An eye diagnosis and triaging system

A-EYE Project Report

MTECH Intelligent Reasoning Systems
Group 6

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Executive Summary

An important tenet of healthcare is in obtaining the correct diagnosis for a patient. However, medical care is complex and involves multiple levels of care, administered by different specialties. Our group project addresses the need for primary care physicians to be able to diagnosis and triage eye conditions accurately. To this end, we designed a machine reasoning system to process the patient's symptoms to reach a diagnosis or a list of differential diagnoses. To supplement the doctor's capabilities, we have also added a feature to identify abnormal pupillary response, which can be indicative of a more serious eye condition.

Problem Description

Eye conditions can present in a variety of ways and may range from simple non-threatening conditions to potentially blinding ones. As first line, patients with eye symptoms usually present to the primary doctors. These include General Practitioners, Polyclinic doctors and Emergency physicians. The doctors will examine the patients and triage them accordingly. For those who require specialist reviews, they are then referred to the hospitals.

In medical practice, the common accepted way of consultation is to start with a patient history, then physical examination. These will then help the doctor reach a diagnosis, or a set of differential diagnoses. This requires clinical experience, and a large body of disease specific knowledge. As the medical care advances, specialty knowledge deepens, primary care doctors may find themselves ill-equipped to deal with certain eye conditions, both in the diagnosis of the condition, and in deciding the urgency to refer.

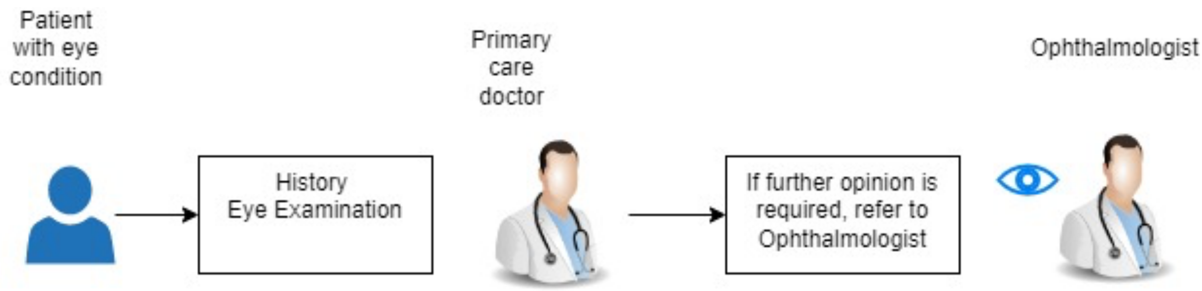


Figure 1: Overview of business process of ophthalmologist consultation

With the recent announcement of **Healthier SG strategy** [1, 2], Singaporeans are encouraged to visit the same family physician clinic regularly for all their care needs. Thus, primary care physicians are expected to play a bigger role within healthcare system. Our group sees a need to develop an eye diagnosis and triaging system which can assist the primary care doctor in their duties.

One of the commonly used examination steps is the pupil examination. This is performed by shining light into the patient's eyes and observing the pupil response to light. This is then repeated for the fellow eye. A relative afferent pupillary defect (RAPD) is characterized by pupillary dilation when the torch is swung from the normal eye to the diseased eye (Figure 2). This test is commonly done by medical practitioners, although the outcome of which is sometimes difficult to interpret. By quantifying the pupil sizes during the light and dark phases, we may be able to get a more reliable and repeatable result.

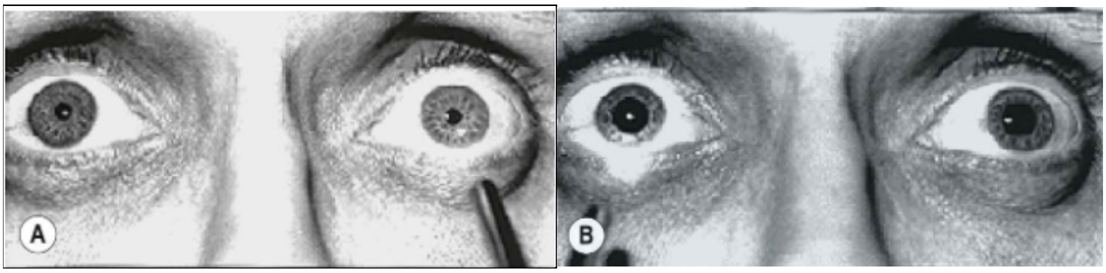


Figure 2: left pupil constriction to light in (A), and pupil dilation to light in (B)

Project Objective

Aims

We aim to design an eye module that allows the expert user (primary care physician) to input patients' symptoms to generate the most likely diagnosis, or if not, a list of differential diagnoses. This is to be paired with a smartphone-based application to measure pupillary responses.

Objectives

- To design an inference engine targeted for use by the expert use through selection of common eye symptoms to generate a diagnosis or list of differential diagnoses,
- To design an image processing software on an Android platform to measure pupil response to light from an Android smartphone

Knowledge Modelling

Knowledge Identification

The knowledge base for this project was obtained from the experience of the Domain Expert (Kelvin), with references from medical textbooks: Clinical Ophthalmology & The Wills Eye Manual.

17 eye diagnoses were identified based on the most common eye diseases, as well as those which can be realistically diagnosed at a primary care level. Diagnoses which require further examination are thus excluded as this would require a specialist to make these diagnoses. According to a 2018 paper in the Annals of the Academy of Medicine of Singapore, all eye conditions are projected to increase by 2040, with myopia and refractive errors being the most prevalent at 2.393 million cases. Other common eye conditions include diabetic retinopathy, glaucoma, and cataract. These conditions are therefore included in our knowledge base.

Photos and videos of the pupillary response to light were also taken from a few volunteers. This was used to develop the smartphone based pupillometer.

Knowledge Specification

To construct the knowledge model, the symptoms and signs which can be present in each of the conditions were identified. Attention was focused on obtaining symptoms which best correspond to the final disease diagnosis. As this was targeted at the primary physician level, physical eye signs are kept to only those which are obvious.

Knowledge Refinement

In line with a standard medical consultation process, the initial knowledge representation was done as a flow diagram. This would mimic the medical consultation scenario where a doctor ask follow up questions to a patient to narrow down the diagnosis. However, during the development of such a flow diagram, it was found to be inefficient as too many questions will need be asked per symptom which will result in a long consultation time. From a user perspective, this would reduce adoption rate.

Rather, a more efficient method would be to represent the knowledge in a matrix format where each symptom is expressed as a “1” or “0” representing “Yes” or “No” respectively. The expert user will only have to select the symptoms as elicited from the patient. The inference engine will then generate the most appropriate diagnosis or a list of differential diagnoses to best match the inputs.

Solution

System Architecture

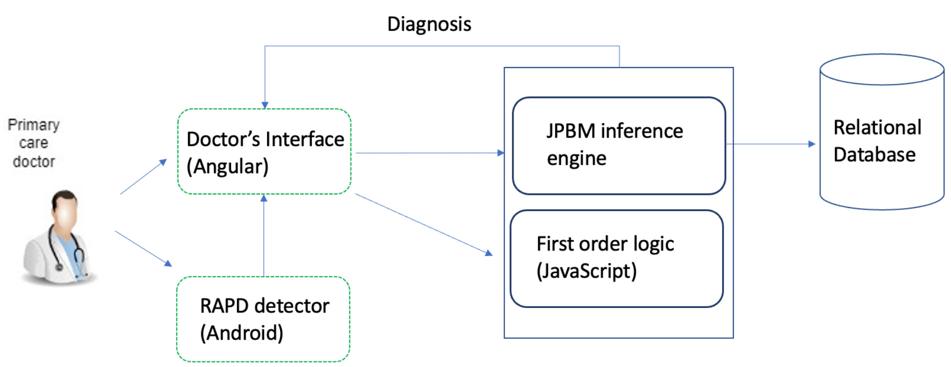


Figure 3: Overview of A-EYE system architecture

The system consists of a web application and an android application (Figure 3). The android application is a stand-alone system that will capture and analyse the video of the eye and report the presence or absence of pupillary abnormalities. The expert user will then enter the information onto the web application, alongside with other available patient information to reach the diagnosis of the patient.

The web application consists of 3 parts: a front-end application built using Angular v13, the JBPM system to perform the inference, and a hand-engineered system for inference using the Open World Assumption. The patient information is then stored in the relational database in the JBPM system.

In the event where the JBPM was not able to make an inference due to data input discrepant with any of the implemented rule using closed-world assumption, the system will fallback and utilize the open-world assumption inference engine.

Inference using jBPM system

To inference the symptoms of patient with the knowledge from domain expert, JBPM was adopted. The initial plan was to used flow charts for business process. This included main process flow and subsequent sub processes according by main symptoms. The process diagrams were shown in Appendix 2.

However, along with the knowledge enhancement from domain expert, our team realized the inefficiency of such a line of reasoning. We explored an alternative version system, relying on a decision table for various kinds of symptoms and possible diagnosis.

ruleTable

F	Description	ject													f
		_with_lubrica	ars_roll_down_che	proves_with_pinh	has_diabetes	vears_contact_len	trauma	unilateral	bilateral	cornea_FB_seen	educed_red_refle	ite_spot_on_corn	RAPD	nid_dilated_pupils	diagnosis
1		☐	☐	☐	☐	☐	☐	☑	☐	☐	☐	☐	☐	☐	Uveitis_Unilateral
2		☐	☐	☐	☐	☐	☐	☐	☑	☐	☐	☐	☐	☐	Uveitis_Bilateral
3		☐	☐	☐	☐	☐	☐	☑	☐	☐	☐	☐	☐	☑	Acute_Angle_Closure_Unilateral
4		☐	☐	☐	☐	☐	☐	☐	☑	☐	☐	☐	☐	☑	Acute_Angle_Closure_Bilateral
5		☐	☐	☐	☐	☐	☐	☑	☐	☐	☐	☐	☐	☐	Viral_Conjunctivitis_Unilateral
6		☐	☐	☐	☐	☐	☐	☑	☐	☐	☐	☐	☐	☐	Allergic_Conjunctivitis_Unilateral
7		☑	☐	☐	☐	☐	☐	☑	☐	☐	☐	☐	☐	☐	Dry_eyes_Unilateral
8		☐	☐	☐	☐	☐	☐	☐	☑	☐	☐	☐	☐	☐	Viral_Conjunctivitis_Bilateral
9		☐	☐	☐	☐	☐	☐	☐	☑	☐	☐	☐	☐	☐	Allergic_Conjunctivitis_Bilateral
10		☑	☐	☐	☐	☐	☐	☐	☑	☐	☐	☐	☐	☐	Dry_eyes_Bilateral
11		☐	☐	☐	☐	☐	☑	☑	☐	☑	☐	☐	☐	☑	Cornea_Foreignbody_Unilateral
12		☐	☐	☐	☐	☐	☑	☐	☑	☑	☐	☐	☐	☑	Cornea_Foreignbody_Bilateral
13		☐	☐	☐	☐	☐	☐	☑	☐	☐	☐	☐	☐	☐	Cornea abrasion_Unilateral
14		☐	☐	☐	☐	☐	☑	☑	☐	☐	☐	☑	☐	☐	Keratitis_Unilateral
15		☐	☐	☐	☐	☑	☐	☑	☐	☐	☐	☑	☐	☐	ContactLensKeratitis_Unilateral
16		☐	☐	☐	☐	☐	☑	☐	☑	☐	☐	☑	☐	☐	Keratitis_Bilateral
17		☐	☐	☐	☐	☑	☐	☐	☑	☐	☐	☑	☐	☐	ContactLensKeratitis_Bilateral
18		☐	☐	☐	☐	☐	☐	☐	☑	☐	☐	☐	☐	☐	Cornea abrasion_Bilateral
19		☐	☑	☐	☐	☐	☐	☑	☐	☐	☐	☐	☐	☐	Nasolacrimal_duct_obstruction_unilateral
20		☐	☑	☐	☐	☐	☐	☐	☑	☐	☐	☐	☐	☐	Nasolacrimal_duct_obstruction_bilateral

Figure 4: Decision Table of "Symptoms and Signs" and "Diagnosis"

The Business Process is shown in the diagram below. This business process uses legacy design which has data-based exclusive pathway function. The first step is to input the patient's symptoms and signs. Knowledge reasoning is performed based on the drool rules in the decision table. The output will be the suggested diagnosis. The decision table is the key step in the process. The data-based exclusive pathway will then split the output diagnosis into different terminals and API will be called to link the results to web.

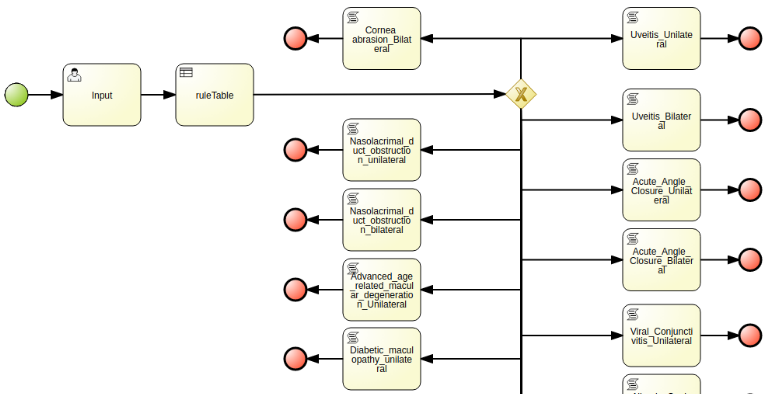


Figure 5: jBPM business process for A-EYE diagnosis system

Inference using Open-World Assumption

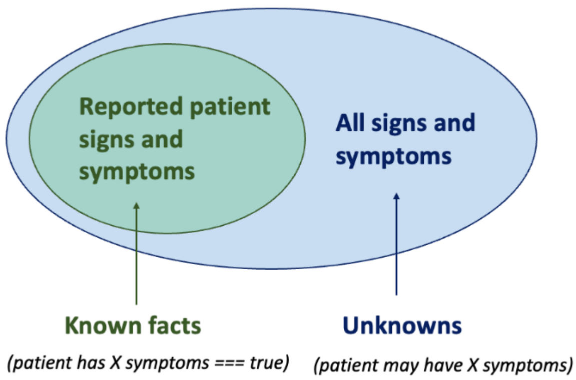


Figure 6: Conceptual diagram of applying open-world assumption for A-EYE diagnosis system

In the design of the application, we did not have the feature that require the user (experts) to explicit rule-out the presence of a particular signs and symptoms (features). While this is an important feature to ensure accurate diagnosis from the jBPM system, a system that requires input to rule-out all possible futures will have high user input burden and unintuitive.

The absence of indicating a particular feature as false creates a possibility that the presence such features *may be* true. Hence, in the event when information on the presentation of features is not complete, we must assume for the unknowns, the presence may be true (Figure 6). Hence, the open-world assumption approach.

We hand-engineered the open-world assumption inference system using plain JavaScript (Figure 7).

```
makeDiagnosis(input: patientSymptomsAndSigns, diagnosisSymptomsAndSigns):
    potentialDiagnosis = []
    For every patientPresentation in patientSymptomsAndSigns Do
        matchSymptomsAndSigns = []
        MATCH patientPresentation in diagnosisSymptomsAndSigns[symptomsAndSign]
        If (isMatch) then
            matchSymptomsAndSigns := patientPresentation
        If (matchSymptomsAndSigns.count >= patientSymptomsAndSigns.count) then
            potentialDiagnosis := diagnosisSymptomsAndSigns
    return potentialDiagnosis
```

Figure 7: Pseudo-code of open-world assumption inference system implementation

Using our hand-engineered inference system, for each symptom and signs that has been explicitly marked as true, the system will search through the library's symptoms and signs of all known eye disorders and finally return a list of all possible diagnosis that matches the patient reported signs and symptoms, without ruling out other unreported signs and symptoms.

Relative Afferent Pupillary Defect (RAPD) detection system (Android Application)

The pupils are an important source of information of the anterior visual pathway. By observing the reaction of the pupil to light, it can differentiate serious eye conditions from less serious ones. For example, patients with unilateral glaucoma can have an abnormal light reaction. In clinical practice, we use the relative difference of light response between the 2 eyes as a clinical sign. This is termed as relative afferent pupillary defect (RAPD).

Light is sensed by the retina and converted into neuronal impulses. (Figure 8) In the afferent arm of the light reflex pathway, these impulse pass through the optic nerve and crosses in the optic chiasm which divides into the right and left optic tract. Nasal fibres crosses to the contralateral aspect and temporal fibres remain on the ipsilateral tracts. These reach the respective pre-tectal area of the midbrain which then sends bilateral signals to the Erdinger Westphal nucleus. The efferent arm travels along the oculomotor nerves and synapses with the ciliary ganglion. Post-ganglionic fibres react the pupils to innervate the iris sphincter which leads to pupil constriction. For this reason, when light is shone onto one eye, both pupils constrict. This is the basic for the RAPD examination.

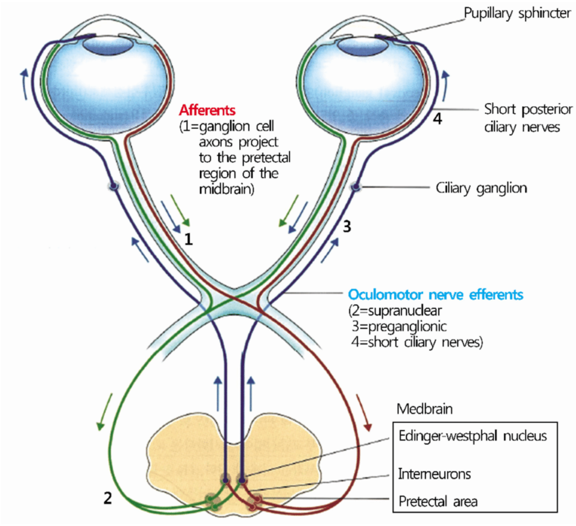


Figure 8: Pupillary light reflex pathway

In our project, we aim to detect and measure the pupillary response to a light source emitted from an Android-based smartphone. Using the same principles as RAPD, we compare the light response between both eyes. An abnormal eye will show weaker light response.

We developed an android application, with image analysis functionality, to help upscale the capacity of RAPD detection. When the user starts the application, the system will process the camera input to determine if eye. Eye detection is achieved through Haar-feature detection and cascading classifier. We used an existing eye detection model provided by the OpenCV library [7].

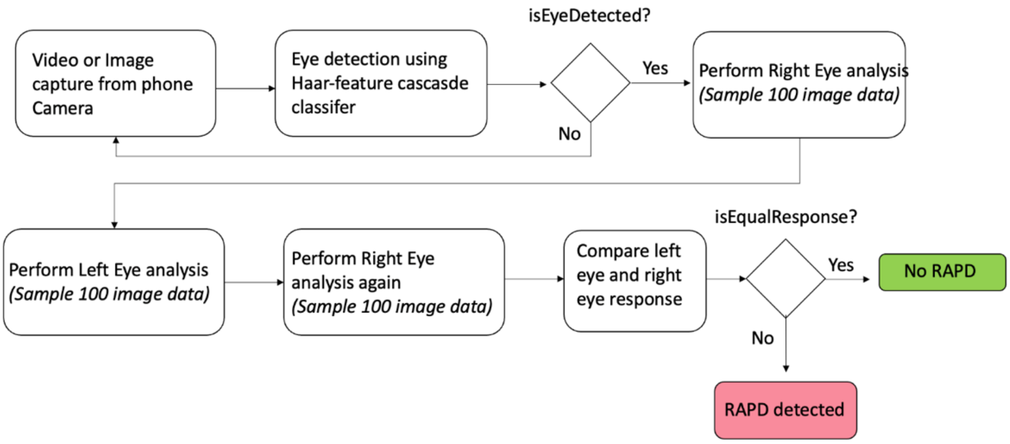


Figure 9: Process of RAPD detection system on A-EYE Android Application

The user will start with analysing the right eye. When right eye is detected, the system will start performing the analysis of the eye by performing the steps described in Figure 9. The sequence of the analysis are as follows:

Right Eye -> Left Eye -> Right Eye

Figure 10: Sequence of RAPD detection using A-EYE Android Application

For each step, the system will sample 100 image data before instructing user to proceed to the next step. For each image collected, the system will perform the image processing and image analysis step described in Figure 11. Briefly, the system will convert the image to grayscale, using available machine learning model to identify the region-of-interest (ROI) that contain the eye. Then using method describe in Figure 12 to identify the pixel count of the iris as well as the pupil.

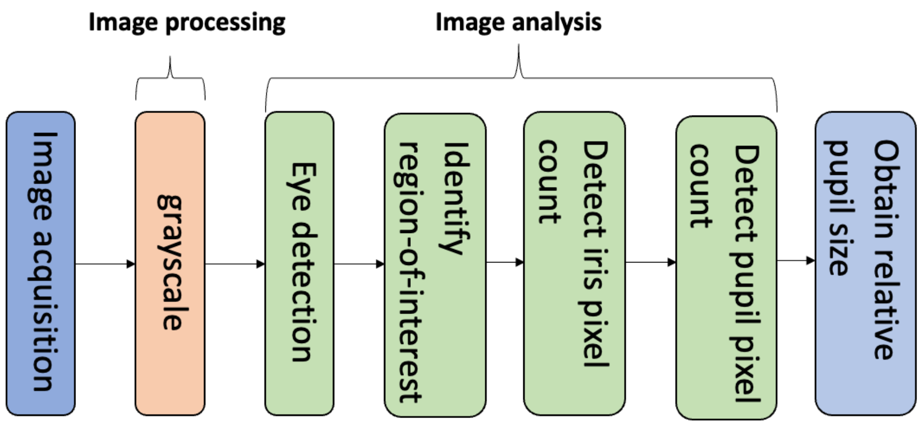


Figure 11: Image processing and analysis steps for RAPD detection

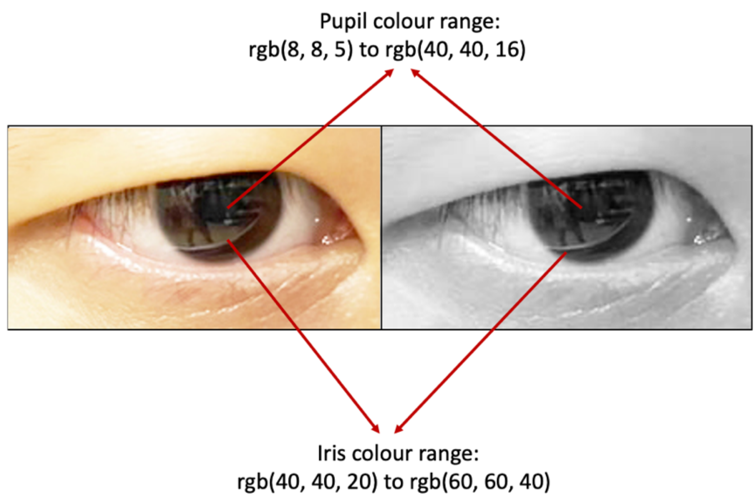


Figure 12: Colour range apply for segmentation of Asian iris and pupil

Due to lack availability of existing model for detection of pupil and iris in Asian eyes, we have to hand-engineer a novel approach to segment iris and pupil. It is extremely difficult to apply typical image segmentation method for Asian population, as Asian tend to have darker eye colour that has very close colour range to the pupil. In addition, different lighting condition will affect detail of the image that limit machine's edge detection capability.

Given the challenge and the time-constrain we had, we decided to apply a naive approach of using colour range of the image to differentiate the different component of the eye.

Based on experience, we define the colour range of the Asian iris to be between RGB (40, 40, 20) and RBG (60, 60, 40), and pupil to be between RGB (8, 8, 5) and RGB (40, 40, 16).

With this approach, we were able to achieve a good level of differentiation between the pupil and the iris (Figure 13).

The size of the pupil is calculated by normalized the pixel count of the pupil to the iris (Equation 1). The output is the relative pupil size for each of the image.

$$relative\ pupil\ size = \frac{pixel\ count(pupil)}{pixel\ count(iris)}$$

Equation 1: Calculation method for relative pupil size

From the collection of relative pupil size data, the system will filter the outliner value of the samples by applying simple heuristic of trimming out the top and bottom 25th percentile of the extreme value and keep the medium representative sample data (Figure 13).

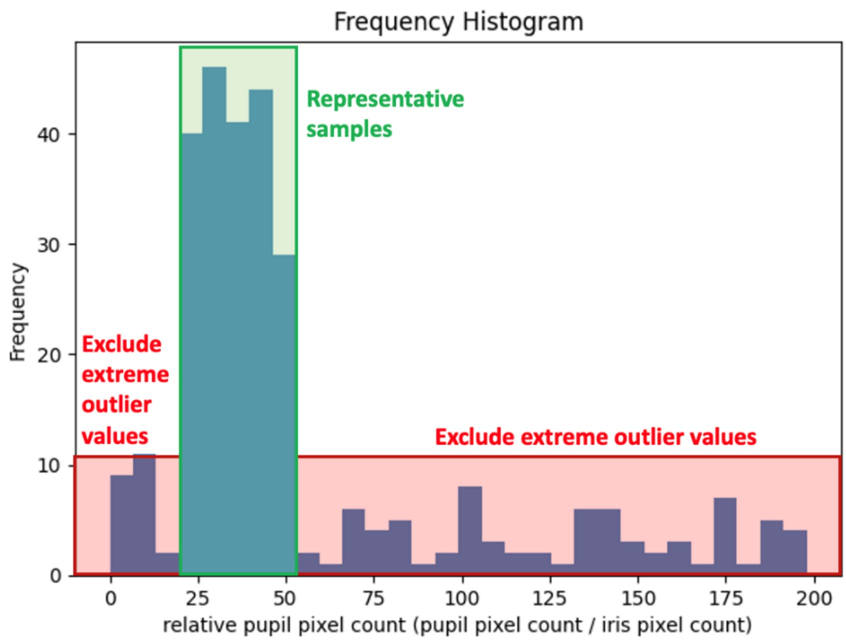


Figure 13: Data distribution of relative pupil size value collected using A-EYE Android application

Finally, the system obtains the average left and right pupil size and perform comparison. To account for some margin-of-error, the system will report the present of RAPD (asymmetric light response) if the difference is greater than 30% (Equation 2).

$$RAPD = \frac{(\overline{relative\ left\ pupil\ size}) - (\overline{relative\ right\ pupil\ size})}{30} \geq 1$$

Equation 2: Calculation method for presence RAPD

Assumptions

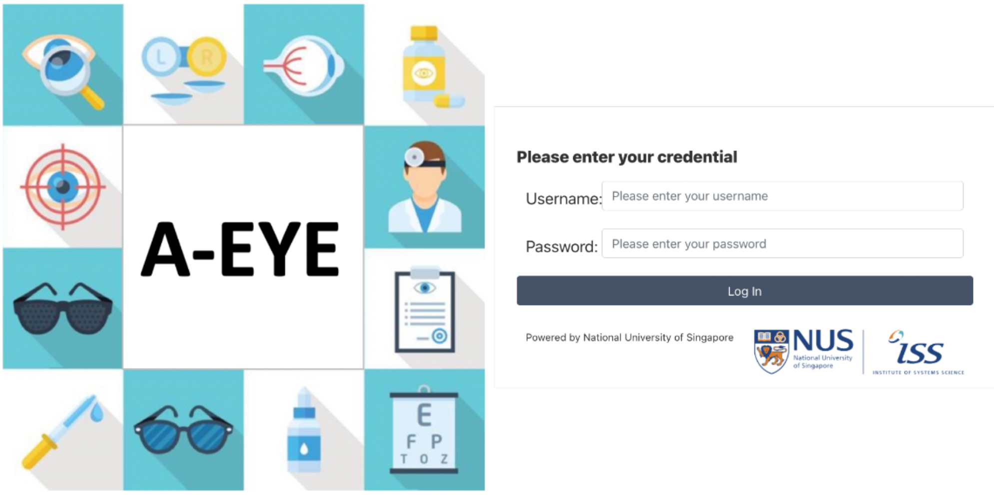
In the implementation of this system, we made the following assumptions:

- We assume the user are medically trained and competent to identify signs and symptoms of the patient and make the correct input.
- We implementation of the pupil scanner is limited to Asian population with dark coloured or brown iris.
- We also assume that only the iris and pupil of the eye will be within the dark colour range that we had defined.

System feature

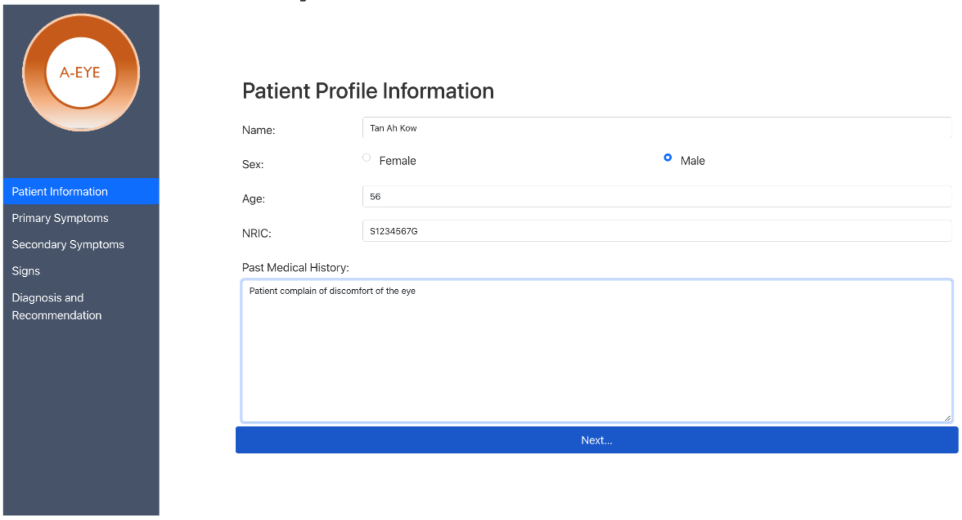
A-EYE Diagnosis System

Login



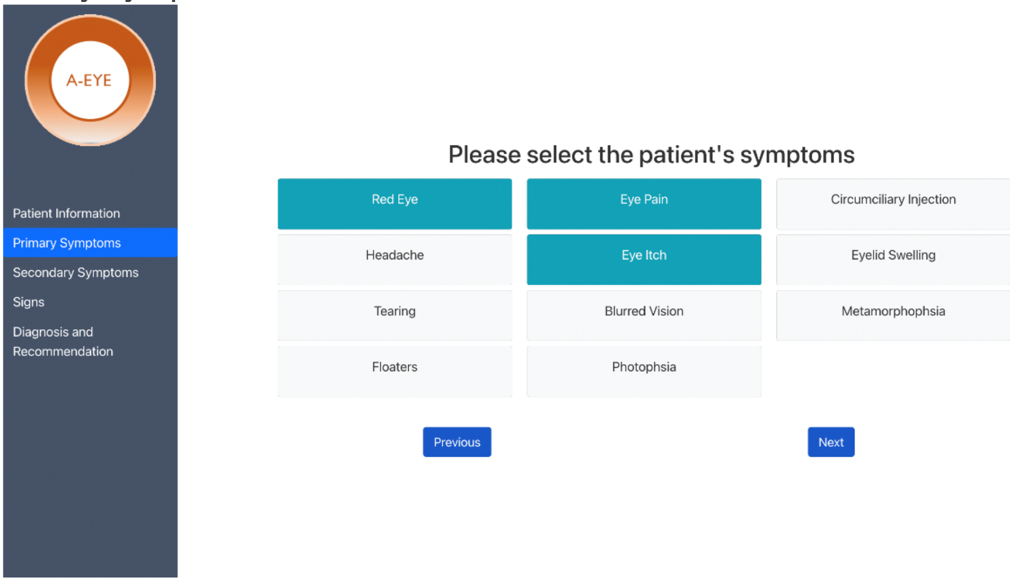
The system will be secure by a username and password credential system. User will log in into the system. The credential is linked to the jBPM system for data input and data inference.

Patient Profile and History



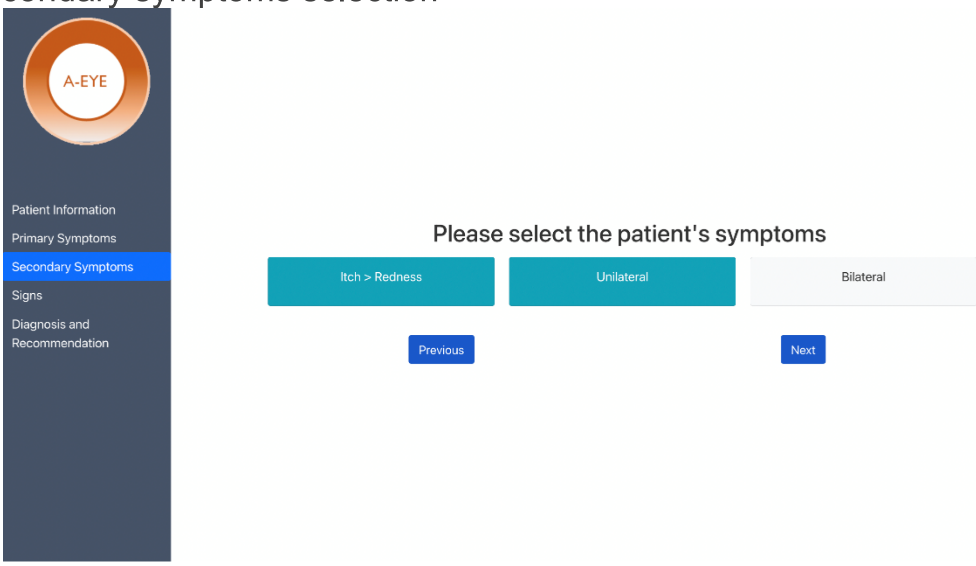
As all patients are unique, we request that the expert users key in the demographics, patient identifiers and past medical history. This helps us track the flow of patients in the system. The past medical history may occasionally be relevant to the eye condition as well.

Primary symptoms selection



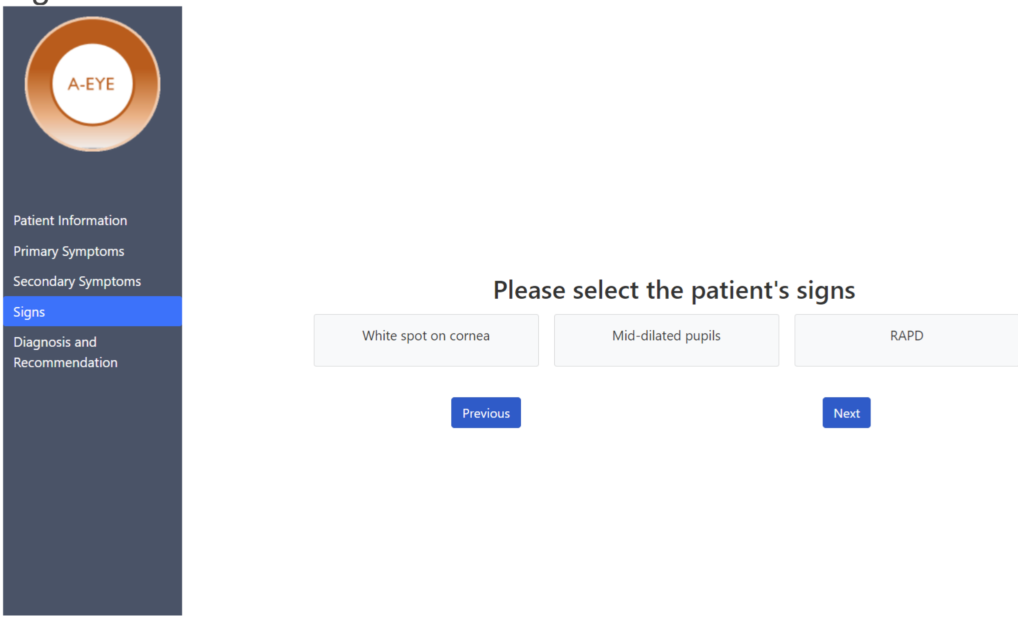
The healthcare provider will perform assessment on the patient and enter the primary symptoms of the patient.

Secondary symptoms selection



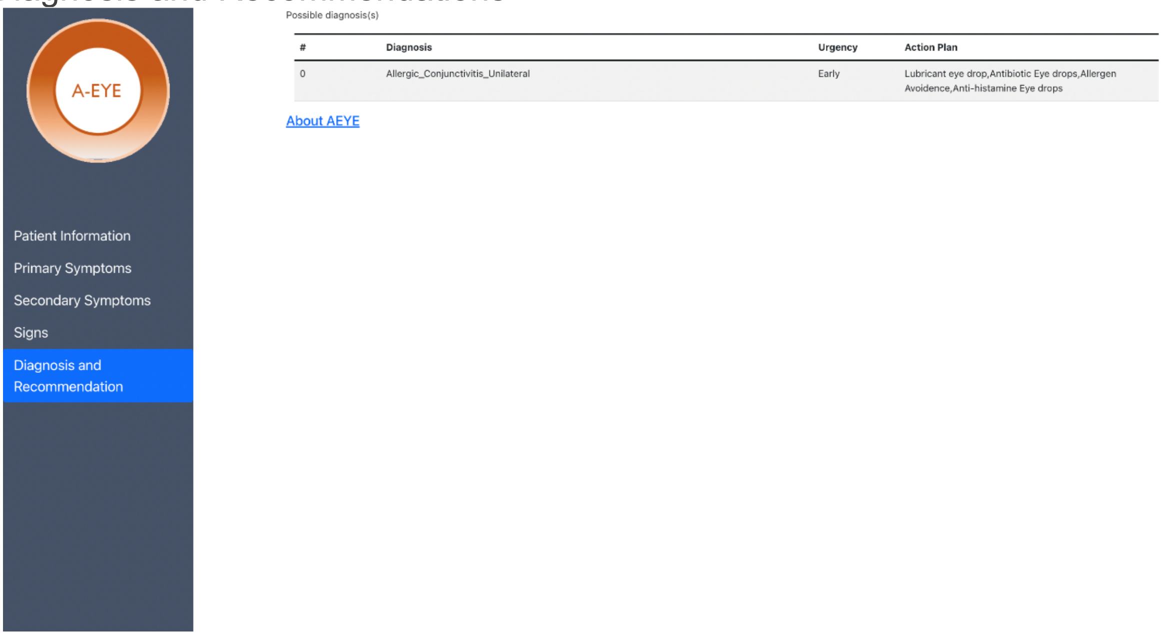
Depending on the primary symptoms input into the system, the system will present a second prompt to follow-up for the secondary symptoms. The healthcare provider will perform the assessment on the patient and select the secondary symptoms present on the patient

Signs selection



Finally, the healthcare provider will select the sign that he/she observed on the patient

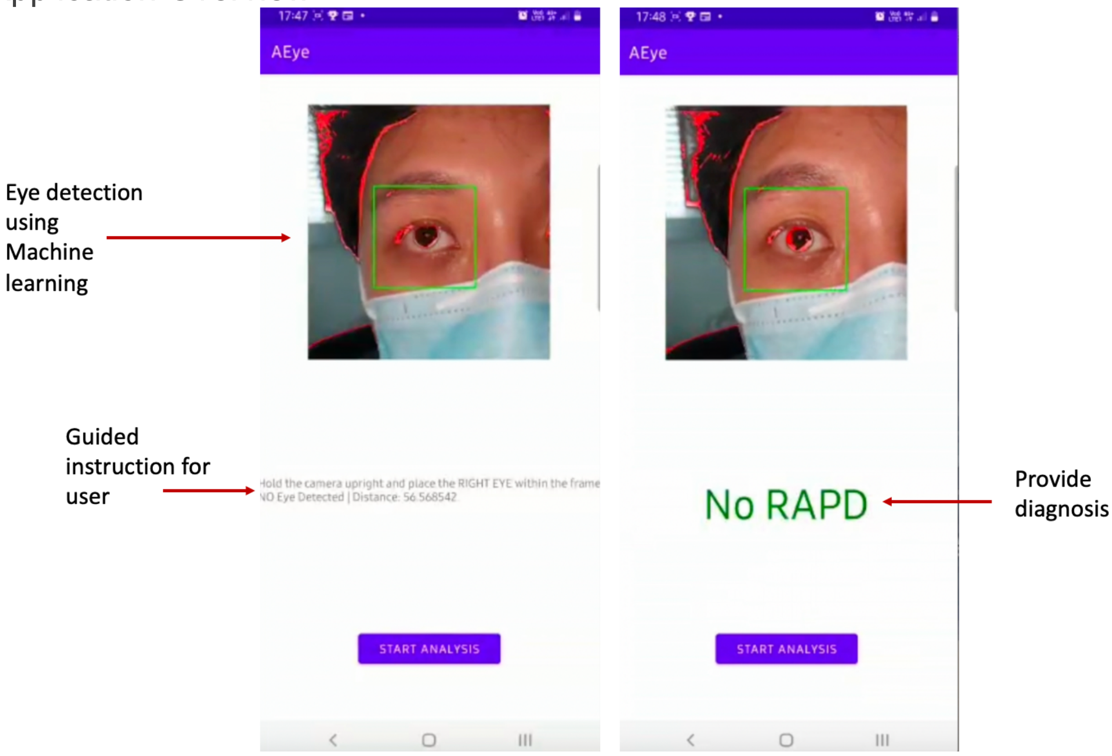
Diagnosis and Recommendations



The system will analyse the input by the healthcare provider and generate a diagnosis recommendation, the urgency of the condition and a proposed care plan for the patient

A-EYE RAPD Detection Application

Application Overview

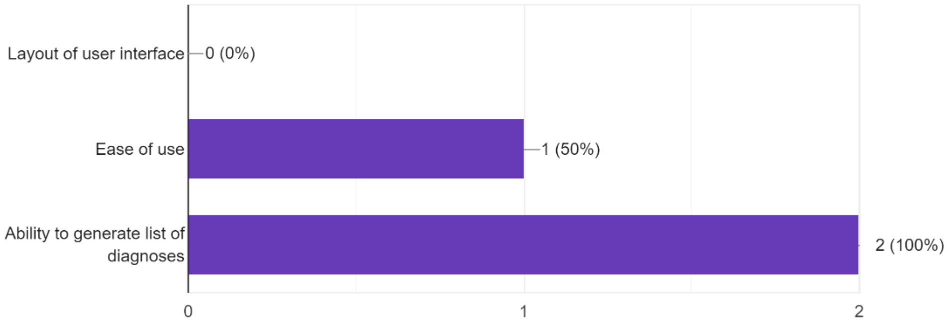


Feedback and Future Plans

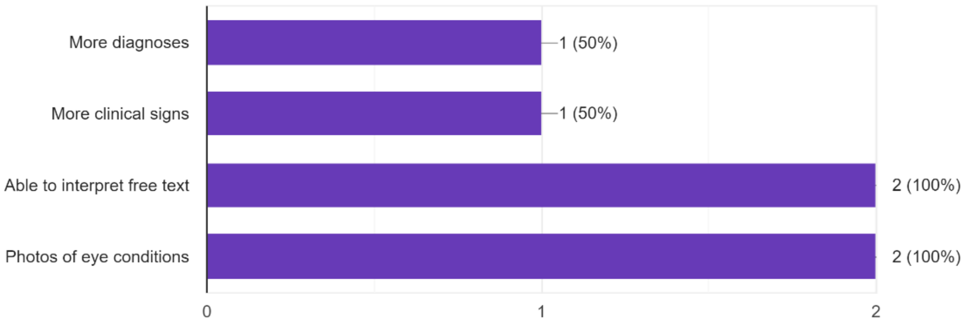
The software was introduced to 2 family medicine doctors for the purpose of obtaining preliminary feedback. The ability to generate diagnoses was appreciated. Responders suggested improvements including a free text interpretation and photos of eye conditions. They would also like it to be integrated into the hospital system, and to have an app-based software. On a scale of 1-5, the doctors indicated that they would most likely use this software (4/5).

With the support of the group, one of the group mates (Kelvin) has also approached his department, Tan Tock Seng Hospital Department of Ophthalmology and applied for intramural funding to develop this project further.

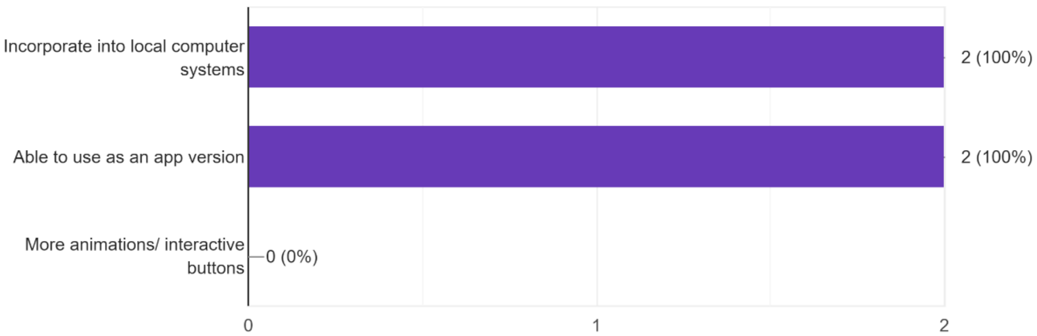
What do you like about the programme?
2 responses



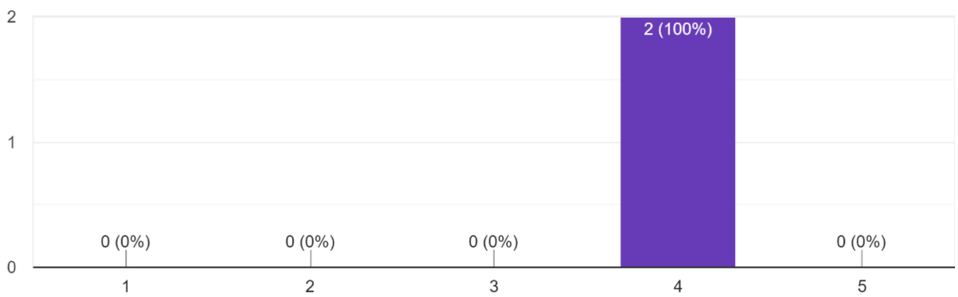
What do you think can be improved?
2 responses



What would make me use the software more often?
2 responses



How likely will you use this software?
2 responses



Limitation

Accurate diagnosis and specific recommendation that is relevant to the patient will be paramount to the value of the product. As an MVP, the system can only provide broad, non-specific management plan to the user. The healthcare professional (HCP) will have to exercise their own judgement and experience to decide which treatment option will be offered to the patient.

A major part of the data input is derived from HCP's assessment of the patient. This may result in bias arise from human subjectivity. To hand-engineering all the possible symptoms and signs presentation will be overly tedious, and the lack of rich dataset that present all the possible eye conditions make a hard limitation of developing an objective, automated or semi-automated signs and symptoms detection.

Finally, the algorithm develop for segmenting Asian pupil from iris in the Android application will only work on specific lighting condition and eye colour. Slight differences in lighting or camera sensor may affect the reliability of the results. Furthermore, the algorithm will only work on Asian eyes at the moment. The system was only tested on normal eyes, and not on disease-state eyes. Therefore, we are unable to lay claims on the reliability on detecting RAPD-positive eyes.

Improvement

The A-EYE diagnosis system can be improved such that it is able to provide personalised treatment plan that is specific to the patient condition. To achieve that, we can (a) improve our knowledge model to consider more factors in patient assessment, (b) extract existing research paper and data set to develop a probabilistic model on the optimal treatment plan based on (c) patient's profile and medical history.

Furthermore, in the event when the system is showing HCP user multiple possible diagnosis, the system can rank this diagnosis in the order of probability and seriousness. This will require gathering of dataset from existing medical literature combined with knowledge from experts to balance between probability and risk of hazard.

Finally, the image segmentation strategy in the A-EYE RAPD detection application (Android) can be improve, so that the approach can be generalized to a wider population with different eyes shapes and colours, as well as different skin colour. Image pre-processing can also be improved to address the issue of reflection from the eyes.

Conclusion

Our team had a wonderful time working on this project, and along the way we have gained valuable knowledge and practical skills while achieving the prescribed objectives of this project.

In this project, we applied the knowledge base and reasoning systems we have learned from machine reasoning system courses, as well as image recognition from cognitive system courses. These practices enhanced our understanding of the classroom material.

Most importantly, the system we have developed has the potential to play a role within the medical system by providing support and assistance to doctors in eye examination and diagnosis.

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Appendix

Appendix 1: Project Proposal

GRADUATE CERTIFICATE: Intelligent Reasoning Systems (IRS)

PRACTICE MODULE: Project Proposal

Date of proposal: 19th February 2022
Project Title: ISS Project – A-Eye Module: Intelligent Chat Bot and Smartphone Pupillometer
Sponsor/Client: *(Name, Address, Telephone No. and Contact Name)* Institute of Systems Science (ISS) at 25 Heng Mui Keng Terrace, Singapore NATIONAL UNIVERSITY OF SINGAPORE (NUS) Contact: Mr. GU ZHAN / Lecturer & Consultant Telephone No.: 65-6516 8021 Email: zhan.gu@nus.edu.sg
Background/Aims/Objectives: Background Eye conditions can present in a variety of ways and may range from simple non-threatening conditions to potentially blinding ones. Patients with eye symptoms usually present to the primary doctors (GPs/ Polyclinics) and or Emergency physicians.These doctors will then refer the patients to the hospitals for specialist reviews. However, sometimes the difficulty is in deciding what conditions the patient may have, as well as the urgency to refer. Other than asking the patient regarding his/her symptoms, a pupillary examination is also necessary. This can help to differentiate a serious condition from a less serious one. Aims We aim to design an eye module that allows the expert user to input patients' symptoms to generate a list of differential diagnoses. This is paired with a smartphone based application to measure pupillary responses. Objectives ● To design an inference engine to narrow down differential diagnoses based on the patient's symptoms ● To design an image processing software on an Android platform to measure pupil response to light from an Android smartphone

Requirements Overview: - *Research ability* - *Programming ability* - *System integration ability* - Natural Language Processing (NLP) - Rule-based Processing - Image processing and analysis
Resource Requirements (please list Hardware, Software and any other resources) Hardware proposed for consideration: - Android smart device, Linux server, Image processing server Software proposed for consideration: - Reasoning systems: KIE jBPM (Drools), AppFormer - Pertained machine learning models: Vision (OpenCV), NLP - Machine learning use cases: Python, SciKit, TensorFlow - Deep learning tools: Python Keras - Cloud computing/server: Amazon, Google - Application container: Docker
Number of Learner Interns required: (Please specify their tasks if possible) **<u>4 team members</u>** Team Lead (Zheng Xiaolan): - Overview of project progress - Facilitate team discussion and team agenda - Development of Knowledge Base for interference engine - Gather requirements from Domain Expert Team Member 1 (Lim Chang Siang): - Software developer - Image processing and vision recognition - Android application architecture design - Provide technical support to team Team Member 2 (Zhong Xiaohui): - Development of Inference Engine - UI design - Report writing - Video production and editing - Product Manager

Team Member 3 (Kelvin Li):

- Domain Expert
- Data collection
- Literature review
- Participant recruitment
- Natural Language Processing

Methods and Standards:

Procedures	Objective	Key Activities
Requirement Gathering and Analysis	The team should meet with ISS to scope the details of project and ensure the achievement of business objectives.	1. Gather & Analyze Requirements 2. Define internal and External Design 3. Prioritize & Consolidate Requirements 4. Establish Functional Baseline
Technical Construction	· To develop the source code in accordance to the design. · To perform unit testing to ensure the quality before the components are integrated as a whole project	1. Setup Development Environment 2. Understand the System Context, Design 3. Perform Coding 4. Conduct Unit Testing
Integration Testing and acceptance testing	To ensure interface compatibility and confirm that the integrated system hardware and system software meets requirements and is ready for acceptance testing.	1. Prepare System Test Specifications 2. Prepare for Test Execution 3. Conduct System Integration Testing 4. Evaluate Testing 5. Establish Product Baseline
Acceptance Testing	To obtain ISS user acceptance that the system meets the requirements.	1. Plan for Acceptance Testing 2. Conduct Training for Acceptance Testing 3. Prepare for Acceptance Test Execution 4. ISS Evaluate Testing 5. Obtain Customer Acceptance Sign-off
Delivery	To deploy the system into production (ISS standalone server) environment.	1. Software must be packed by following ISS's standard 2. Deployment guideline must be provided in ISS production (ISS standalone server) format 3. Production (ISS standalone server) support and troubleshooting process must be defined.

Team Formation & Registration

Team Name: A-Eye (Project team 6)
Project Title (repeated): ISS Project – A-Eye Module: Intelligent Chat Bot and Smartphone Pupillometer
System Name (if decided): Dr. A-Eye
Team Member 1 Name: Zheng Xiaolan
Team Member 1 Matriculation Number: A0249271B
Team Member 1 Contact (Mobile/Email): 90583040 zhengxiaolan5@gmail.com
Team Member 2 Name: Lim Chang Siang
Team Member 2 Matriculation Number: A0176266W
Team Member 2 Contact (Mobile/Email): 82010357 e0231993@u.nus.edu
Team Member 3 Name: Zhong Xiaohui

Team Member 3 Matriculation Number: A0249305E
Team Member 3 Contact (Mobile/Email): 92709508 youthmail@hotmail.com e0938910@u.nus.edu
Team Member 4 Name: Li Zhenghao Kelvin
Team Member 4 Matriculation Number: A0031400J
Team Member 4 Contact (Mobile/Email): 96271282 kalphine@gmail.com

Appendix 2: Mapping System Functionality again knowledge, techniques and skills of IRS module courses

IRS Modules	Knowledge, Techniques, Skills	System function
Machine Reasoning	Application of AI to business problem	System design and project approach
	Knowledge Modelling	Diagnosis inference
	Knowledge Representation	Diagnosis inference
	Rules and Logical Inference	Diagnosis Inference
	jBPM KIE System	Diagnosis Inference
Reasoning Systems	Search Reasoning	Diagnosis Inference (Open world assumption)
	Ensemble architecture design	Dual inference system design
Cognitive Systems	Vision Cognitive	RAPD detection functionality in Android Application

Appendix 3: Installation and User Guide

System Pre-requisites

- A Mac OS X or Linux operating system
- Google Chrome (latest version)
- An Android device and back-facing camera with flashlight

Software requirements

- Java JDK 1.8
- Android Studio v4.0 or above

Java JDK can be download at: https://www.oracle.com/java/technologies/downloads/

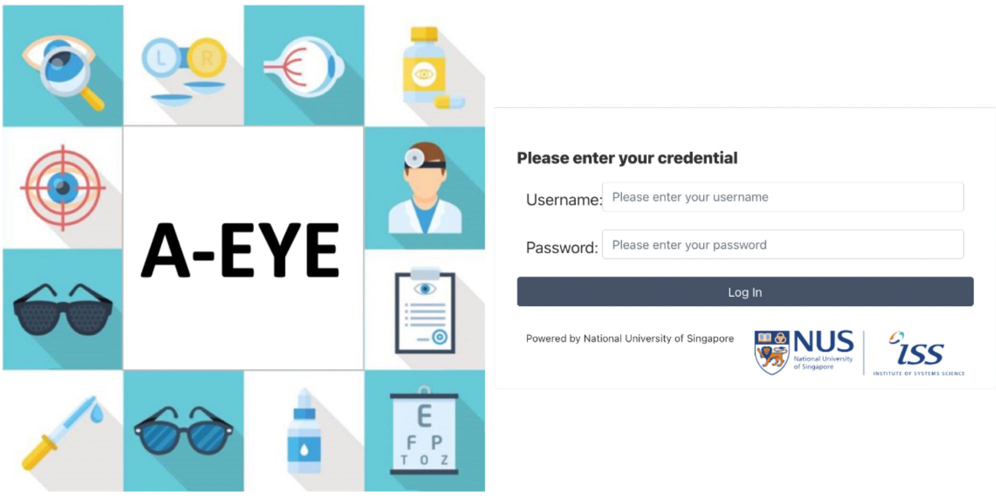
Android Studio can be download at: https://developer.android.com/studio

Deploy the A-EYE diagnosis system locally

1. Unzip the file jbpm-server-7.67.0.Final-dist.zip to local directory
2. Execute the bash script “standalone.sh”

```
bash ./jbpm-server-7.67.0.Final-dist/bin/standalone.sh
```

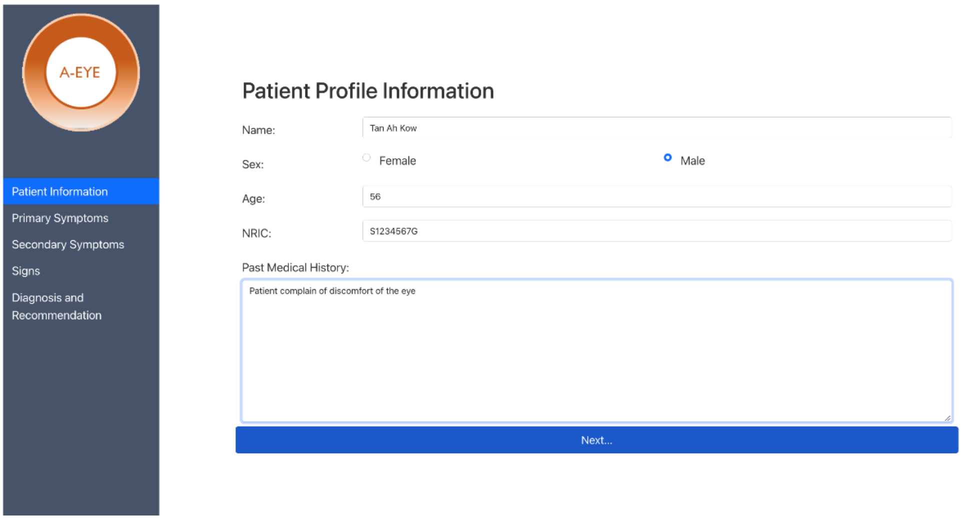
3. Open Google Chrome
4. Navigate to localhost:8080 to see the A-EYE Login Page



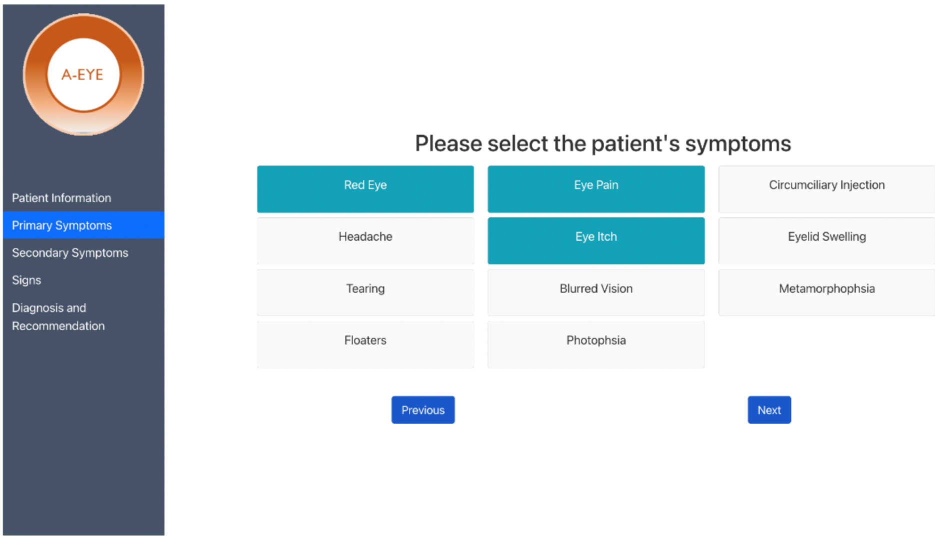
5. Login with the following credentials:

   Username: wbadmin | Password: wbadmin

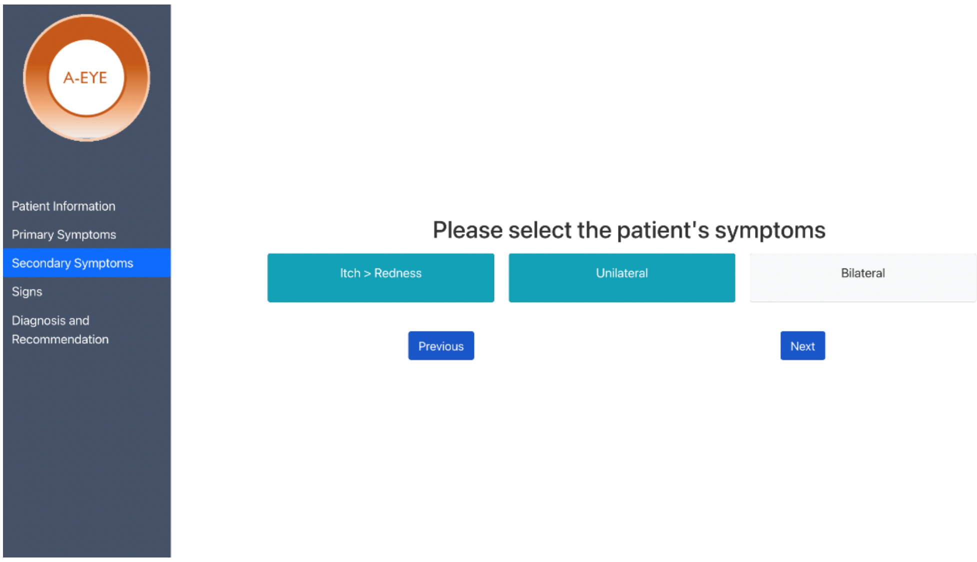
6. Enter patient profile information
7. Click “Next”



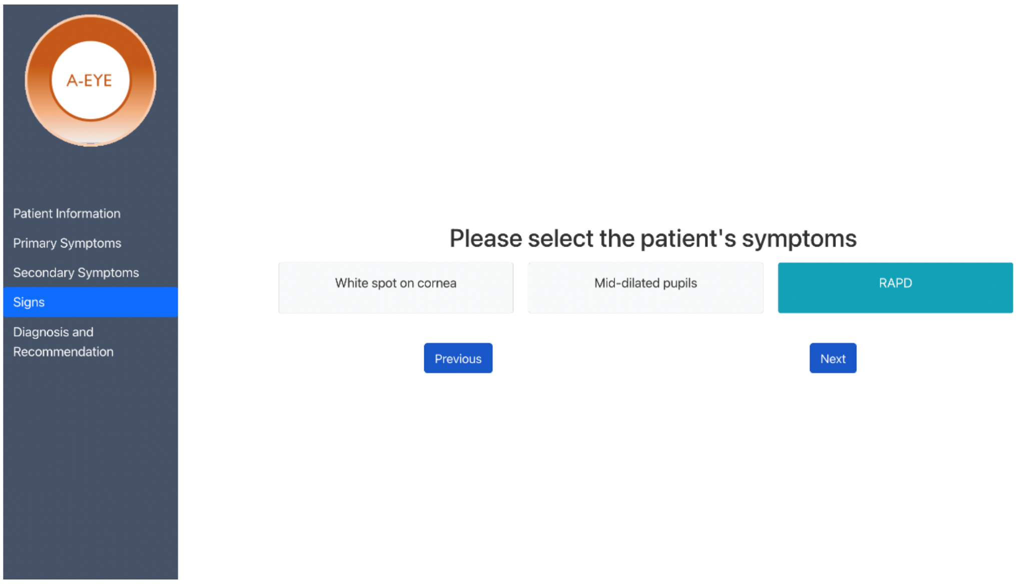
8. Select primary symptoms presented by patient
9. Click “Next”



10. Select following secondary symptoms presented by patient
11. Click “Next”



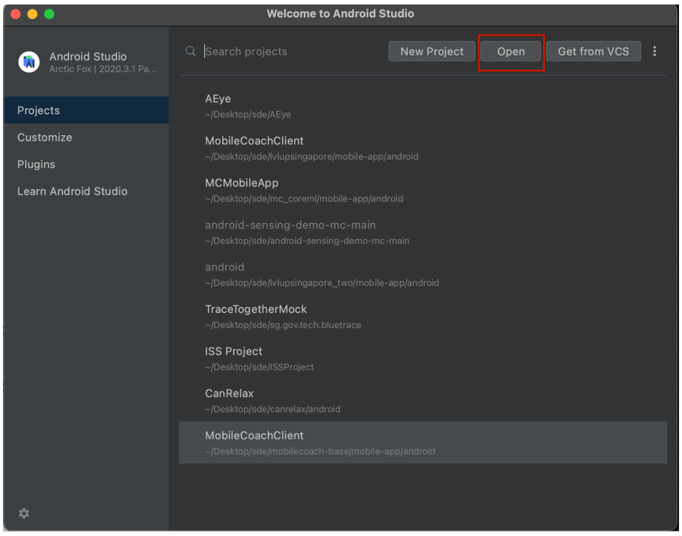
12. Select signs observed on patient
13. Click “Next”



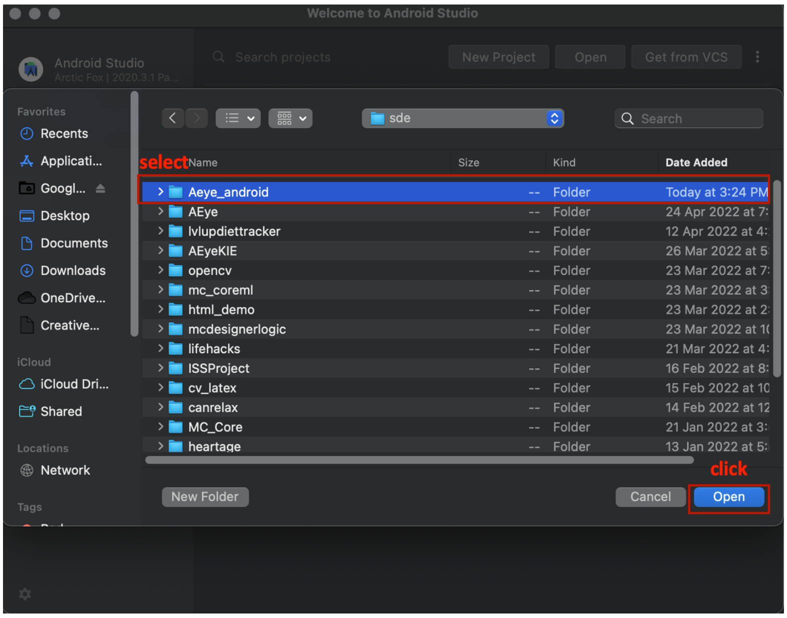
14. Review the diagnosis report.

A-EYE RAPD detection Android Application

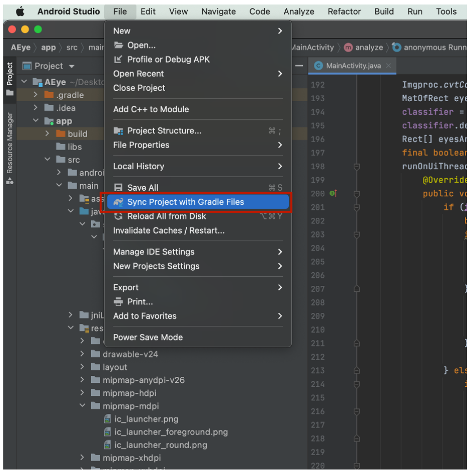
1. Unzip the file Aeye_android.zip
2. Connect Android device to your computer
3. Run Android Studio
4. On the “Welcome to Android Studio” screen, click “Open”



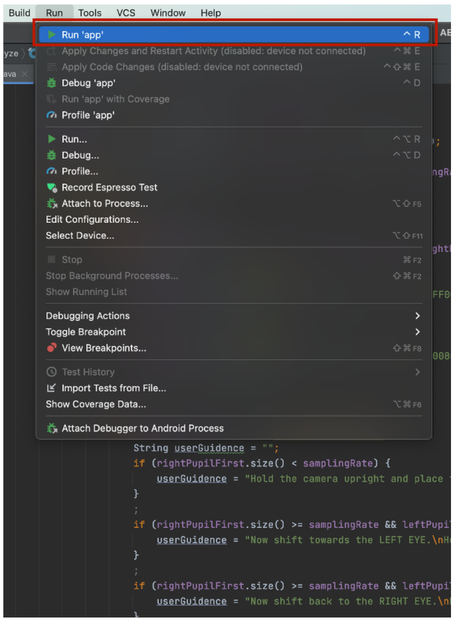
5. Select Aeye_android folder, click “Open”



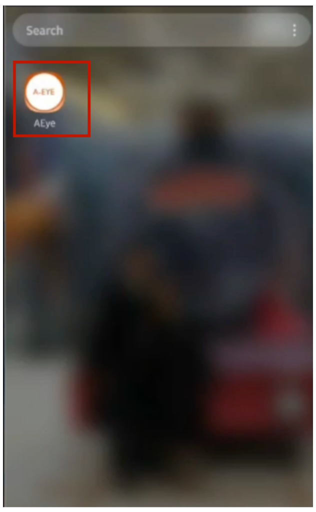
6. Click “File” and select “Sync Project with Gradle File”



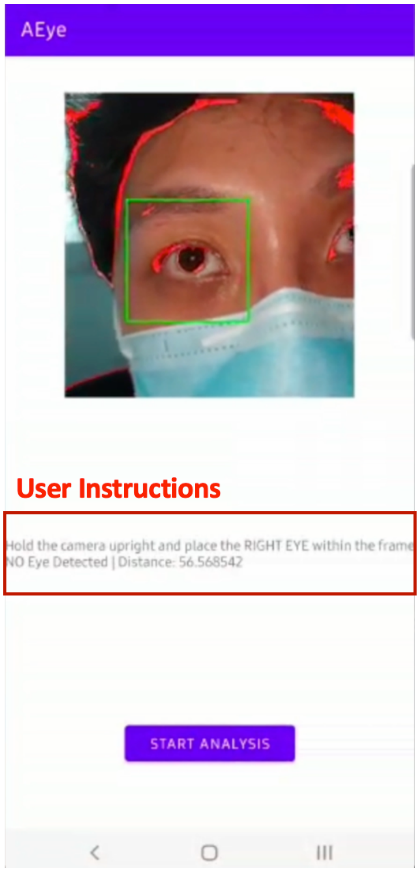
7. Click on “Run” and select “Run App”



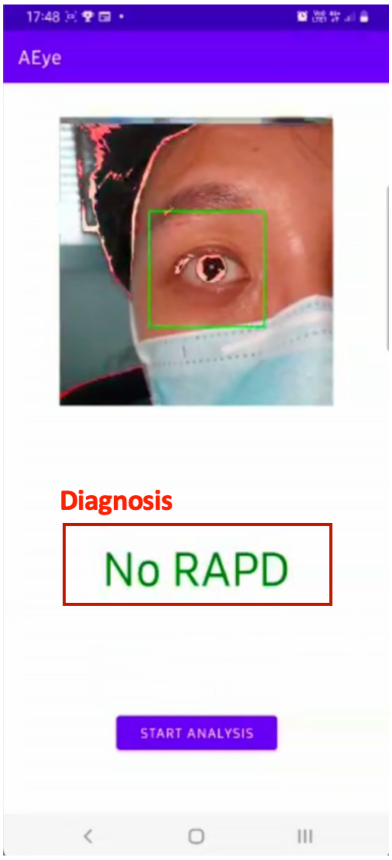
8. Android Studio will deploy the application to your Android device
9. On your Android device, tap on the “Aeye” App



10. Upon start up, follow the instruction on screen



11. At the end of the progress, the system will display a diagnosis



Appendix 4: Individual project report by project members

Individual reflection of project journey by Lim Chang Siang (A0176266W)

1. **Personal contribution to group project**
I am the primary software developer of the project. I contributed to the project in all phases of application development life-cycle, including • Project scoping • Requirement elicitation and clarification • System architect • Solution design and proposal • Software implementation • Testing and evaluation I have also contributed to the following section of the project report • System Architecture • Inference using Open-World Assumption • RAPD detection system • Assumption • Limitations • Improvement • Installation and User Guide
2. **What learnt is most useful for me**
The biggest lesson I have learnt is the importance of clarifying business domain to adopt the correct knowledge modelling approach. In the initial phase of the project, with the preliminary information we have gathered, we assumed that the decision tree approach would work and started model the business process in that manner. However, halfway through the project, we realized that we may have adopted the wrong modelling approach. Although medical diagnosis intuitively feels like a decision tree, in certain domain, it can actually be in the form of decision matrix. We found that if we were to stick with the decision tree approach, we will not be able to cover the diagnosis comprehensively, and hence we have to change the approach. Fortunately, that was when we were at the Reasoning Systems module, where I learnt about the concept of "Open-World Assumption", and was able to quickly apply the concept to our solution. From the project, I have also learnt that OWA is also used in other medical diagnosis solution. This finding gave me and my team the confidences that this is the right approach. Upon implementation, we validated it with domain expert, and it met the expert's requirement. Apart from that, I have also learnt that it is possible to develop an AI / automated solution without the luxury of huge data set. It is possible to obtain rich and useful information through interview with domain expert. The most important thing is to ask the right question and test my assumption with them. Finally, I have a first taste with image processing and image analysis. I have implemented a very naïve solution. I look forward to the next module to further deepen my skills and refine my solution.

3. **How I can apply the knowledge and skills in other situations or my workplaces**
The knowledge of proper knowledge modelling and representation will help to guide me in the process of designing an AI solution, especially when I am planning for an interview with an expert to elicit knowledge. Such model can also help to communicate the solution design and testing assumption, making sure that the solution meets the needs of the business. I am also excited to implement solution using OWA assumption to help with diagnosing medical conditions in environment where knowledge is often incomplete, and we have to make sure that life-threatening conditions are not missed by the clinicians.

Individual reflection of project journey by Zheng Xiaolan(A0249271B)

1. **Personal contribution to group project**
In this A-Eye group project, I mainly focus on knowledge reasoning system. On JBPM platform, created drool rules and business process for our project. • Communicate with domain expert on the knowledges. • Self-trained KIE software and build knowledge system • Join group discussions.
2. **What learnt is most useful for me**
From this project, I experienced how the reasoning system works and how the rules interference. It applied what we have learned from our module courses in class. In the beginning, I didn’t know how to use KIE software or how to build business process flow and rules. From the optional KIE workshop file, I learned how to deploy the business process for a project first. Then I searched massive online training videos about how to build a JBPM project. After that, I started creating JBPM process flow for our project. During this journey, I encountered lots of bug or errors. To overcome them, I tried countless times. Besides, I learned that communication with team members is important. They may give you inspire to solve the problem.
3. **How I can apply the knowledge and skills in other situations or my workplaces**
I have learned several ways to build rules engine in knowledge JBPM system. I worked in a technology intensive industry. And knowledge is critical for my company. I may apply the KIE rule engine to auto decide which reliability test need to be performed to evaluate the risk of the process change. It’s based on the knowledge and experience.

Individual reflection of project journey by Zhong Xiaohui (A0249305E)

1. **Personal contribution to group project**
I am the product manager of the project; I have contributed the parts below for this project • Business value evaluation • UI design for both web and Android APP.

• Development of Inference Engine • RAPD design consultation • Testing and evaluation I have also contributed to the following section of the project report • Report writing • User guide writing • Video production and editing
2. What learnt is most useful for me
I am not from a software develop background, so coding is a bit difficult for me. However, to complete this project I have self-study through google for the coding part. And through this project, I have learnt how to transform a data base into automated solution by using AI technology. Team discussed together for the flow chart and finalized the knowledge modeling. Then to add the rules and logical Inference for the diagnosis. The most important is to transfer what I learnt and implement into a business, consider the actual scenario and solve a actual pain point.
3. How I can apply the knowledge and skills in other situations or my workplaces
The knowledge of use KIE to generate the solution will be helping to guide me to develop an information checkup system in my workplace. By using this model, users able to provide the issue they faced, and system may provide a potential root cause and a solution to solve the issue. I can consider integrating this model with a chat bot and provide the application in our main website or app in the system, by doing this will be able to save manpower of technical support engineer and response time to customers and save the total cost eventually.

Individual reflection of project journey by Li Zhenghao Kelvin (A0031400J)

1. Personal contribution to group project
I am the domain expert of the project. I have contributed to the parts below for this project: • Knowledge modelling: flow diagram initially, then matrix representation • Obtaining and refining user requirements • Photo and videos collection for pupil detection • RAPD design consultation • UI design consultation • Video design consultation • Testing and evaluation • Market survey from family medicine doctors I have also contributed to the following section of the project report • Executive summary • Problem description

- Project objective
- Knowledge Modelling
- Solution: description of RAPD
- Feedback and Future plans
- References
- Report proof-reading

2. What learnt is most useful for me

Coming from a limited IT background, the course and the ensuing project was a mind-opener. While initially thought that the practice module would be highly technical, I learnt that one of the key considerations in such a project would be the usability of the product. As alluded to multiple times in the course, it is not enough to have an efficient product that does not solve a real-world problem. As such, our team spent much effort in refining and crystallizing a real-world problem that not only could be realistically addressed in the short time given for this project, but also has enough potential to be developed into a larger, more feature-filled product. As mentioned in our future plans, our student project has now been submitted for a hospital-level grant funding and it is my hope that it can be incorporated into the hospital workflow.

3. How I can apply the knowledge and skills in other situations or my workplaces

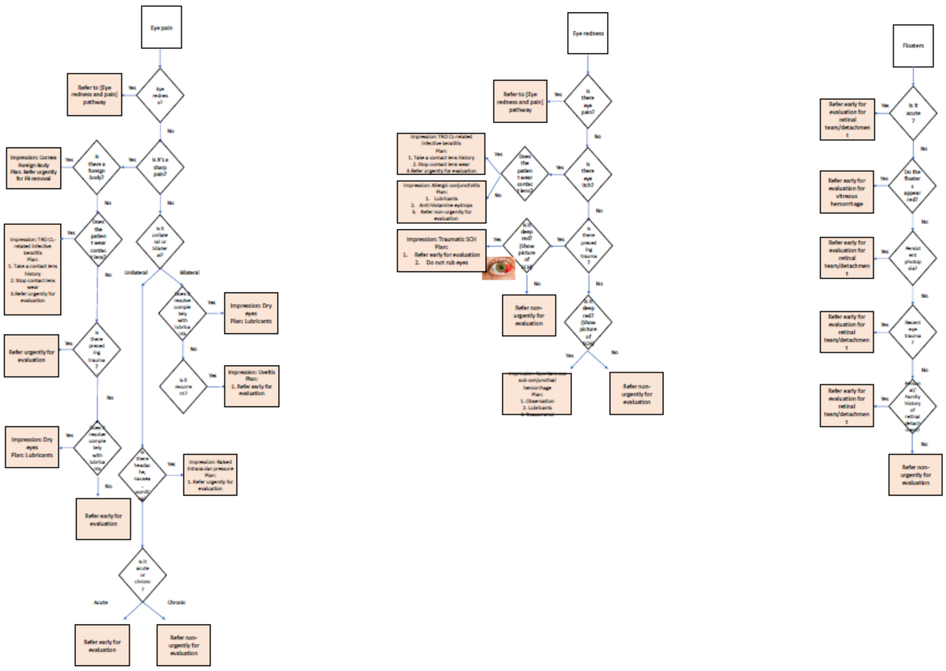
Healthcare is always looking for intelligent designs to solve complex solutions. However, amongst the lay public, Artificial intelligence (AI) and Machine Learning (ML) has always carried a mystic, even magical aura. Through this course, I was able to demystify and better understand how an AI project is conceptualized and refined, the various approaches at our disposal to tackle the project, and the issues with testing and implementation.

I now look at the problems with a more realistic point of view, being cognizant that not all problems can be or should be solved by AI/ML methods. Some problems may be protocol-/ system- related and should be better solved by targeting those root issues.

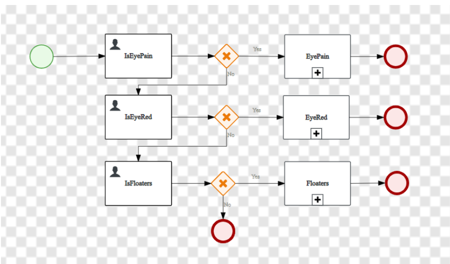
I am particularly keen on introducing some of the techniques from the course in the workplace. For example, the Excel Solver would be an excellent way for roster planning, and resource planning within the department. Chat bots can also be used for patient education about the common eye conditions. KIE Drools are applicable to care pathways where the care management is well defined given a particular diagnosis (i.e., stroke patients going onto care pathway). These are be optimized for activations which is especially important for time-critical diseases.

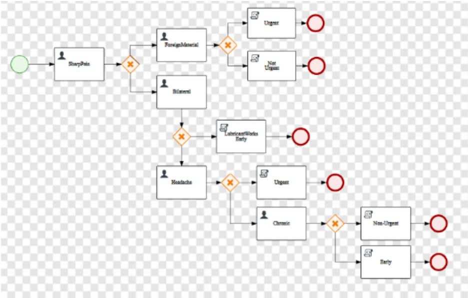
Appendix 5

Example of initial flow diagram



Initial Business Process Flow

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Headache
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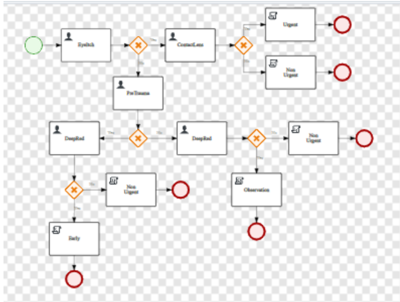
Chronic
Non-Urgent
Early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ContactLens
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PreTrauma
DeepRed
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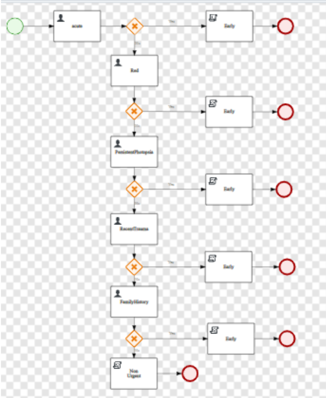
Non Urgent
Observation
Early


acute
Early
Red
Early
PersistentPhotopsia
Early
RecentTrauma
Early
FamilyHistory
Early
Non Urgent