WIA3003: Academic Project II Report

Project Title: Automated Screening of Autism Spectrum Disorder Based On Eye Gaze Information

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Abstract

Autism Spectrum Disorder (ASD) is a group of mental neurodevelopmental disorders that affects communication and behaviour. It is called as a developmental disorder because symptoms usually appear early on during the first two years of life. People diagnosed with ASD generally have language impairment, difficulties in social communication and repetitive behaviours. These symptoms damage the capacity of a person to function properly in college, work and other places.

ASD has a significant economic impact in the healthcare sector, both owing to the rise in the amount of ASD instances and owing to the time and expenses involved in the diagnosis of the patient. Early identification of ASD can help individuals and the healthcare industry by prescribing the treatment and/or drug they need, thereby lowering the long-term expenses of late diagnosis.

Thus, global medical experts need a simple, time efficient, reliable, and easily available ASD screening techniques that correctly predict if a child is ASD-positive or not and advise them to go for formal clinical diagnosis.

Our data set was created by collecting data from Autism Spectrum Disorder (ASD) subjects at Yayasan Fakih and Typically Developing (TD) subjects at United Arakan Institute Malaysia. The gaze distributions of participants were collected while they were watching a 54 second long video consisting of social or non social scenes.

Upon analysing, the gaze distributions of ASD and TD subjects were observed to be significantly different. Neural networks were trained using the collected data. After training, the neural networks were able to give predictions for new users. An ASD risk score was calculated based on this prediction. Based on this score, users were advised whether or not to go for clinical diagnosis. We found out that our model worked well with the data. To measure the efficiency of the algorithms, we used three distinct metrics (accuracy, precision and recall), and it seems that all metrics revealed a good classification of ASD cases. The website that was built based on this model proves to be an accurate and easily available screening method that uses gaze information of the user and suggests whether the child shall go for clinical diagnosis or not

Introduction

Autistic Spectrum Disorder (ASD) is the name of a set of developmental disorders affecting the nervous system. ASD symptoms range from mild to severe: mainly language impairment, difficulties in social communication, and repetitive behaviors. Other possible symptoms consists of anxiety, mood disorders and Attention-Deficit/Hyperactivity Disorder (ADHD).

According to the Diagnostic and Statistical Manual of Mental Disorders (DSM-5), a guide created by the American Psychiatric Association that is used for the diagnosis of mental disorders, ASD patients have communication and interaction difficulties with others, recurring behaviours and symptoms that damage the capacity of a person to function properly in college, work and other places.

Autism is referred to as a 'spectrum' disease because the type and seriousness of the diseases in individuals vary widely. ASD occurs in all ethnic, racial, and economic groups. Although ASD can be a permanent condition, medications and facilities can enhance a patient's symptoms and capability to function. The American Academy of Pediatrics advises autism screening for all kids.

Doctors diagnose ASD by examining the conduct and growth of a person. ASD can normally be diagnosed reliably by age 2. Early therapy for ASD is essential as the correct therapy can help people discover their abilities and take advantage of their abilities. But there is a lack of easily accessible and accurate ASD screening tools.

There are difficulties to carry out studies on detection of ASD because data sets that contains behavioural data and other information like gender, age, ethnicity, etc, are required. Such data sets are rare, which makes it hard to thoroughly analyze the efficiency, sensitivity, specificity and predictive accuracy of the ASD detection method. Currently, very few clinical or testing autism data sets are accessible, most of them are genetic in nature. For personal and personal purposes and for the rules around them, these information are highly delicate and difficult to obtain.

Several researchers have used machine learning to detect whether a person has ASD or not. Some of them are based on questionnaires and medical data while others are based on the video data.

This project was completed within 7 weeks, starting from 2nd July 2019.

This report consists of the project objectives, literature review, problem statement, research methodology, system analysis and design as well as conclusion regarding ASD screening using machine learning.

Objectives

1. To provide ASD risk levels for new children based on the probability of them belonging to ASD class using their eye gaze information.
   It is based on binary classification problem, where, for a new child with certain eye gaze positions on the video shown, our model should predict how probable is that the child might have ASD, where this probability is the probability measure of the child belonging to ASD class in the machine learning process.
2. To recommend children with high risk of having ASD, to go for clinical diagnosis.

Literature Review

In a paper, some researchers explore a new ASD screening method, namely Gaze-Wasserstein, that is non-invasive, fast, and widely accessible. Based on the gaze tracking and analysis, Gaze-Wasserstein is able to provide objective gaze pattern-based measurements for home-based ASD screening, and can eventually be deployed on any mobile technologies with a front camera. To test the performance of Gaze-Wasserstein, they conducted a pilot study with 32 child participants where 16 children have ASD and 16 children are typically developing. Evaluation results demonstrate the effectiveness and time-efficiency of their proposed method in the ASD screening, which indicates that their Gaze-Wasserstein is a promising autism screening approach in the clinical practice.
(Cho, et al. 2016)

Another research has been done on identifying children with autism spectrum disorder based on their face processing abnormality using machine learning. A prior study has constantly found atypical facial imaging models in people with Autism Spectrum Disorder (ASD). The current research examined whether its facial imaging models could possibly be helpful for identifying kids with ASD by using the classification machine learning algorithm. In particular, the machine learning method was applied so that children with or without ASD can be classified through the analysis of eye motion data from the facial recognition task [Yi et al., 2016]. The performance of the model in terms of its accuracy, sensitivity, and specificity of classifying ASD was measured. The results showed successful evidence for implementing

the machine-learning algorithm based on face scanning models to recognize kids with ASD with a maximum classification accuracy of 88.51 percent.
(Liu, Li, & Yi, 2016)

A study demonstrated an eye-tracking algorithm using a tablet-based system estimates gaze preference children with and without ASD with sufficient accuracy. In this study, they designed a simple eye-tracking algorithm that does not require calibration or head holding, as a platform for future validation of a cost-effective ASD potential screening instrument. This system operates on a portable and inexpensive tablet to measure gaze preference of children for social compared to abstract scenes. A child watches a one-minute stimulus video composed of a social scene projected on the left side and an abstract scene projected on the right side of the tablet's screen. It is important to highlight that this system works without requiring intensive calibration, previous training, or restriction of the child's head movement making it applicable in the ASD population including young children.
(Vargas-Cuentas, et al., 2017)

In another study, researchers presented children with 10 videos. Each video showed an actress looking directly into the camera, playing the role of caregiver, and engaging the viewer (playing pat-a-cake, peek-a-boo, etc). Children's visual fixation patterns were measured by eye tracking. They found out looking at the eyes of others was significantly decreased in 2-year-old children with autism ($P < .001$), while looking at mouths was increased ($P < .01$) in comparison with both control groups. Llooking at the eyes of others is important in early social development and in social adaptation throughout one's life span. The results indicate that in 2-year-old children with autism, this behavior is already derailed, suggesting critical consequences for development but also offering a potential biomarker for quantifying syndrome manifestation at this early age.
(Jones, Carr, & Klin, 2008)

In another study, a preferential looking paradigm was developed that examined looking time toward highly salient social images, such as children dancing and doing yoga, in comparison with highly salient geometric images, such as repeating and moving concentric circles. This study provides strong evidence that some infants at risk for an ASD begin life with an unusual preference for geometric repetition. They believe that it may be easy to capture this preference using relatively inexpensive techniques in mainstream clinical settings such as a pediatrician's office. Furthermore, they also believe that infants identified as exhibiting preferences for geometric repetition are excellent candidates for further

developmental evaluation and possible early treatment. Mechanisms of developmental plasticity provide clear rationale that an enriched environment, such as one afforded by careful early treatment, can significantly improve brain structure and function. The discovery of an early preference for geometric repetition moves beyond the more commonly studied social defects and opens up a new line of inquiry into the early emerging developmental abnormalities in autism.
(Pierce, Conant, Hazin, Stoner, & Desmond, 2011)

In another research, participants viewed a 5-minute video that included 44 dynamic stimuli from 7 distinct paradigms while gaze was recorded. Gaze metrics were computed for temporally defined regions of interest. Autism risk and symptom indices aggregated gaze measures showing significant bivariate relationships with ASD diagnosis and Autism Diagnostic Observation Schedule, Second Edition (ADOS-2) symptom severity levels in a training sample (75%, n = 150). Eye tracking measures appear to be useful quantitative, objective measures of ASD risk and autism symptom levels. If independently replicated and scaled for clinical use, eye tracking–based measures could be used to inform clinical judgment regarding ASD identification and to track autism symptom levels.
(Frazier, et al., 2018)

In another research, while viewing social scenes, eye-tracking technology measured visual fixations in 15 cognitively able males with autism and 15 age-, sex-, and verbal IQ-matched control subjects. They reliably coded fixations on 4 regions: mouth, eyes, body, and objects. They found out that when viewing naturalistic social situations, individuals with autism demonstrate abnormal patterns of social visual pursuit consistent with reduced salience of eyes and increased salience of mouths, bodies, and objects. Fixation times on mouths and objects but not on eyes are strong predictors of degree of social competence.
(Klin, Jones, Schultz, Volkmar, & Cohen, 2002)

A patent, EarlySee, is an app developed by ESC Lab in University at Buffalo, SUNY. It is convenient for daily-use and and allows for early detection of Autism Spectrum Disorder symptoms. The app utilizes the advanced computer vision technology. It tracks behavioral information like expression of the face and gaze attention which shows the cognitive response of kids watching a variety of social scenes. Ultimately, this information helps assess the danger of autism in young age kids.
(https://cse.buffalo.edu/~wenyaoxu/project/asd.html)

A patent, Autism & Beyond, is an app developed by a team of child psychiatrists, psychologists, pediatricians, engineers and computer scientists at Duke University. It is powered by Apple's ResearchKit. There are 2 operations involved in the study, which are video activities, i.e., kid watches four brief clips while the iPhone captures reactions from the kid and surveys, i.e., guardians will be requested to finish brief surveys on themselves and their children.
(https://autismandbeyond.researchkit.duke.edu/ch)

Problem Statements

ASD has an important impact on the economy in the healthcare sector, due to the rise in the amount of ASD diagnosed patients and the time and expenses involved in the diagnosis of the patient. Early detection of ASD can help individuals and the healthcare industry by prescribing the treatment and/or drug they need, thereby lowering the long-term expenses of late diagnosis.

Unfortunately, ASD is not diagnosed before the age of 4 in the United States of America. About 27% of cases remain undiagnosed at age 8. The main cause of this delay in diagnosis is an absence of efficient screening tools. Currently, very few clinical or testing autism data sets are accessible and most of them are genetic in nature.

Thus, healthcare experts worldwide require simple, time efficient, reliable, and easily available ASD detection techniques that can accurately predict if a person has ASD or not and advise them to go for formal clinical diagnosis. ASD screening tools, when created using machine learning models provide the above mentioned features in the ASD screening tool.

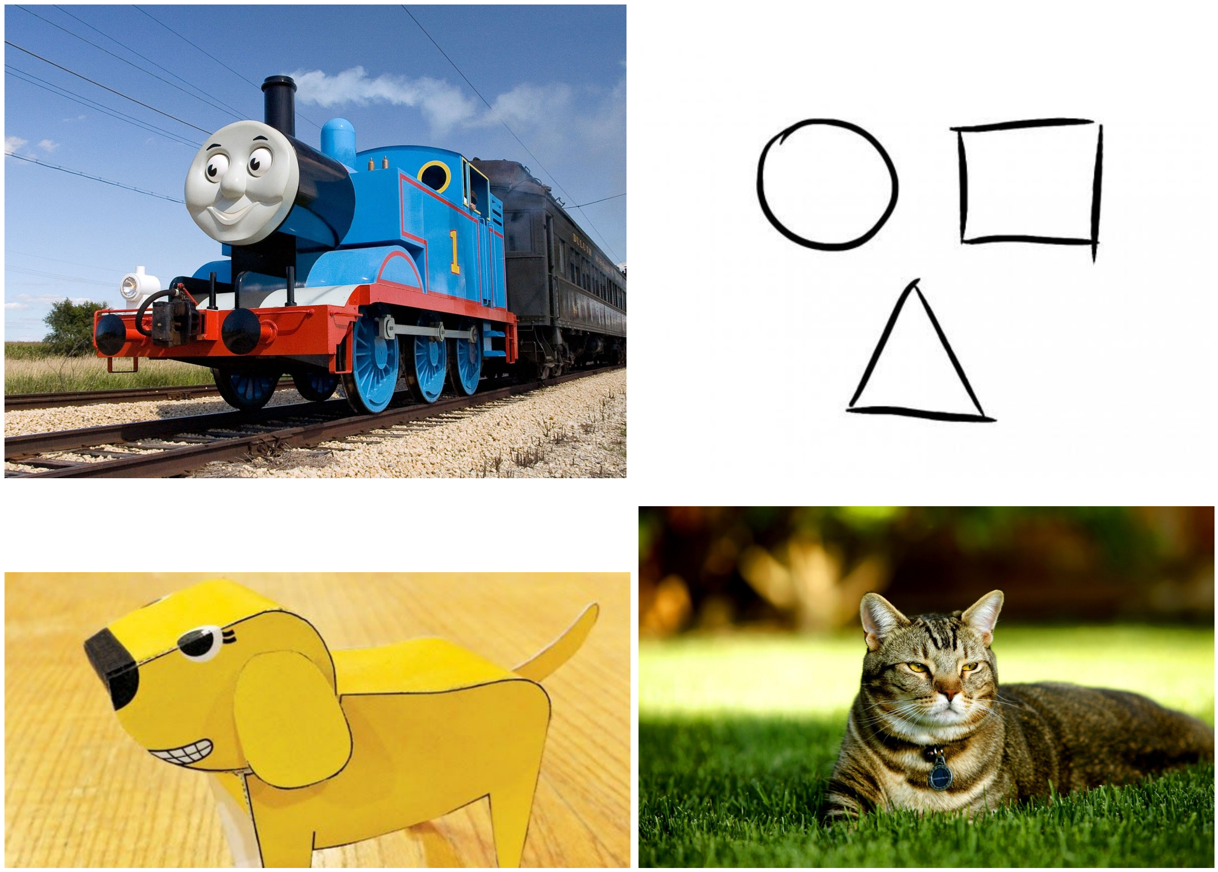
Research Methodology

Data Collection

Data collection was done through collaboration with Projek Rintis Fakih, Centre of Quranic Research, which is a community centre for special needs children, and United Arakan Institute Malaysia which is an orphanage in Puchong.

Participants were shown a video consisting of 8 scenes, which comprises of 4 social scenes and 4 non social scenes which are given below. While they were watching the video, their gaze positions on the screen was recorded using an in-browser webcam gaze tracker. Each pre-designed image was displayed to the participants for 5 seconds and shifting to following image took 2 seconds. Thus, total experimental process took 54 seconds. For selection of the visual stimulus, images that have a visually clean background were chosen in order to prevent any unintentional distraction from irrelevant stimuli.

Figures: Social scenes



Figures: Non social scenes

Implementation

During the experiment, gaze positions of the subjects on screen were recorded as distributions. These distributions were fed to artificial neural networks for training. This trained model was then used to build an ASD screening website.

System Analysis & Design

Requirements

Functional Requirements

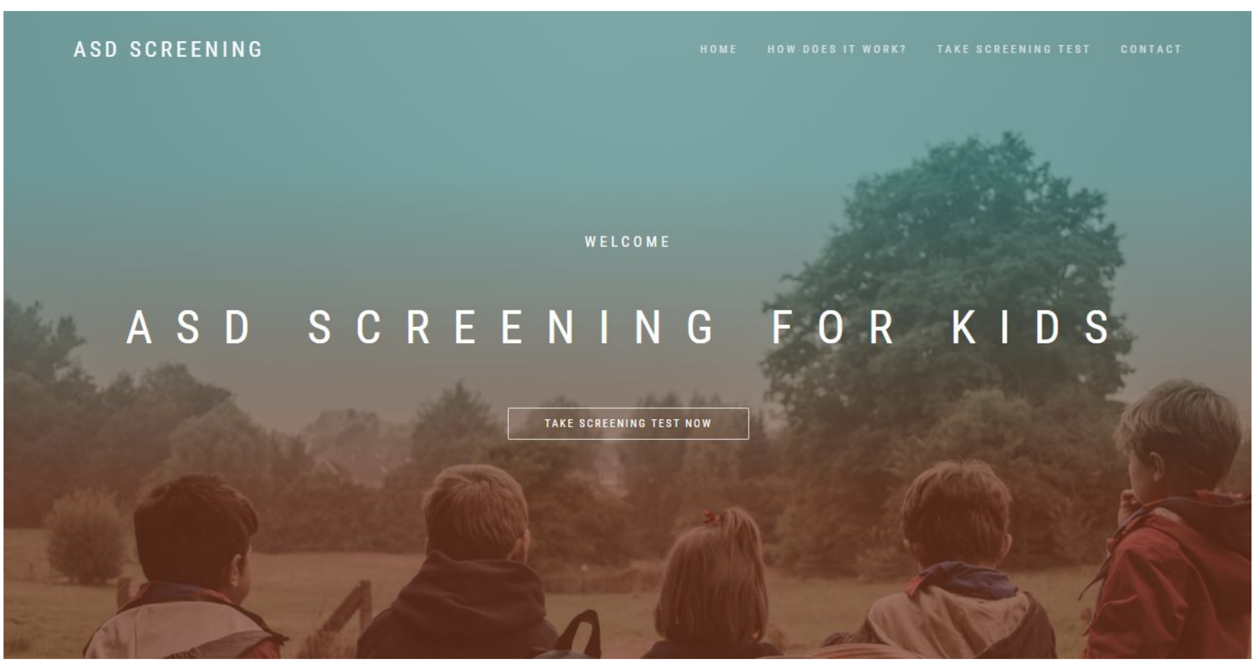
For a new child with certain eye gaze positions, when shown different social and non social scenes on screen, accurately predict whether or not that child has a high probability of having ASD.

Non - Functional Requirements

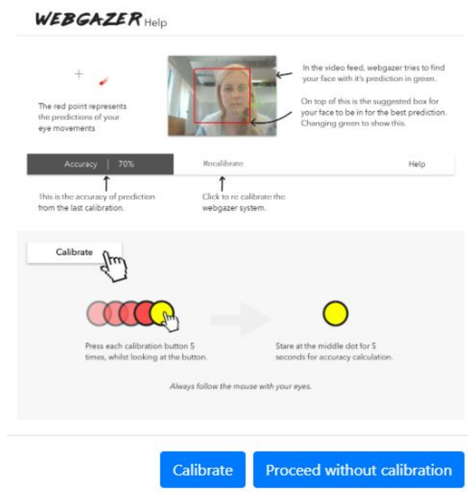
For positive prediction, there must be sufficiently strong risk of ASD to suggest the individual to go for further clinical diagnosis.

Interface Design

Mock-up

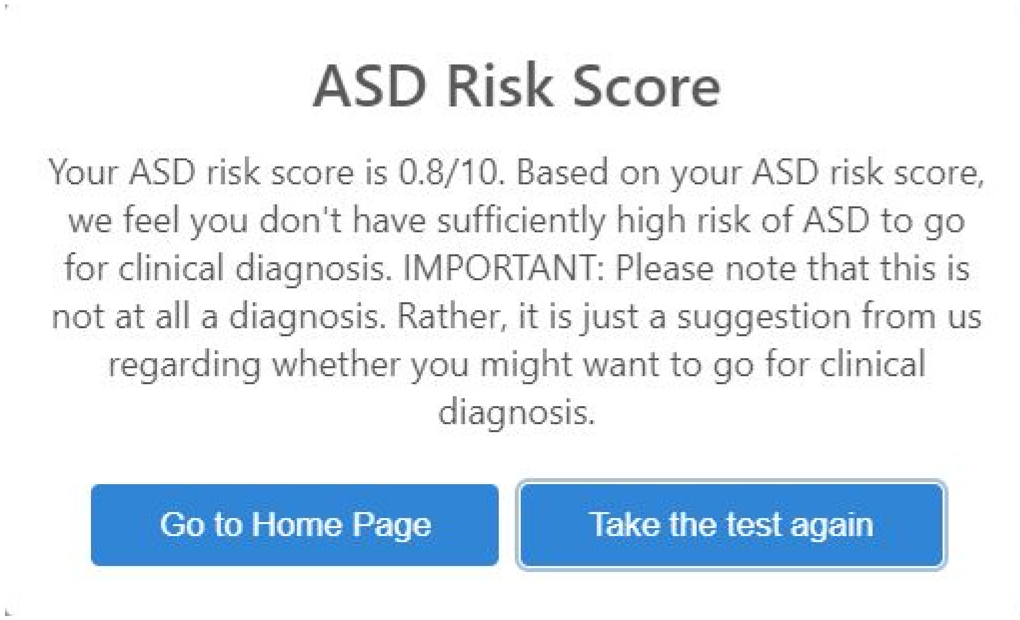


Homepage Mockup



Calibration Instructions

Video to be shown in full screen mode

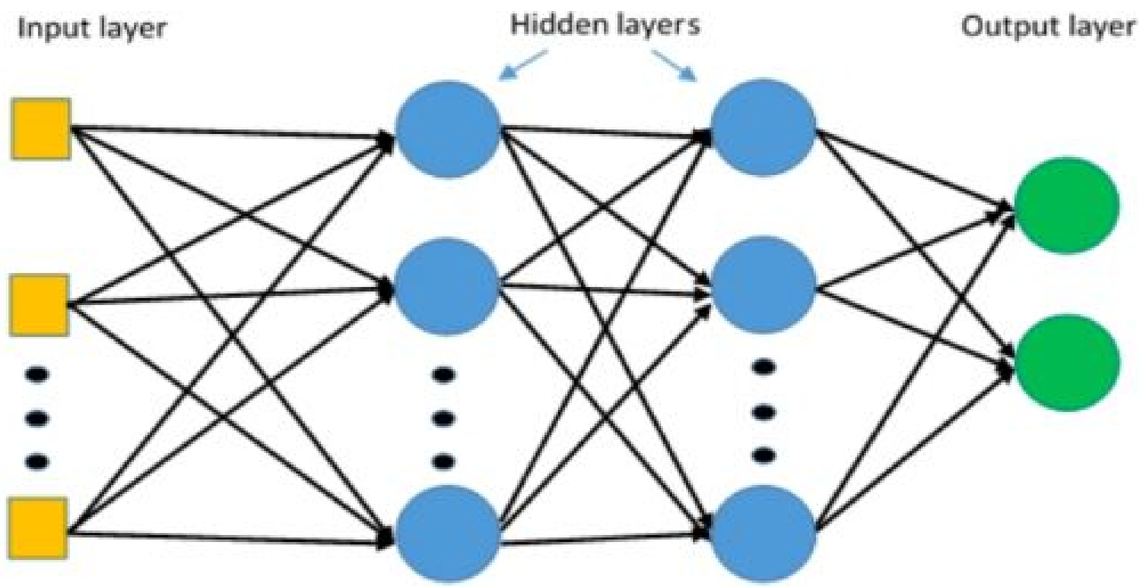


Risk Score Display

System Design: Algorithms & Techniques

Neural Network: Multi-Layer Perceptron(MLP)

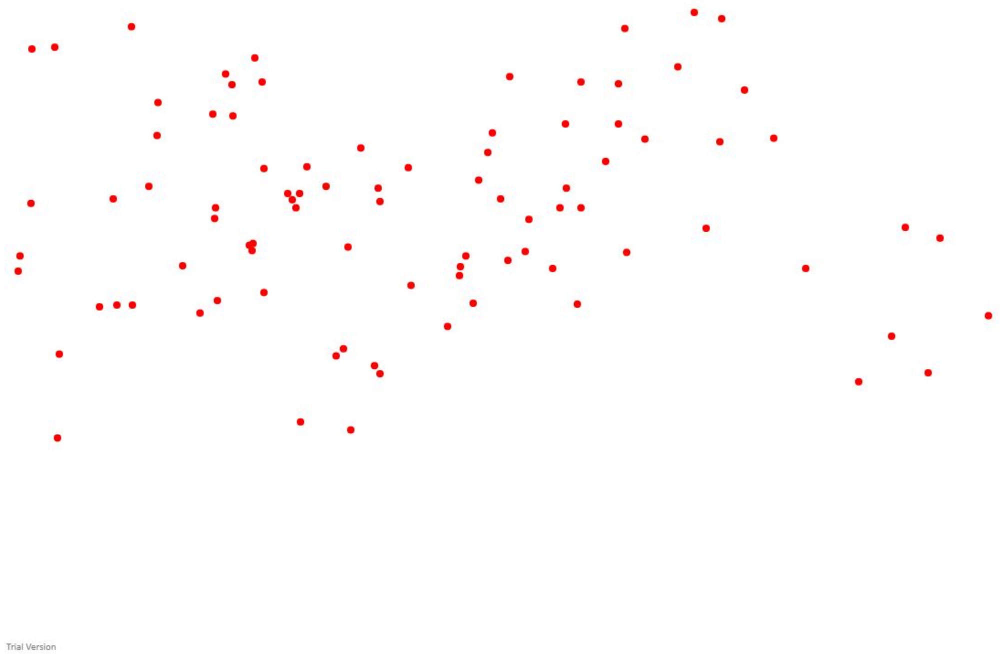
A multilayer perceptron (MLP) is a class of feedforward artificial neural network. An MLP comprises of at least three layers of nodes. Except for the input nodes, each node is a neuron that utilizes a nonlinear activation function. MLP uses a supervised learning algorithm called backpropagation for training. It is different from a linear perceptron because of the multiple layers and nonlinear functions. It can differentiate data that is not linearly separable. Multilayer perceptrons are sometimes referred to as 'vanilla' neural networks, especially when they have a single hidden layer.



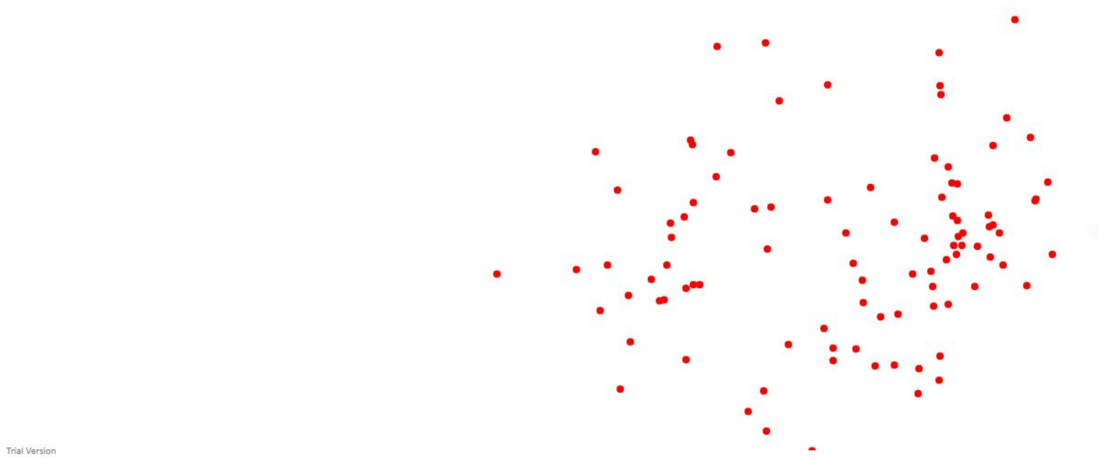
System Development

Technical Implementation

During the experiment, for each scene that was shown to the participant, their gaze positions on the screen were recorded as distributions. Therefore, we could obtain 8 different gaze distributions for the 8 scenes shown to each participant. An in browser webcam based gaze position tracker called Webgazer.js was used to detect the gaze positions of the participants. Webgazer.js was able to give the x and y coordinates of the users' gaze on the screen every few milliseconds. We acquired the gaze gaze positions every 50 millisecond for each scene, allowing us to acquire 100 gaze positions for each scene, that was shown for 5 second. These 100 gaze positions were converted into a chart using CanvasJS. The following is an example of gaze distribution chart of an Autism Spectrum Disorder (ASD) subject compared to a Typically Developing (TD) subject on a social scene.



Gaze Distribution of ASD subject on a social scene.



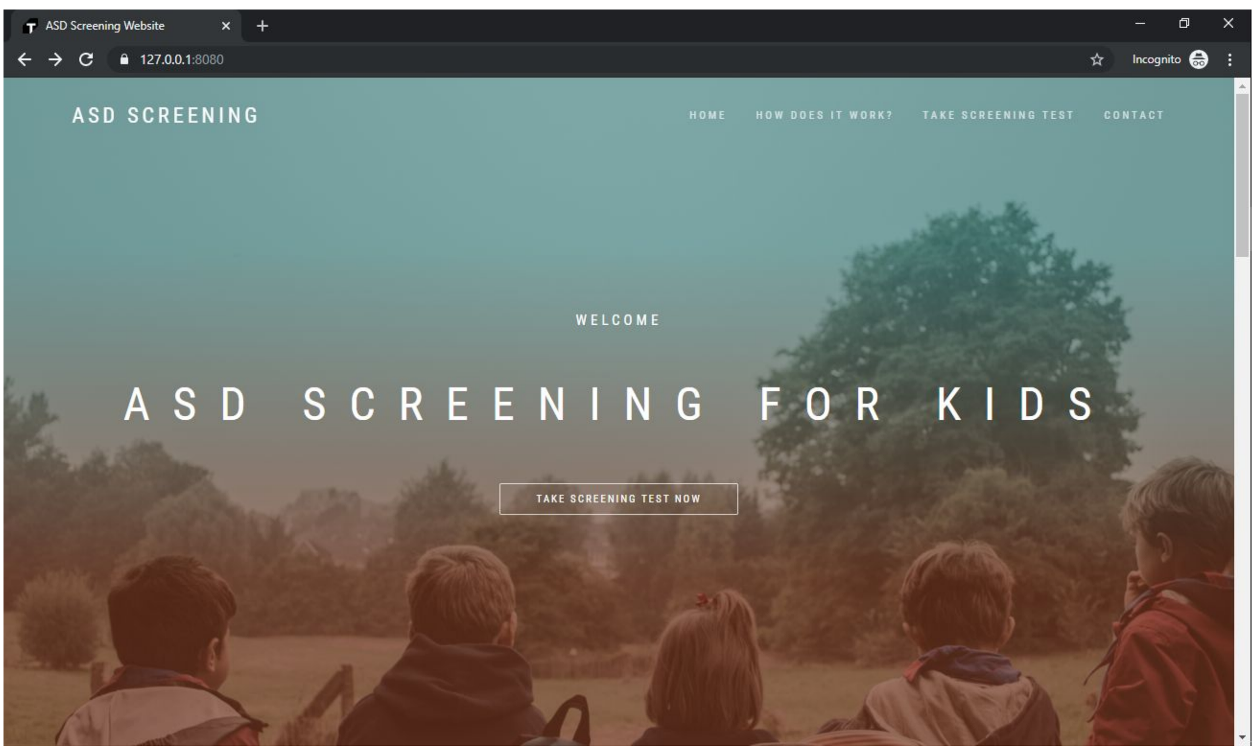
Gaze Distribution of TD subject on the same social scene.

It can be observed that there is a significant difference between their gaze distributions.

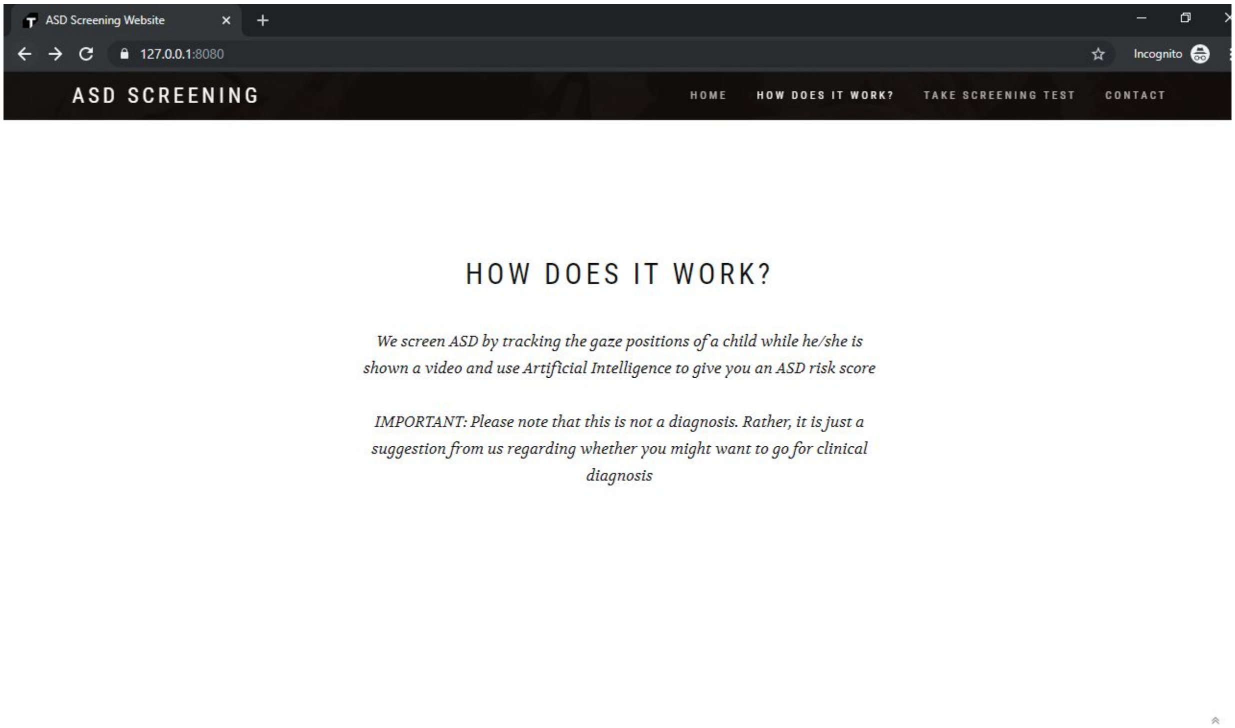
Tensorflow.js was used to create, train and test neural networks for each scene, which resulted in eight neural networks in total. Each neural network was trained for 100 epochs with the gaze distributions of 12 ASD subjects and 12 TD subjects on a scene. The gaze distributions of rest of the participants, i.e, 3 ASD subjects and 3 TD subjects were kept for testing purposes. After training, the neural network learned the differences between gaze distributions of ASD and TD subjects on each scene, i.e, it learned how an ASD subject looks at a social or non social scene and how a TD subject looks at a social or non social scene. Then, the 8 trained neural networks were able to give predictions as to whether it thinks that a new gaze distribution belongs to an ASD or TD subject for each scene. The arithmetic mean of these 8 predictions on 8 scenes were used to calculate the ASD risk score for that user.

User Interface

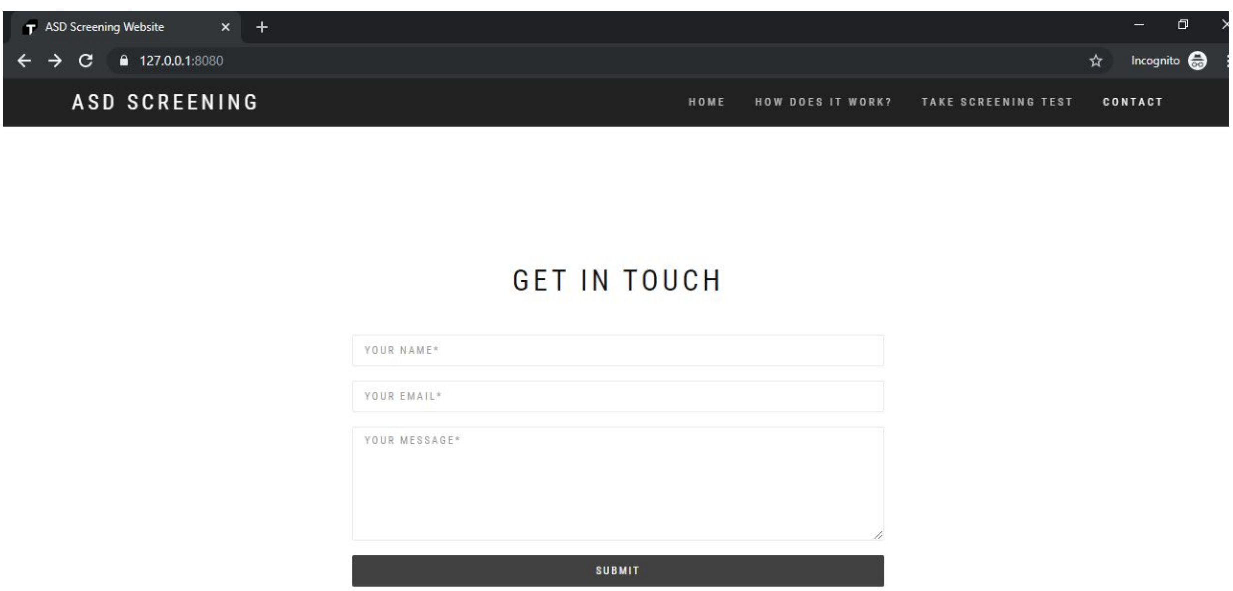
The interface was designed to be used with ease. It was also made beautiful using a vibrant background picture as well as elegant fonts. The instructions were given very clearly so that process goes on smoothly. It was also made friendly so that the children feel comfortable.



Homepage

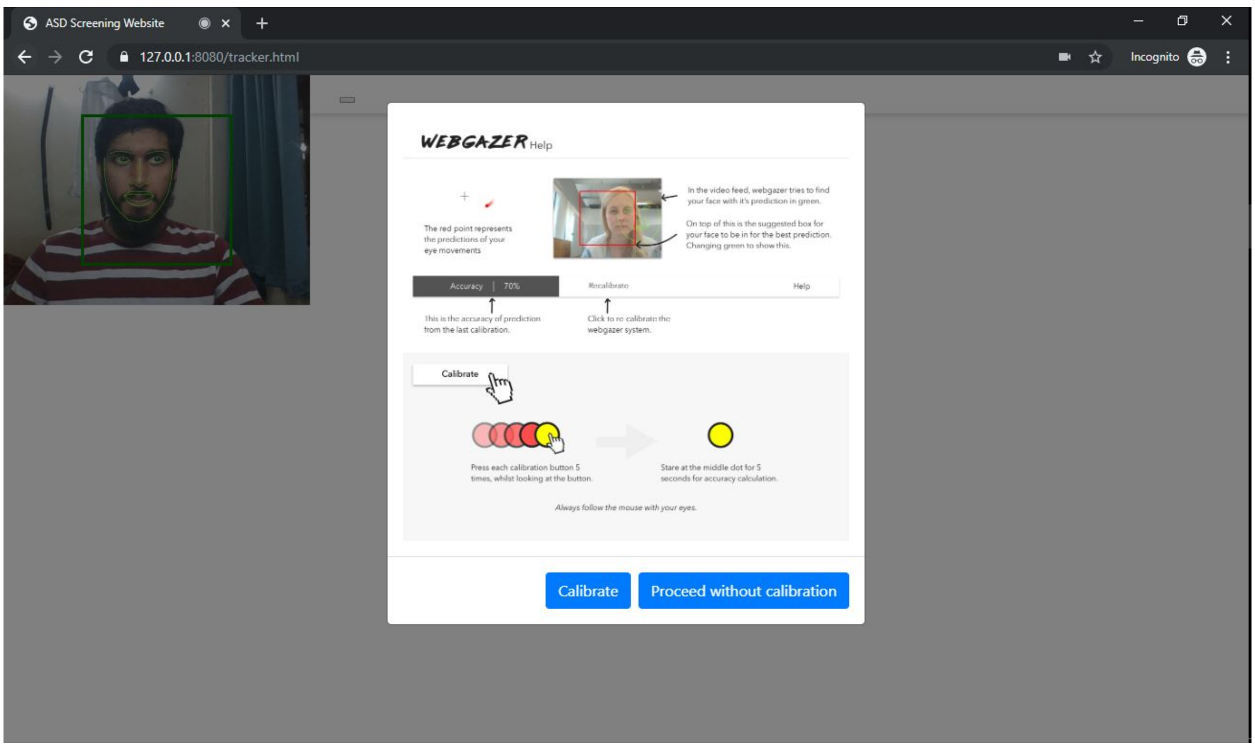


Description about the working page

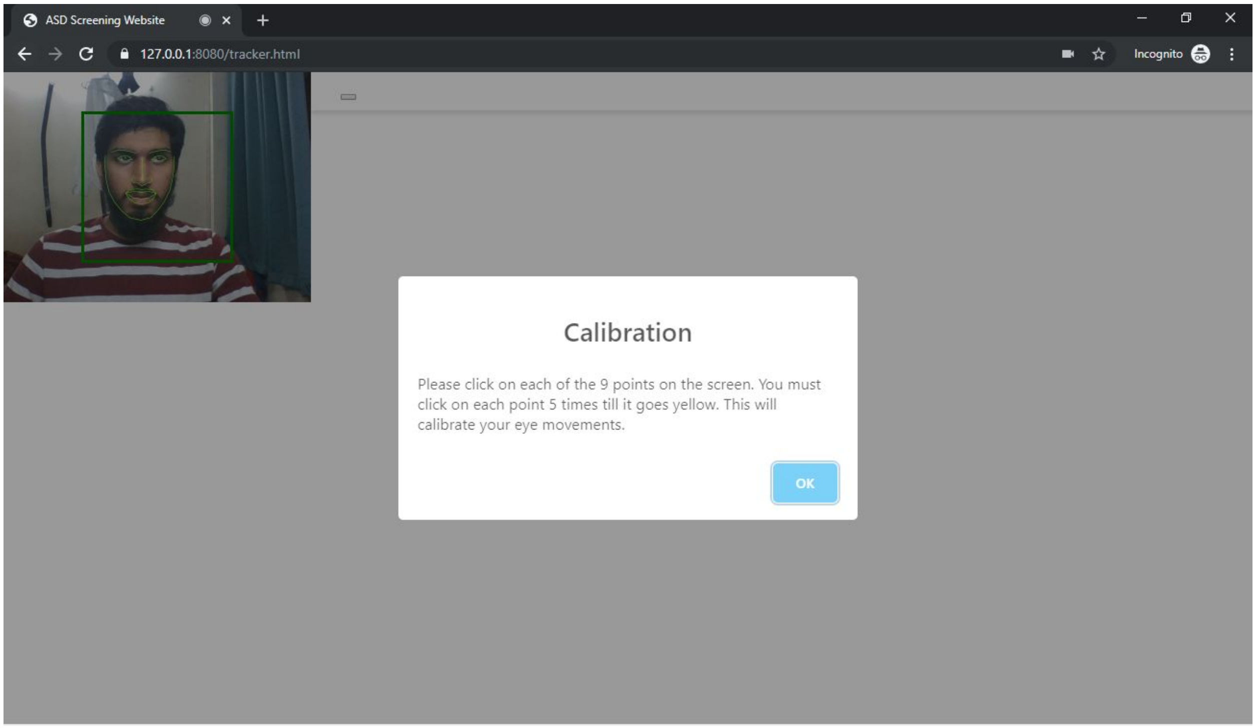


Contact page

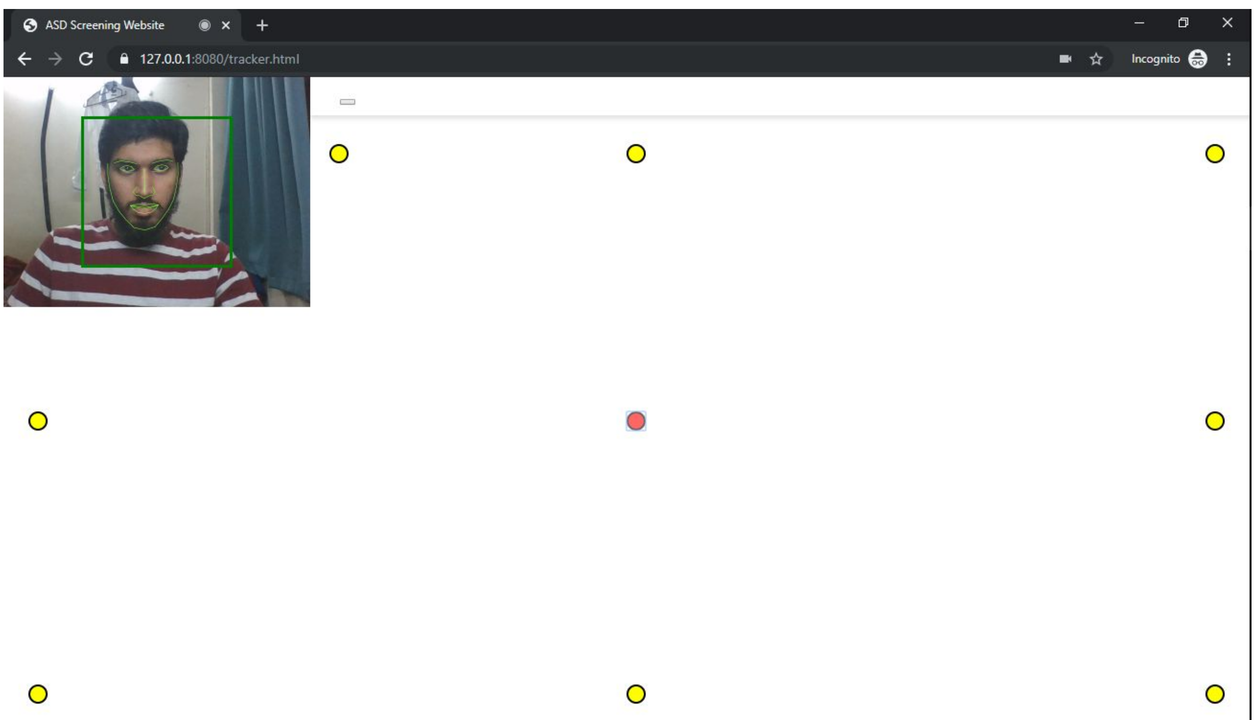
Footer



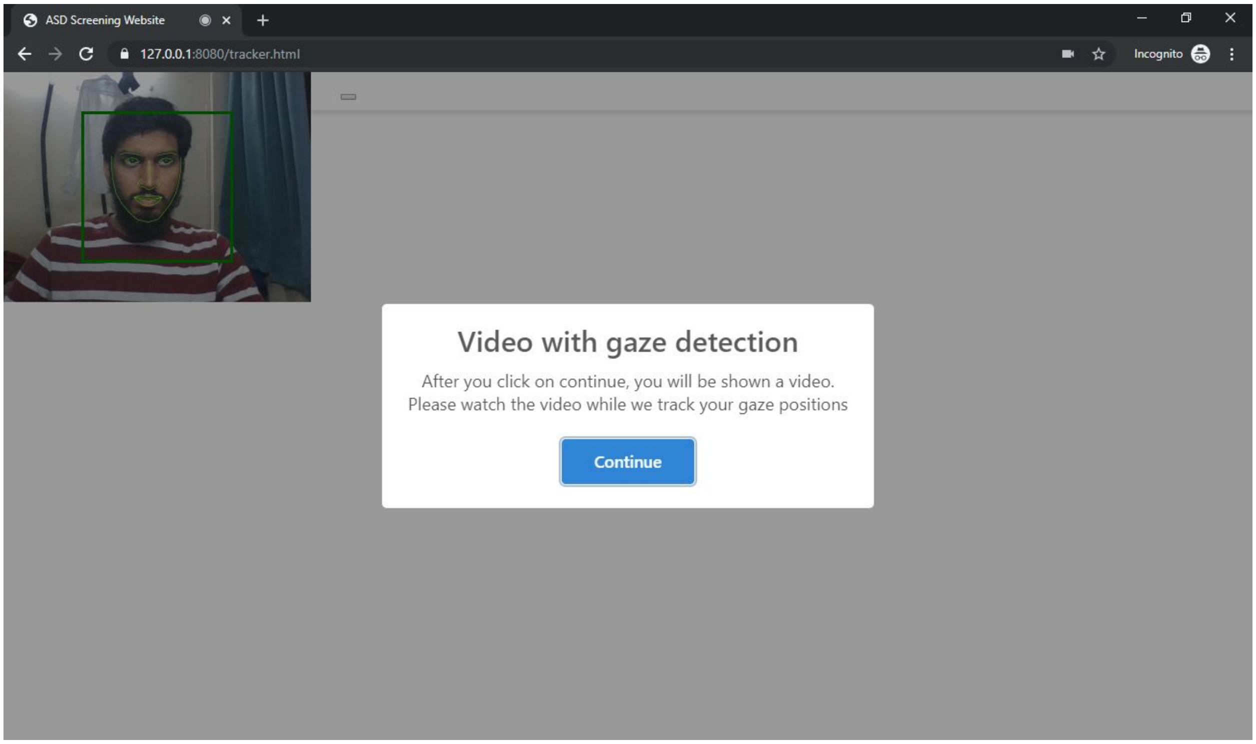
Option to proceed with or without calibration



Calibration Instructions

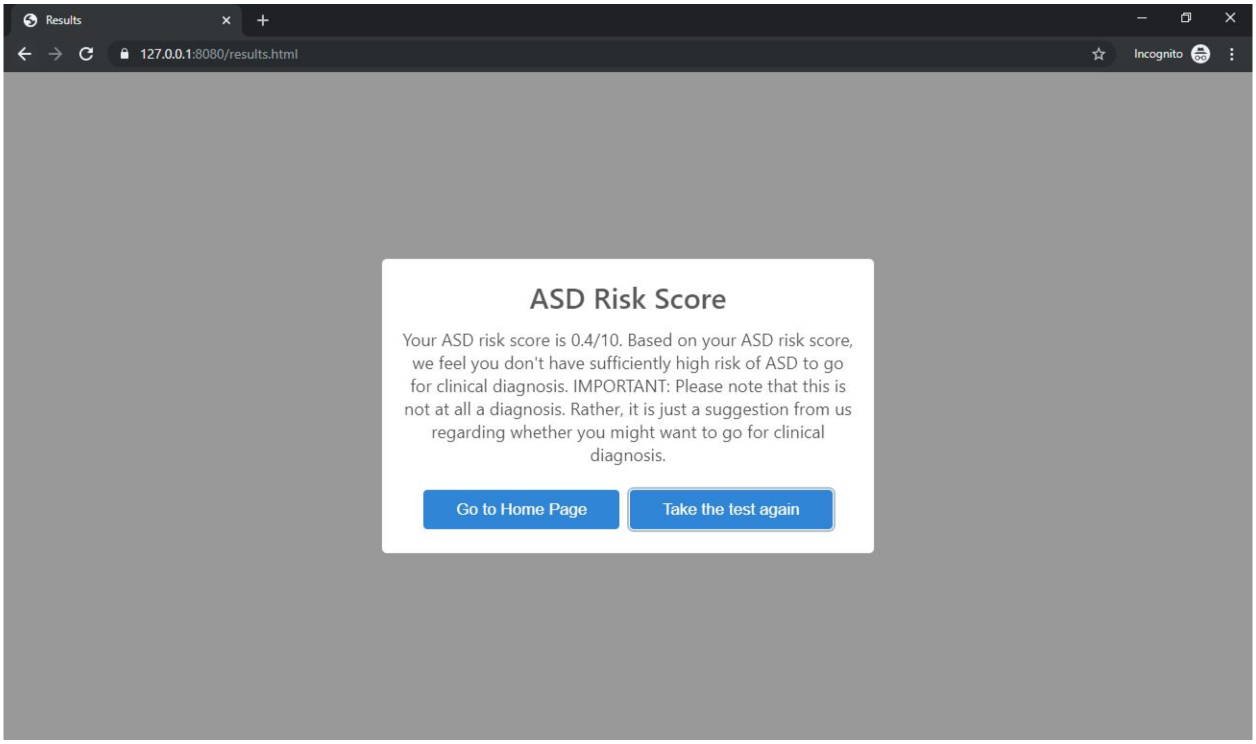


Calibration based on mouse clicks



Introduction to video

Video shown in full screen mode while gaze positions are detected



Results page

System Complexity

The backend of the system deals with complex processes such as training and testing neural networks, predicting gaze positions and gaze distributions chart creation. Everything is handled smoothly while the user interface looks vibrant and friendly.

System Evaluation

Model Evaluation and Validation

Metrics

True positive: The adult individual DID have ASD and we correctly predicted that the individual would have ASD.

True negative: The individual did NOT have ASD and we correctly predicted that the individual would NOT have ASD.

False positive (Type 1 Error): The individual did NOT have ASD, but we incorrectly predicted that the individual would have ASD.

False negative (Type 2 Error): The individual DID have ASD, but we incorrectly predicted that the individual would NOT have ASD.

In our model,

No. of true positives = 2

No. of true negatives = 3

No. of false positives = 0

No. of false negatives = 1

Accuracy

It measures how often the classifier makes the correct prediction, i.e., the ratio of number of correct predictions to the total number of predictions (the number of test data points)

$$\text{accuracy} = \frac{\text{true positive} + \text{true negative}}{\text{true positive} + \text{false positive} + \text{false negative} + \text{true negative}}$$

For our model,

Accuracy = 0.83

Precision

It measures how accurate our positive predictions were, i.e., out of all the points predicted to be positive how many of them were actually positive.

$$\text{precision} = \frac{\text{true positive}}{\text{true positive} + \text{false positive}}$$

For our model,

Precision = 1

Recall

It measures what fraction of the positives our model identified, i.e., out of the points that are labelled positive, how many of them were correctly predicted as positive

$$\text{recall} = \frac{\text{true positive}}{\text{true positive} + \text{false negative}}$$

For our model,

Recall = 0.67

Testing Techniques

Functionality testing

This was done to check if the website is as per the specifications as well as the functional requirements mentioned. To do this the following were checked accordingly

1. Links inside the website
2. Calibration and gaze detection
3. Neural networks testing
4. Form for contact

5. Cookies
6. HTML and CSS errors

Usability testing

This was done to ensure that the content and navigation was working properly. The navigation was checked by ensuring that the menu, buttons and links all lead to required pages or sections. The content was checked by ensuring there were no spelling or grammatical errors and the images had “alt” text.

Interface testing

This was done to ensure that the neural networks hosted by tensorflow.js was connected properly, and that it was able to give accurate predictions for new gaze distributions.

Compatibility testing

This was done to ensure that the web application displays correctly across different browsers. Same website in different browsers will display differently. It was tested if the web application is being displayed correctly across browsers and JavaScript is working fine.

Performance Testing

This was done to ensure that the site works under all loads. Therefore, website application response times at different connection speeds were tested to make sure it works at minimum connection speed.

Security testing

The website was created using secured local host, by generating SSL certificates. Therefore, SSL certificates were tested to make sure they’re valid and secured to be able to defend against attacks.

Error Handling

The HTML, CSS and JavaScript files were checked to make sure that the code is error free. But unanticipated errors may occur. Therefore error handling was done to ensure that these errors are properly dealt with. In development mode, especially for JavaScript functions, console messages were displayed for errors and warnings. Few errors related to gaze tracking that are caught using JS code are shown below.

```
tracking.initUserMedia_ = function(element, opt_options) {
  window.navigator.getUserMedia({
    video: true,
    audio: opt_options.audio
  }, function(stream) {
      try {
        element.src = window.URL.createObjectURL(stream);
      } catch (err) {
        element.src = stream;
      }
    }, function() {
      throw Error('Cannot capture user camera.');
    }
  );
};
```

Catching camera capture errors

```
tracking.track = function(element, tracker, opt_options) {
  element = tracking.one(element);
  if (!element) {
    throw new Error('Element not found, try a different element or selector.');
  }
  if (!tracker) {
    throw new Error('Tracker not specified, try `tracking.track(element, new tracking.FaceTracker())`.');
  }
```

Catching gaze tracker related errors

```
tracking.ColorTracker = function(opt_colors) {
  tracking.ColorTracker.base(this, 'constructor');

  if (typeof opt_colors === 'string') {
    opt_colors = [opt_colors];
  }

  if (opt_colors) {
    opt_colors.forEach(function(color) {
      if (!tracking.ColorTracker.getColor(color)) {
        throw new Error('Color not valid, try `new tracking.ColorTracker("magenta")`.');
      }
    });
    this.setColors(opt_colors);
  }
};
```

Catching color related errors

```
tracking.ObjectTracker.prototype.track = function(pixels, width, height) {
  var self = this;
  var classifiers = this.getClassifiers();

  if (!classifiers) {
    throw new Error('Object classifier not specified, try `new tracking.ObjectTracker("face")`.');
  }
```

Catching tracker object related errors

Conclusion

System Performance

Literature review has certainly helped in identifying the possibility of using gaze information as a screening method for ASD. We have been successfully able to accomplish all the objectives by building an accurate and easily available screening method using gaze information and suggesting whether the child shall go for clinical diagnosis or not. This system in no way is meant to provide diagnosis. It is only meant to screen children at potentially high risk and suggest users to go for clinical diagnosis if the risk level is high. Risk score is calculated based on a lot of research done which correlates children's gaze pattern to ASD. As the model evaluation suggests, the system has performed very well, considering the limited resources and data available at hand.

Improvement

This work can certainly serve as a good screening method that is easily available and provides accurate results. But to build an accurate and robust model, one needs to have larger datasets. But, it is extremely difficult to collect a lot of well documented data related to ASD. This study has created a well developed model that can accurately screen ASD in children using their gaze distributions on social and non social scenes. It can definitely be improved with more research into this domain of analyzing gaze information of children.

References

Retrieved from https://cse.buffalo.edu/~wenyaoxu/project/asd.html

Retrieved from http://archive.ics.uci.edu/ml/datasets/Autism Screening Adult#

Retrieved from
https://study.com/academy/lesson/project-requirements-definition-types-process.html

(n.d.). Retrieved from
https://www.nst.com.my/education/2018/06/377146/advocating-religious-education-differently-abled

Abbas, H., Garberson, F., Glover, E., & Wall, D. P. (2018). Machine learning approach for early detection of autism by combining questionnaire and home video screening. *Journal of the American Medical Informatics Association*, *25*(8), 1000–1007. doi: 10.1093/jamia/ocy039

(2019, August 15). Autism spectrum. Retrieved from https://en.wikipedia.org/wiki/Autism_spectrum

Cho, et al. "Gaze-Wasserstein: a Quantitative Screening Approach to Autism Spectrum Disorders." *2016 IEEE Wireless Health (WH)*, 2016, doi:10.1109/wh.2016.7764551.

(2019, May 22). Decision Tree: Decision Tree Introduction With Examples. Retrieved from https://www.edureka.co/blog/decision-trees/

(2018, July 4). Functional and Non-Functional Requirements for Predictive Maintenance. Retrieved from
https://www.presenso.com/blog/functional-requirements-machine-learning-predictive-maintenance

Frazier, T. W., Klingemier, E. W., Parikh, S., Speer, L., Strauss, M. S., Eng, C., … Youngstrom, E. A. (2018). Development and Validation of Objective and Quantitative Eye Tracking−Based Measures of Autism Risk and Symptom Levels. *Journal of the American Academy of Child & Adolescent Psychiatry*, *57*(11), 858–866. doi: 10.1016/j.jaac.2018.06.023

Home. Retrieved from https://autismandbeyond.researchkit.duke.edu/ch

Jones, W., Carr, K., & Klin, A. (2008). Absence of Preferential Looking to the Eyes of Approaching Adults Predicts Level of Social Disability in 2-Year-Old Toddlers With Autism Spectrum Disorder. *Archives of General Psychiatry*, *65*(8), 946. doi: 10.1001/archpsyc.65.8.946

kbasu2016. (2018, May 15). kbasu2016/Autism-Detection-in-Adults. Retrieved from https://github.com/kbasu2016/Autism-Detection-in-Adults

Klin, A., Jones, W., Schultz, R., Volkmar, F., & Cohen, D. (2002). Visual Fixation Patterns During Viewing of Naturalistic Social Situations as Predictors of Social Competence in Individuals With Autism. *Archives of General Psychiatry*, *59*(9), 809. doi: 10.1001/archpsyc.59.9.809

Library Guides: APA Quick Citation Guide: In-text Citation. Retrieved from https://guides.libraries.psu.edu/apaquickguide/intext

Liu, W., Li, M., & Yi, L. (2016). Identifying children with autism spectrum disorder based on their face processing abnormality: A machine learning framework. *Autism Research,9*(8), 888-898. doi:10.1002/aur.1615

Papoutsaki, A. (2015). Scalable Webcam Eye Tracking by Learning from User Interactions. *Proceedings of the 33rd Annual ACM Conference Extended Abstracts on Human Factors in Computing Systems - CHI EA 15*. doi: 10.1145/2702613.2702627

Pierce, K., Conant, D., Hazin, R., Stoner, R., & Desmond, J. (2011). Preference for Geometric Patterns Early in Life as a Risk Factor for Autism. *Archives of General Psychiatry*, *68*(1), 101. doi: 10.1001/archgenpsychiatry.2010.113

Rueben, Chris, Choudhary, S., Mary, Godambe, P., Ruchi, … Alpa. (n.d.).

Vargas-Cuentas, N. I., Roman-Gonzalez, A., Gilman, R. H., Barrientos, F., Ting, J., Hidalgo, D., … Zimic, M. (2017). Developing an eye-tracking algorithm as a potential tool for early diagnosis of autism spectrum disorder in children. *Plos One*, *12*(11). doi: 10.1371/journal.pone.0188826

Web Application Testing: 8 Step Guide to Website Testing. (n.d.). Retrieved December 18, 2019, from https://www.guru99.com/web-application-testing.html.

WebGazer.js. (n.d.). Retrieved from https://webgazer.cs.brown.edu/.

Zwaigenbaum, L., Bryson, S., Lord, C., Rogers, S., Carter, A., Carver, L., … Yirmiya, N. (2009). Clinical Assessment and Management of Toddlers With Suspected Autism Spectrum Disorder: Insights From Studies of High-Risk Infants. *Pediatrics*, *123*(5), 1383–1391. doi: 10.1542/peds.2008-1606