Classifying Eye-Tracking Scanpaths to make Autism Spectrum Disorder (ASD) Diagnoses More Accessible

... improve People’s Lives with Early Diagnosis

Team: Shine with Eyes
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Introduction of the Team

- **NINA**
  - Product Manager / Project Manager

- **MOHITH**
  - Data Engineer / Project Manager

- **JESSE**
  - Machine Learning Engineer / Deployment Architect

- **WAQAS**
  - Machine Learning Engineer / Data Engineer

- **MAKENZIE**
  - SME Feedback/Website Development Lead
Autism Spectrum Disorder (ASD)

- Communication
- Social Interaction
- Motor Skills
- Severe Depression
- Self Harm
- Trouble Staying Employed
- Require Extensive Caregiving
- Lower Life Expectancy
A Closer Look at Autism Spectrum Disorder (ASD)

**NO CURE** but **TREATMENT** can **REDUCE SYMPTOMS** to **UNLEASH POTENTIAL** and **IMPROVE QUALITY OF LIFE**

- **1.5 yrs old**
  - early ASD detection

- **5 yrs old or younger**
  - for effective early intervention (e.g. ABA)

- **2-year average ASD diagnostic wait time**

**Sensitive Time Window for Diagnosis**
ASD - What does it mean?

- Half the children in the US are currently being screened for ASD
  - 5 million children are at risk of developmental delay

- Negative symptoms can worsen over time if untreated
  - Untreated Children: Poor motor abilities and social skills; Self harm in children
  - Untreated Adults: Employment; Severe depression; Lower life expectancy

- Moms with children having ASD earns 33%-56% less

- Cost of caring for Americans with autism costs >$268 billion today and projected to reach $461 billion by 2025
Emerging ASDDiagnostic Solution Landscape

- **An alternative** or supplementary solution to the conventional development monitoring approach focusing on a wide range of drivers:
  - Health history
  - Behavioural data
  - Eye movement

- **Target users:**
  - Healthcare providers
  - Patient & families

- **Leaders:**
  - EarliTec Diagnostics Inc.
  - Cognoa
Our Solution: Shine with Eyes
... improve People’s Lives with Early Diagnosis

Step 1
- Developmental Monitoring
  - Informal observations

Step 2
- Developmental Screening
  - Formal observations
  - Developmental questions

Step 3
- Conventional ASD Diagnosis
  - accelerated with Shine-with-Eyes

- Developmental Diagnosis
  - Genetic counseling

- Early Intervention / Treatment

- A supplementary diagnostic solution which is HIPAA compliant with no PHI stored
- AI powered diagnosis based on eye scanpath
- Introduced in early stages (steps 1-2) of the ASD diagnostic journey to accelerate the
- Supports healthcare providers who want to have more confidence in their medical diagnostic decisions for children 2.5-5 years of age
SME INTERVIEWS
- Pediatric psychiatrist
- PhD Professor in Dept. of Psychiatry & Behavioral Sciences

MAIN CHALLENGES
- Heavily reliant on in-person observations
- Narrow participant window, focus on younger siblings of
- Increasingly high demand for diagnostic screens
- Child may behave differently in different settings
- Lack of standardization across specialists
MVP - Addressing SME Pain Points

**Ease of Use**
Straightforward interface and easily interpretable results

**Reliability**
Secure connection to machine learning model and image database storage

**Explainability**
Increased description of results and outcome probability

**Quicker Results**
Higher efficiency for part of the diagnostic process
Shine with Eyes
An Autism Spectrum Disorder (ASD) Early Diagnostic Support Tool

Early is everything in child development.
Deployment Architecture

- Highly Available
  Access anywhere, anytime

- Highly Reliable
  No interruptions. Ever

- Highly Scalable
  No throttling no matter the traffic
Deployment Architecture

Key Learnings

- **Lots of logging** for deployment
- Packages are **identical** between development and deployment
- Unblock yourself
Classifying these images is a DIFFICULT problem to solve.

Data & Features

**Images - Eye Scanpath**

**Features**

- Cyan: Fixation
- White: Saccade
- Green: Acceleration
- Blue: Jerk
- Red: Velocity

**Challenges**

1. Small Dataset
2. Lack of Features
3. Unknown Start/End-point
Data Split - Test/Train/Validation

**DataSize**
- Image Count: 547
- Positive Class (ASD): 219
- Negative Class (Non-ASD): 328

**Train-Test Split**
- Train: 90% - 492 images
- Test: 10% - 55 images

**Train-Val. Split**
- Train: 70% - 344 images
- Validation: 30% - 148 images

*Data augmentation increased training data size by 10x.*
Data Augmentation - Mix & Match Strategy

Horizontal & vertical concatenation of all image combinations (within each participant) increased training data size $10x$.

Pros: Huge multiplier of data & mitigated overfitting issue.
Cons: Caveat as synthetic data.
<table>
<thead>
<tr>
<th>No.</th>
<th>Model</th>
<th>Description</th>
<th>Training Time</th>
<th>Parameters</th>
<th>Validation Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>CNN</td>
<td>CNN Full Feature</td>
<td>11min 15 epoch</td>
<td>19.7M</td>
<td>73%</td>
</tr>
<tr>
<td>2</td>
<td>CNN</td>
<td>CNN Compressed</td>
<td>15min 50 epoch</td>
<td>8.9M</td>
<td>79%</td>
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<tr>
<td>3</td>
<td>CNN</td>
<td>CNN All In One (with manually extracted features)</td>
<td>15min 50 epoch</td>
<td>8.9M</td>
<td>79%</td>
</tr>
<tr>
<td>4</td>
<td>CNN</td>
<td>CNN Features + Random Forest</td>
<td>15min 50 epoch</td>
<td>8.8M</td>
<td>69%</td>
</tr>
<tr>
<td>5</td>
<td>Transformer</td>
<td>Language Transformer Model / Coordinates Data (only 100)</td>
<td>25 min. 5 epoch</td>
<td>14M</td>
<td>15%</td>
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<tr>
<td>6</td>
<td>ViT</td>
<td>Pre-trained / fine-tuned / Original Data</td>
<td>1 hrs. 25 epoch</td>
<td>85M</td>
<td>69%</td>
</tr>
<tr>
<td>7</td>
<td>ViT</td>
<td>Pre-trained / fine-tuned / Encoder unfrozen / original Data</td>
<td>1 hrs. 25 epoch</td>
<td>85M</td>
<td>72%</td>
</tr>
<tr>
<td>8</td>
<td>ViT</td>
<td>Pre-trained / fine-tuned / Augmented Data</td>
<td>2 hrs. 25 epoch</td>
<td>85M</td>
<td>99%</td>
</tr>
<tr>
<td>9</td>
<td>ViT</td>
<td>Pre-trained / fine-tuned / Encoder unfrozen / Augmented Data</td>
<td>2 hrs. 25 epoch</td>
<td>85M</td>
<td>98%</td>
</tr>
</tbody>
</table>
Model Training

**Small data size and lack of features were our biggest challenges and it caused overfitting and poor validation accuracy.**
Data-augmentation fixed the over-fitting problem. 

ViT model along with data augmentation has the best validation accuracy.
## Model Evaluation

### Pre-trained ViT + Data Augmentation

![Confusion Matrix A](image)

<table>
<thead>
<tr>
<th>Model</th>
<th>Class</th>
<th>Precision</th>
<th>Recall</th>
<th>Test Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0</td>
<td>77%</td>
<td>77%</td>
<td>82%</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>85%</td>
<td>85%</td>
<td></td>
</tr>
</tbody>
</table>

### Pre-trained ViT + Data Augmentation + Unfrozen embeddings

![Confusion Matrix B](image)

<table>
<thead>
<tr>
<th>Model</th>
<th>Class</th>
<th>Precision</th>
<th>Recall</th>
<th>Test Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>0</td>
<td>73%</td>
<td>73%</td>
<td>78%</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>82%</td>
<td>82%</td>
<td></td>
</tr>
</tbody>
</table>
Absence of characteristic features i.e. total eye movement and saccade led to false negative.
Extended Capstone - Future Ideas

**Technical**
- Improve Language Transformer Model by improving coordinates selection
- Set up lab to collect our own eye scanpath data

**Non-Technical**
- Clinical partnership outreach to improve product
- Website enhancement to professional startup standard
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Waqaas Ali: wali@ischool.berkeley.edu
1. **Average autism diagnosis delayed by more than two years**, Spectrum
2. **How Much Does An Autism Evaluation Cost?**, Cross River Therapy
3. **About Us**, Cognoa
4. **Evidence-Based Treatments for Autism Spectrum Disorder**, Regis College
5. **The Treetop**, ABA Therapy
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13. **Treatments that are not recommended for autism**, United Kingdom National Health Service
14. **Treatment and Intervention Services for Autism Spectrum Disorder**, Centers for Disease Control and Prevention