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IMPLEMENTATION FOR AUGMENTATIVE AND ALTERNATIVE COMMUNICATION (AAC) TOOLS FOR RETT SYNDROME INDIVIDUAL IN ACTIVITIES OF DAILY LIVING (ADL)

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Abstract

Rett Syndrome occurs between one in 10000 to 15000 girls in Indonesia. In Hasan Sadikin Hospital, Bandung, Indonesia, there is a girl suffering from Rett Syndrome. Doctors in Hasan Sadikin Hospital find a lot of difficulties in communicating with the patient, since Rett Syndrome patients has little-to-no speech capabilities, and their hands often move involuntarily, especially with regards to Activities of Daily Living (ADL). Hence, a method to communicate with Rett Syndrome patient is being proposed using Augmentative and Alternative Communication (AAC) to support communication between the caregiver and the patient. Two of those methods are using gaze-tracking and head-pose. The methods tested consists of head-pose algorithm, gaze-tracking with Dlib, gaze-tracking with Haar Cascades, and EyeTribe. Each method is tested first with normal people before being tested with the patient. EyeTribe, head-pose, and gaze-tracking algorithm using Dlib achieve good results, with the best results being at 50cm distance and with high light intensity, however the Rett Syndrome patient achieves poor results when using the application, although head-pose achieves the best results in terms of determining needed ADL at around 45% accuracy. Hence, the Rett Syndrome patient needs training to use the application properly.

Keywords : *Activity of Daily Living, Augmentative and Alternative Communication, Gaze Tracking, Head-pose, Rett Syndrome*

INTRODUCTION

Rett Syndrome is a genetic disorder that mostly affect girls. The disorder is caused by mutation of the gene MECP2, which is located on the human's X chromosome (Hagberg, et.al., 1983). Currently, there is no exact statistics regarding Rett Syndrome, however in Australia, Rett Syndrome affects almost one in ten thousand girls between 5 to 18 years old (Laurvick, et.al., 2006). In Indonesia, it is estimated to affect one in 10000 to 15000 girls (Samiadi, 2017).

Patients affected with Rett Syndrome will have the following symptoms: a) Normal brain development for the first 6 to 18 months, b) After 7 to 18 months, the brain development stops, and followed by rapid decline of mental and neurological functions, c) Loss of hand functions, even though during normal brain development the hands had functioned normally, d) The patient sometimes acquires Microchepaly, e) After a while, the patient's mental status stablizes, followed by the decline of neurological functions.

Due to Rett Syndrome patients declining mental and neurological abilities, especially hand functions and speech ability, it is very difficult to communicate with Rett Syndrome patients normally. One of such case is in Rumah Sakit Hasan Sadikin at

Bandung, Indonesia, where there is a girl hospitalized there. Currently the doctors uses some sort of timetable for the patient to follow through, for example at 13:00, it is time for the patient to eat her lunch, at 15:00 is the time for the patient to take a nap. However, the doctors still can not reliably determine what the patient needs at the moment.

The research objective is to develop a web-based Augmentative and Alternative Communication (AAC) application to help the caregivers to communicate with the patient. The AAC application will either use head-pose or gaze-tracking in order to help the doctors or caregiver determine the needs that need to be satisfied. The researcher wants to find out whether the use of web-based AAC will speed up the communication between the Rett Syndrome patient and the caregivers. EyeTribe is a low-cost eye-tracker, which is claimed to have a cost of only $199. It has SDK that supports C#, Java, and C++ programming language. Before using the EyeTribe, the user needs to do the calibration first. The calibration consists of the user needing to gaze to the circle, and every several seconds, the circle moves to the new position of the screen, and the user needs to gaze to the new position of the circle. After the calibration is finished, EyeTribe will give the rating of the calibration, with one stars being the worst, and five stars being the best.

There are a lot of AAC programs that are available currently. One of the most notable ones are Communicator 5, which is developed by tobii dynavox. I tis a software that uses AAC to support communication between different-abled patients and caregivers. There are several ways to use Communicator 5. However, there seems to be no support for eye trackers that are not developed by tobii dynavox. To fully take advantage of Communicator 5, the user needs to use the eye tracker from tobii dynavox, which is PCEye Control. Once the user has launched Communicator 5, the user can create their own screen appropriate for their use. or use a premade screens. Another is TAP / TAPC, where the researcher developed a mobile-based application to support communication with different-abled patients, which in this case is Cerebral Palsy patients. The user will select a set of ADL categories, from which the user will be able to select an activity from each category. After the user has made a selection, then a short message is sent to the caregiver about the corresponding selection, letting the caregiver know which needs the user needs to be satisfied. This research also deals with the diffabled patients, although the main syndrome is different, which in this case is for the Cerebral Palsy. Moreover, since Cerebral Palsy still have speech communication to some extent, as well as hand movement, it is feasible for the researcher to develop a mobile-based application, where the user can simply touch the desired ADL option (Young, 2018).

Another research implements pupil tracker to communicate with paralyzed patients, since many times, the patients' hands are unable to move, and they also cannot speak to know what they want. For the research, the author uses PS3 Eye to detect the eye of the patient, which is then integrated with OpenCV Library to help improving the accuracy of the eye-tracking. The research uses a virtual keyboard, in which the patient uses their eyes to type using the virtual keyboard. However, since the patient still can not read, it is not very feasible for the patient to use the virtual keyboard (Dirgantara, 2015). Finally, there is a research by Galinium, et.al. (2016), which uses head-pose algorithm to gather information about which part of the advertisement the people often look at. The researcher uses C# to implement the algorithm, as well as Microsoft Kinect SDK to detect the face. This research also uses head-pose algorithm in order to track where the users are looking at, however the main difference from the research by Galinium et.al. (2016) with this research is they use Microsoft Kinect to detect the face, whereas this research uses EyeTribe and ordinary webcam to detect the faces.

METHOD

1. Architecture Diagram

Figure 1 shows the architecture diagram of the application. Currently, there will be only front-end part of the application, since the objective of the research is to determine whether using AAC is a viable option to support communication with Rett Syndrome patient. The application will take advantage of the front camera of the tablet PC to detect the face of the patient. The researcher uses

Python Programming Language, as well as OpenCV and Dlib Library to develop the algorithm for the head-pose and gaze-tracking.

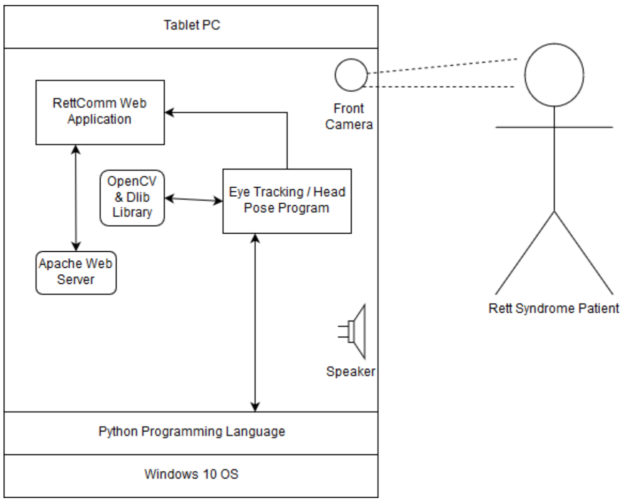

Figure 1 Architecture Diagram for the application

2. Research Overview

The research begins on literature review, which is done to make sure that the method that will be used is viable. Next, the researcher develops a web-based AAC program, which will be used for the experiment. Then, the researcher develops the algorithm for the head-pose and gaze-tracking. Once the researcher are satisfied with the results of the algorithms, the experiment begins. If the experiment hasn't yielded satisfactory results, the algorithms will be further refined until the results are better. After we get good results from the experiment, the researcher will go to the hospital, so that the algorithms can be tested to the patient with the Rett Syndrome. The researcher will take the result to determine the best way to assist communication between the caregiver with the patient. There are four algorithms or tools that are tested for this experiment. The first is EyeTribe, the eye-tracking tool.

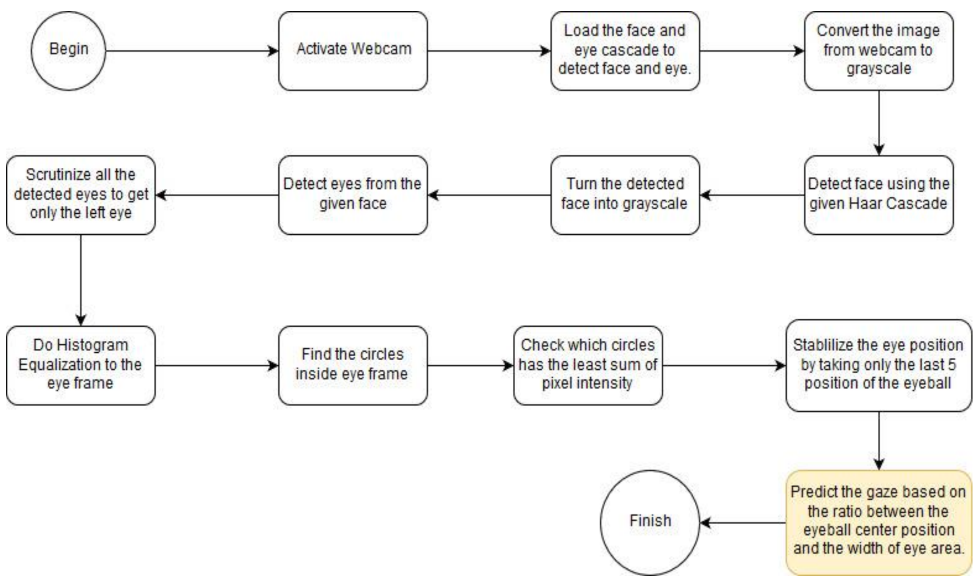

Figure 2 Flowchart of the gaze-tracking algorithm with Haar Cascade

The second is an eye-tracking algorithm that uses Haar Cascades to detect the face and the eyes, as well as houghCircles method from OpenCV. The algorithm is derived from Araujo (2017). However, since the original implementation of the algorithm compares the last position of the eyeball with the current position of the eyeball, the algorithm does not satisfy what the researcher needs. Hence, the researcher modify the algorithm, which will instead determine the gaze by comparing the distance of the eyeball from the left side of the eye area with the width of the eye. Figure 2 shows the flowchart of the algorithm which uses Haar Cascades to detect the face. As shown on the figure, the program will activate the webcam first, and loads the pre-trained Face and Eye Cascades to the program. Then, some image-preprocessing is done, in which the image is converted into grayscale. Then, the program will detect the face and eyes using the pre-trained face and eye cascades, respectively. After that, the program will only get one of the two eyes, which in this case, is the left eye. Then the program does Histogram Equalization to the obtained eye, and after that, the program uses Hough Circles method to try detecting the pupil inside the eye region. However, since there can be many circles detected, the program will choose the circle with the least sum of pixel intensity to be declared as the pupil. Then, to make the pupil coordinates more stable, the program gets the last 5 position of the pupil. Finally, the program moves the cursor based on the ratio between the center of the eyeball and the width of the eye area.

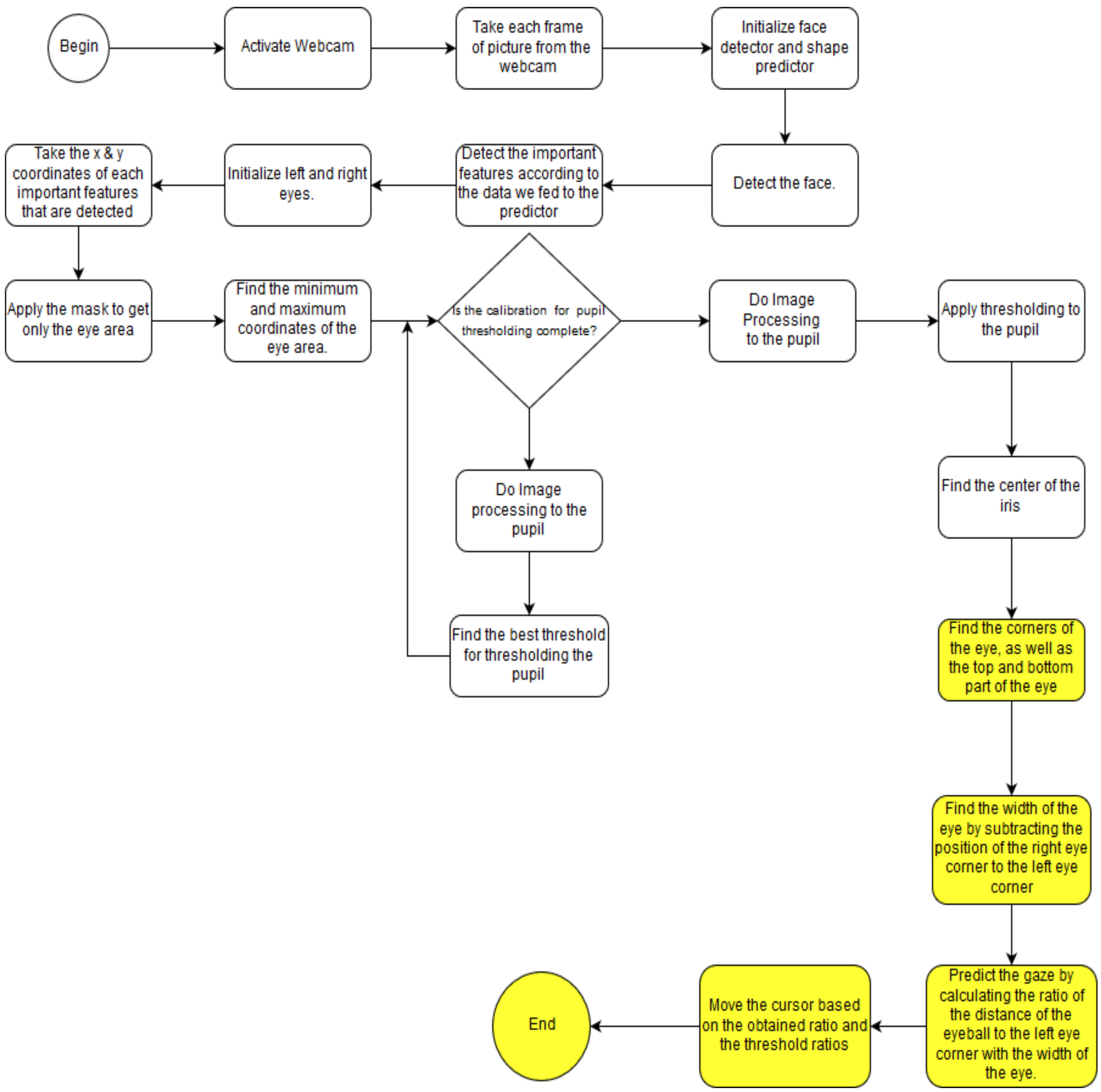

Figure 3 Flowchart of the gaze-tracking algorithm with Dlib

The third is an eye-tracking algorithm that also uses Dlib Library to detect the faces, as well as the eye area. The algorithm is derived from Lamé (2019). Originally, the algorithm uses the ratio of the eyeball position, relative to the left part of the eye to the width of the eye area to determine the gaze. However, the researcher found the results to be disappointing. The researcher then modify the algorithm. The modified algorithm will instead calculate the rasio between the distance of the eyeball from the left eye corner and the distance between the left corner of the eye and the right corner of the eye.

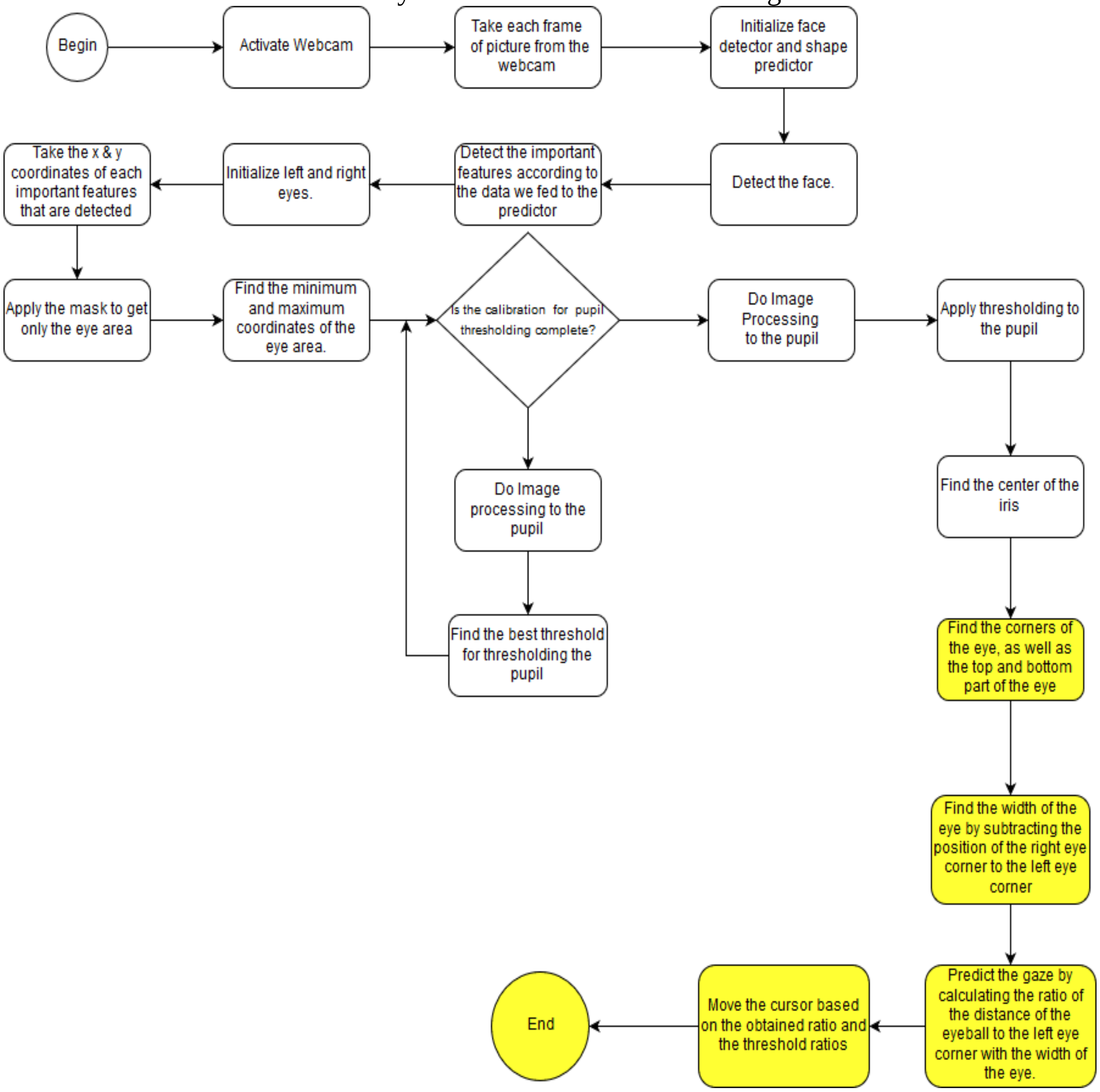

Figure 3 Flowchart of the gaze-tracking algorithm with Dlib

shows the flowchart of the gaze-tracking algorithm using Dlib

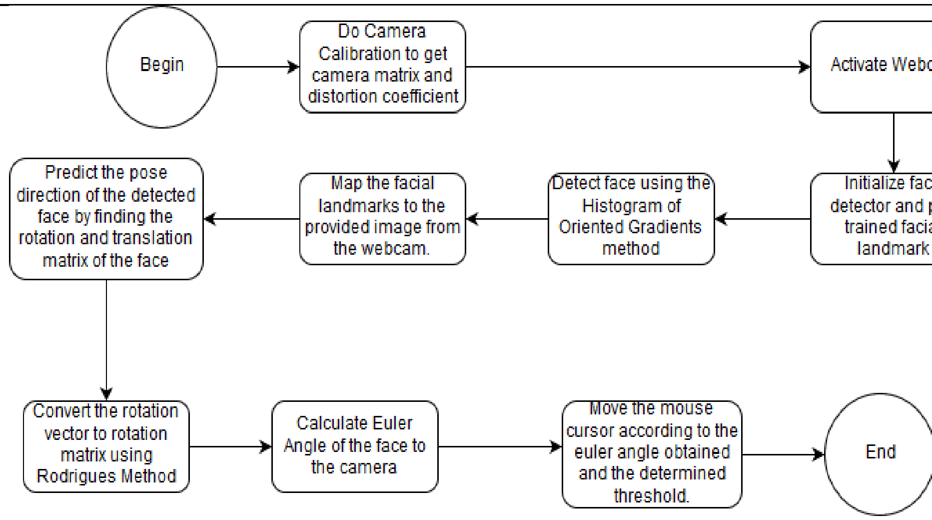

Figure 4 Flowchart of the head-pose algorithm

The final algorithm to be tested is head pose library. OpenCV has several methods that allows easy calculation of the head pose, which are solvePnp , Rodrigues, and decomposeProjectionMatrix. solvePnp method will attempt to find the rotation vector of the object, while Rodrigues method will find convert the rotation vector to the rotation matrix, and finally decomposeProjectionMatrix convert the rotation matrix to euler angle. OpenCV's solvePNP method uses the algorithm by Zhengyou (2000), and we can convert rotation matrix to euler angle with the method described by Slabaugh (1999).

3. Experiment

To determine the best algorithm to communicate with Rett Syndrome patients, the four algorithms / devices is tested with several scenarios to eight respondents:

Table 1 Experiment scenarios for distance

Scenario Number	Description
1	The respondent sits 50 cm in front of the camera.
2	The respondent sits 75 cm in front of the camera.
3	The respondent sits 100 cm in front of the camera.

Table 1 shows the scenario between different distance of the respondent's eyes with the sensor. These distances are chosen because 50 to 100 cm are the best distance between the eye and the screen in regular use.

Table 2 Experiment scenarios for lighting

Scenario	Description
1	Both lights with high intensity and low intensity will be turned on
2	Only lights with lower intensity is turned on
3	None of the lights are turned on.

Table 2 shows the scenario between different lightings in a room. This is done because regular camera relies on light from external source, whereas EyeTribe uses infrared to detect the eyes, and the latter works well even under minimal lighting conditions. To ensure that the results are consistent, there are several conditions that are standardized: a) The respondent doesn't wear glasses, b) The respondent sits with their eyes 50 cm from the camera, unless when experimenting with different lengths, c) All two lights in the room is on, except when conducting the experiment for no lighting. The laptop screen has an angled approximately 90 degrees from the keyboard.

To gather the result, a website is set up, which consists of two ADL options. For each experiment, the researcher asks each respondent to gaze (for EyeTribe / gaze-tracking algorithms) or look over (for head-pose) to the ADL option that the researcher has announced. The researcher records the actual results, as well as the mean of x-coordinates and the standard deviation. After that, the researcher asks the respondent to look to the other ADL option, and the researcher records the results.

Table 3 Accuracy of determining ADL of different algorithms / device under different conditions

Conditions	**Eyetribe**	**Dlib (Algorithm 1)**	**Haar Cascade (Algorithm 2)**	**Headpose (Algorithm 3)**
High Intensity	100%	93.75%	12.5%	100%
Medium Intensity	100%	81.25%	25%	68.75%
Low Intensity	87.5%	0%	0%	0%
50 cm	100%	93.75%	12.5%	100%
75 cm	87.5%	81.25%	12.5%	100%
100 cm	37.5%	31.25%	25%	81.25%

Furthermore, the researcher visited Hasan Sadikin Hospital. EyeTribe, head-pose algorithm, as well as gaze-tracking using Dlib were tested with the doctor, the Rett Syndrome patient's father, a diffable boy, and finally the Rett Syndrome patient, using the prototype website which have been developed further.

The prototype website consists of following options:

a) Eat-drink option: This set of options determines whether the patient wants to eat or drink. Selecting "eat" leads to the eating snack and eating lunch option, while selecting "drink" leads to the drinking water and drinking milk option, b) Father-mother option: This set of options determines whether the patient wants to be taken care with her mom or her dad. Upon choosing one of the two options, another set of options consisting of the patient's sister and the chosen option appears, so the patient needs to make sure that she wants to be taken care by her mom or her dad., c) Cousins option: This set of options determines which of the patients' two cousins that she wants to play with., d) Sleep-bath option: This set of options determines whether the patient wants to sleep or to bath.

The research methodology goes as follows as seen on Figure 5. This research first finds out the avilable methods of OCR that are available.This research focuses on finding out both training accuracy and testing accuracy. The training accuracy will be determined by Mean Edit Distance (MED) and the testing accuracy will be determined by the web service accuracy.

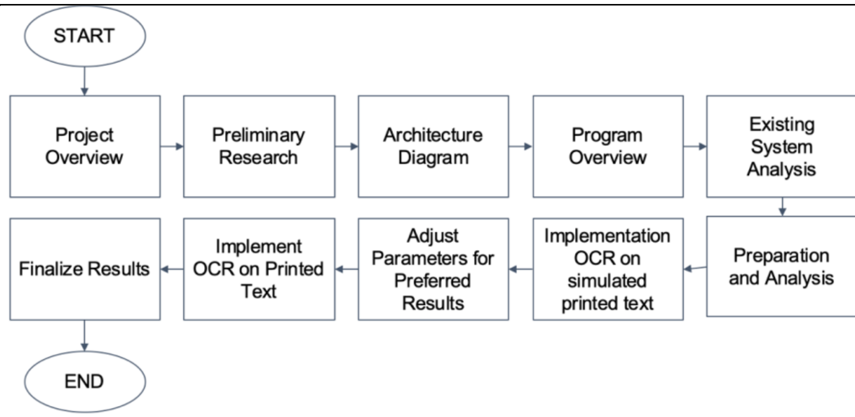

Figure 5. Research Methodology Diagram

Result and Discussion

1. Results of Normal people

Table 3 shows the accuracy of the algorithms under different conditions in percentage. The accuracy is defined whether the actual result as a result of the cursor movement due to the gaze-tracking / head-pose is the same with the expected result, as well as whether the mean x-coordinates lies between the expected coordinates of the chosen option. As shown on the table, EyeTribe performs the best, even at low light intensity, with 100% accuracy at both high and medium light intensity, and only slightly dropping to 87.5% accuracy at low light intensity. However, EyeTribe does not perform well at 100 cm distance, managing only 37.5% accuracy. This is because the specifications of EyeTribe states that it performs best at 45-75 cm. Head-pose and Gaze-tracking with Dlib achieves good results at 50cm distance and high light intensity, the former in also obtains perfect accuracy in both 50 and 75 cm. However, at 100 cm results, only the headpose achieves above 80% accuracy. Conversely, at low light intensity, only EyeTribe manages to get accuracy above 80% on low light intensity experiment. This is because EyeTribe uses infrared as a sensor, whereas regular webcams rely on outside light to get a clear image of the face.

Also, the gaze-tracking algorithm using Haar Cascades attains very poor results, with its best results being 25%. This is because houghCircles method of OpenCV only detects the circle, and if the respondents' eyes are not fully opened, then the pupil would not appear circular, making the pupil unable to be detected. Moreover, the houghCircles method often fails to find the pupil position properly.

2. Observation with Diffable and Rett Syndrome patient

The authors went to Hasan Sadikin Hospital to observe how the diffabled and Rett Syndrome patient uses the application. The diffable patient has decreased motoric abilities, however the patient still has normal intelligence, as well as speech capabilities. Moreover, the diffable boy does not have difficulties in moving his neck. Meanwhile, the Rett Syndrome patient has the following characteristics: a) She cannot communicate at all since birth, b) She is approximately 6 years old, c) She is currently learning to walk.

The diffable patient is then asked to do the EyeTribe calibration, then the patient is asked to choose one of two options using EyeTribe with the eat-drink combination, then one time using the sleep-bath combination. After that, the boy used gaze-tracking using Dlib and head-pose to choose one of two options with the eat-drink and sleep-bath combination. The observation shows that the diffable patient manages to choose the correct option after minimal training. The Rett Syndrome patient is then asked to choose the options from the website using EyeTribe, gaze-tracking algorithm by Dlib, and head-pose. Before using EyeTribe, the patient is asked to do the calibration process of the EyeTribe. After that, using EyeTribe and head-pose, the researcher asks the patient to choose what the researcher announced in the eat-drink tab. This is helped by the patients' parents to help the patient choose the option. Then, since the patient would be more familiar with the face of their parents, the researcher decided to switch the eat-drink options to mom-dad options. Using head-pose algorithm and gaze-tracking algorithm with Dlib, the patient is asked to choose one of the two options shown. Based on the observations, the researcher obtained the following results: a) The patient manages to complete the calibration of EyeTribe, even though the calibration quality is only 1 star. This means that the patient can focus to the screen for certain amount of time., b) While the Rett Syndrome patient is in the mood to use the application, the patient manages to choose the correct option from the two options in the website. The results are especially good when using head-pose, c) However, the patient has a short-attention span, so the patient would become bored if the experiment is conducted for too long. While she was bored, her head also often moves involuntarily, d) Based on the points above, the patient needs training in order to choose the correct options from the website. However, with enough training, the patient should be able to choose the correct option from the website.

3. Results with diffable patient

Table 4 Accuracy of determining ADL for diffable patient with different methods

Algorithm / method	**Number of Trials**	**Accuracy of determining ADL (%)**
EyeTribe	10	80
Head Pose	4	66.7

Table 4 shows the accuracy of determining ADL for diffable patient with different methods. As shown on the table, as well as the observation described on previous section, the diffable patient manages to use the eye-tracking and head-pose well. The lower accuracy of head pose may be attributed with the patient losing focus, as well as less number of trials done for head-pose compared to EyeTribe.

4. Results with Rett Syndrome Patient

Table 5 Accuracy of determining ADL for Rett Syndrome Patient with different methods

Algorithm	**Number of trials**	**Accuracy of determining ADL (%)**
EyeTribe	14	21.42
Dlib	4	25
Head Pose	22	45.45

Table 5 shows the accuracy of determining ADL with different methods for the Rett Syndrome patient. As evident from the observations made at 2, due to the patient's short attention span, all three methods have low accuracy in determining the ADL needed for the patient. However, head pose method does give a better result for the patient, with almost twice as accurate as gaze-tracking using either EyeTribe or Dlib at around 45% accuracy.

CONCLUSION

Under experimental conditions, both algorithm DLib and Head pose, as well as EyeTribe provides accurate results when determining the user's ADL to be satisfied at the moment. Meanwhile, algorithm Haar Cascade fails to reliably determine the user's need even at normal conditions. The Algorithm DLib and Headpose performs best at 50-cm distance under high light intensity. There are several method to improve this research. Future works can include expanding the program to include more ADLs, so that the Rett Syndrome Patient can have more needs satisfied. To accomplish this, more ADLs should be included in one screen, which means that a way to detect the eye or head-movements vertically is needed. Since some users still complained about the inaccuracies for the gaze-tracking, a way to calibrate the program must be developed, at least for normal people. Alternatively, to make sure the program can be used by Rett Syndrome Patient without calibration, one can gather data regarding the thresholds for the rasio of the distance of the eyeball from the left eye corners to the distance of the two corners of the eye.

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