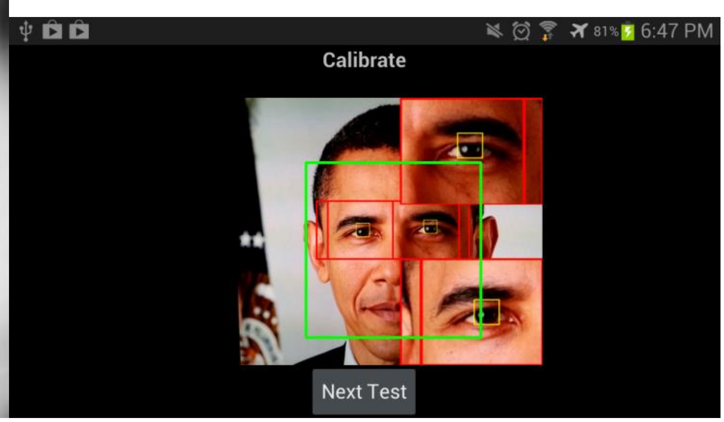
This functionality can be demonstrated by the following walkthrough:

Step 1 – Start Tracking:
The user is brought to the main screen for eye detection and calibration. The user should then hold the mobile phone approximately 1 foot away from the patient's face. The patient should then be asked to look straight ahead into the camera.

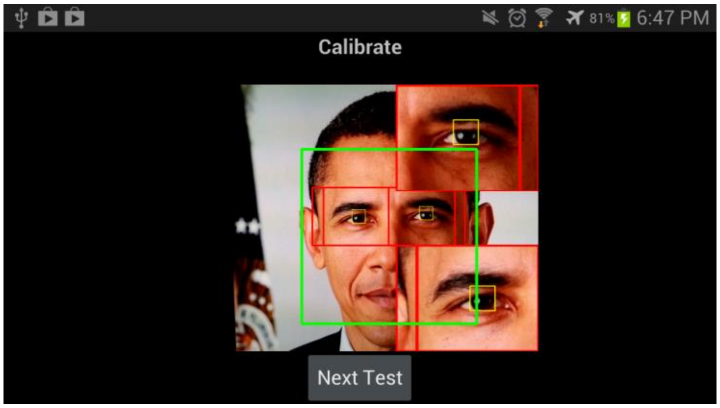
At this point, the app will perform the following detection:

1. Face – will be surrounded by a green coloured rectangle
2. Eye Orbits – will each be surrounded by a red coloured rectangle
3. Eyes – will each be surrounded by a yellow coloured rectangle
4. Pupils – will each be marked by a bright point

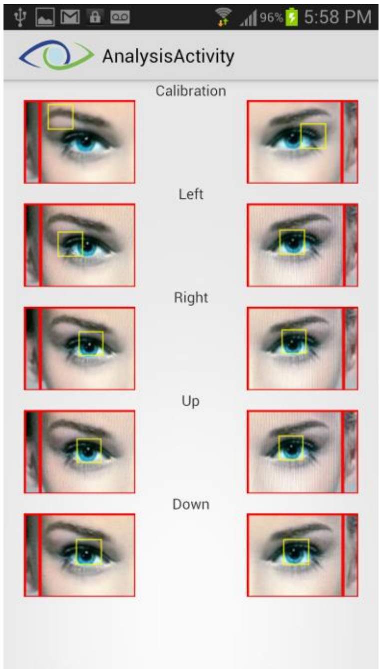




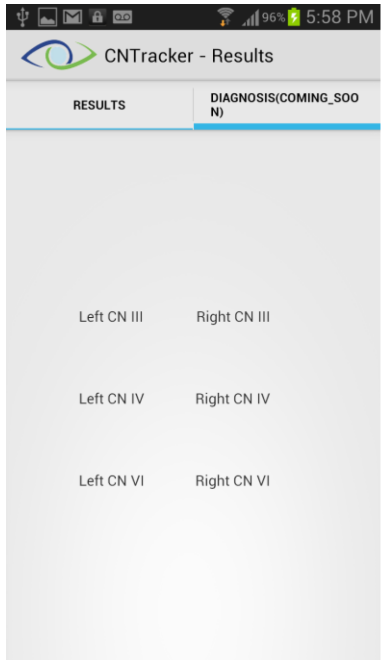
Step 2 – Start Testing:
Once the image has been calibrated, the user can click on “Next Test” to advance the testing. Both on screen prompts and a computer voice will instruct the patient to look towards four specified directions (up, down, left and right) to complete each step of the test. Upon completion on testing, the user will be brought to the results screen.



Step 3 – Review Results:
The results screen will allow the user to review the position of each eye, initially and in each of the four specified directions. These images can be reviewed clinically, and also downloaded off the mobile phone and stored into a patient’s health records.



Step 4 – Diagnosis:
In the background, the diagnostic engine is performing an analysis of each eyes position. A provisional diagnosis is then provided to the user, along with additional diagnostic considerations which the clinician can review further.



Functionality Issues and Limitations:

Eye Detection:
The App can generally detect eyes/pupils with high accuracy in ideal environmental conditions including having the patient stationary/seated and having adequate lighting. In less ideal conditions, the accuracy can be quite variable, and in some cases, either one, or no eyes/pupils are detected. Additionally, there may be more optimized eye detection algorithms available that can improve the detection accuracy, which will require ongoing research by our team.

Diagnosis:
The App is currently quite limited with regards to diagnostic capacity and provides limited/no accurate diagnoses at this stage. Limited algorithms have been developed that can provide a "normal" diagnosis, and four additional diagnoses for each eye – namely the abnormal movement in one of the four linear directions. However, extracting accurate positional data from the eye/pupil detection proved to be a far more challenging endeavor than our programmers had anticipated – particularly due to limited knowledge of OpenCV. This is further complicated by the currently limited accurate eye/pupil detection as noted previously. We will continue to explore OpenCV to determine how the positional data of each eye/pupil can be extracted and mapped – and enable the algorithms to provide a provisional diagnosis.

Key Learning:

Team Member:	**Key Learning:**
Baieruss	Learned to convey field-specific medical knowledge to non-healthcare professionals Learned to design algorithms for eye disorder detection
Babak	Learned the basics of OpenCV Learned image processing under OpenCV Learned Android development for the first time Learned eye anatomy – structure and function
Jeff	Learned the basics of OpenCV Learned Android UI design Learned eye anatomy – structure and function

Group Member Contribution:

Group Member:	**Contribution:**
Baieruss	Role of team leader – organized team meetings and collaborative efforts Construction of presentations for each spiral Construction of initial project reports and final report Design of eye detection algorithms (pending implementation) Input for user interface Discussion with clinical specialists on (eventual) testing of App on patients
Babak	Voice engine OpenCV image capture code Database design Display of final results page
Jeff	User Interface design Set up common source code repository (GitHub) Set up initial source code using inputs from several open source code repositories

Apper Context:

Whether it is Android or iOS, there has been an ongoing paucity of medical applications, particularly using a mobile phone as a diagnostic aid or device. As of April 10, 2013, not a single top 50 application on the Google Play App Store 'Medical' section uses a single sensor on the phone! Our App was therefore conceived to attempt to bridge this gap, and to further the utilization of mobile phones in clinical diagnostics.

As a primary care physician, who practices in outpatient, inpatient, and emergency department settings, I have observed that the use of mobile phones as a diagnostic tool has been limited to non-existent thus far. Additionally, as a practitioner in downtown Toronto, which has the highest concentration of medical resources anywhere in Canada, I have certainly recognized that these resources are not uniformly available to all Canadians, especially those who are living in more rural centres. Not only is the access to subspecialists limited, but so too is access to specialized diagnostic equipment.

From an ongoing research perspective, iTracker will have broad clinical and research applications:

Enhanced Collaboration:

We view iTracker is a first step in utilizing widely available mobile phone technology as a potential clinical aid and diagnostic tool, especially when access to highly specialized diagnostic equipment and sub-specialists (e.g., Neuro-Ophthalmologists) is limited. iTracker can potentially further enhance collaboration not only amongst primary care physicians and subspecialists, but also physicians working in different geographic regions across Canada. The consultative process can be enhanced with the addition of sending images of potential eye movement disorders – a practice that I have yet to encounter.

Adding Objectivity to the Clinical Exam:

iTracker can provide both primary care providers and subspecialists another utility to enhance the objectivity of not only detecting eye movement disorders, but also capturing and storing the information for reference, and further analytics.

Eye Detection – Other Applications:

Eye detection has broad applications, especially in other clinical areas such as psychiatry. For example, autistic children have been well described to have abnormal behaviours, including making poor eye contact. iTracker may potentially be able to provide further insight into patterns of eye movements in these children, including potentially detecting abnormalities earlier.

Future Work:

- *Enhance Accuracy and Performance:*
  - We are endeavoring to enhance the accuracy and performance of iTracker, including evaluating and testing other eye detection algorithms. Additionally, while we generally used some of the fastest available phones with the Android OS (e.g., Samsung Galaxy S3 and Google Nexus 4), benchmarks on different devices will be helpful to assess performance issues.
- *Additional Capture Directions/Additional Diagnoses:*
  - We will aim to add additional capture directions (e.g., up-left, down-left, up-right, down-right) and thus be able to capture all the directions visualized in the clinical examination. Additionally, video capture may also be a future functionality. By adding the additional capture directions, we will be able to add additional potential diagnoses.
- *Clinical Validation:*
  - We will require clinical testing on patients both with and without eye movement disorders to enhance application performance and accuracy. Plans to test iTracker at a large volume Neuro-Ophthalmology clinic are currently underway.
- *Use in Low-Resource Areas:*
  - By making our App publically available, we are aiming for clinical adoption especially in areas with limited healthcare resources and access to specialists – and potentially add means of contacting and collaborating with specialists across Canada.
- *Google Glass:*
  - We would like to explore the options for using iTracker on the Google Glass platform – ideally, clinicians can perform a routine extraocular movement examination and have the Google Glass camera track the eyes alongside; analyses can then take place on the mobile device or potentially in the Cloud.

Marketing/Entrepreneurship:

We are not currently interested in having a business school class on marketing/entrepreneurship take up our project. Our goal is to make our project open source and publicly available for students, researchers, and healthcare professionals to modify, use, and enhance.

Source Code:

We are planning on releasing our source code to the public once we have completed the remaining basic functionality that we have intended to achieve. We anticipate on having this functionality ready over the next 30 to 60 days. At that point, we will make a link to download our source code publicly available.

Essential References:

Bradski, Gary, and Adrian Kaehler. 2013. *Learning OpenCV.* O'Reilly.

This book is an important key reference to learning OpenCV, and computer vision in general, and we consider this essential material for any programmers wishing to use OpenCV.

Corco, Chet, and Garrett Menghini. 2012. *Learning OpenCV with Xcode.* Accessed April 2013. https://sites.google.com/site/learningopencv1/.

While not specifically geared towards Android development, provided essential code samples and learning.

GitHub. 2013. *GitHub.* Accessed April 2013. https://github.com/.

Essential website/utility for having a common code repository.

Hosek, Roman. 2013. *Android eye detection and tracking with OpenCV.* Accessed April 2013. http://romanhosek.cz/android-eye-detection-and-tracking-with-opencv/.

Essential code samples for eye detection and overall learning.

OpenCV. 2013. *OpenCV - Android.* Accessed April 2013. http://opencv.org/platforms/android.html.

—. 2013. *OpenCV4Android Samples.* Accessed April 2013. http://opencv.org/platforms/android/opencv4android-samples.html.

Stack Overflow. 2013. *Stack Overflow.* Accessed April 2013. http://stackoverflow.com/.

Stack Overflow provided a general reference site for any code related issues – as other users may have certainly encountered a similar problem as us.