Learning Clusters in Autism Spectrum Disorder: Image-Based Clustering of Eye-Tracking Scanpaths with Deep Autoencoder

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https://ieeexplore.ieee.org/document/8856904

Background: Autism Spectrum Disorder

- Autism Spectrum Disorder (ASD) is a pervasive developmental disorder characterised by a set of impairments including social communication problems.[1]
- ASD has been considered to affect about 1% of the world's population (US Dep. of Health, 2018). [2]
- The hallmark of autism is an impairment of the ability to make and maintain eye contact. [3]

[1] L. Wing, and J. Gould, "Severe Impairments of Social Interaction and Associated Abnormalities in Children: Epidemiology and Classification". Journal of Autism and Developmental Disorders, 9(1), pp.11-29, 1979.

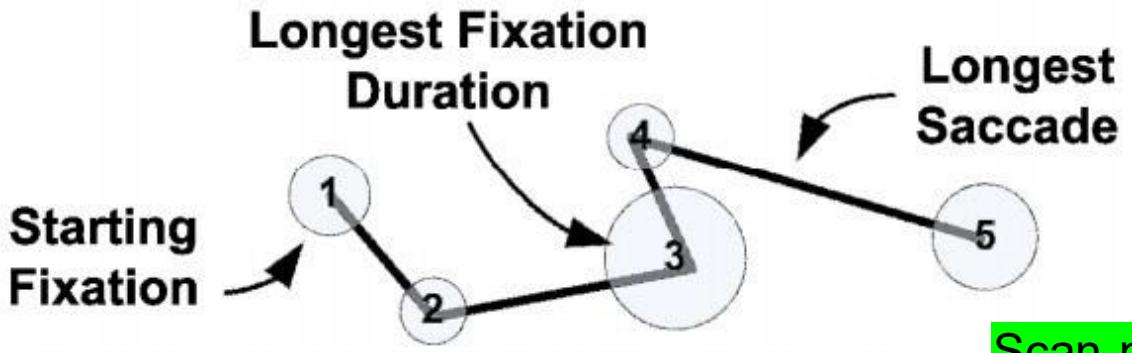
[2] U.S. Department of Health & Human Services. Data and statistics | autism spectrum disorder (asd) | ncbddd | cdc, 2018. URL: https://www.cdc.gov/ncbddd/autism/data.html.

[3] Coonrod, E. E. and Stone, W. L. (2004). Early concerns of parents of children with autistic and nonautistic disorders. Infants & Young Children, 17(3), 258–268.

Background: Eye-Tracking Technology

Screen-based eye trackers

Glasses



Scan-path

Image Source: https://imotions.com/blog/eye-tracking/

J.H. Goldberg, and J.I. Helfman, “Visual scanpath representation”, In Proceedings of the 2010 Symposium on Eye-Tracking Research & Applications, ACM, 2010, pp. 203-210.

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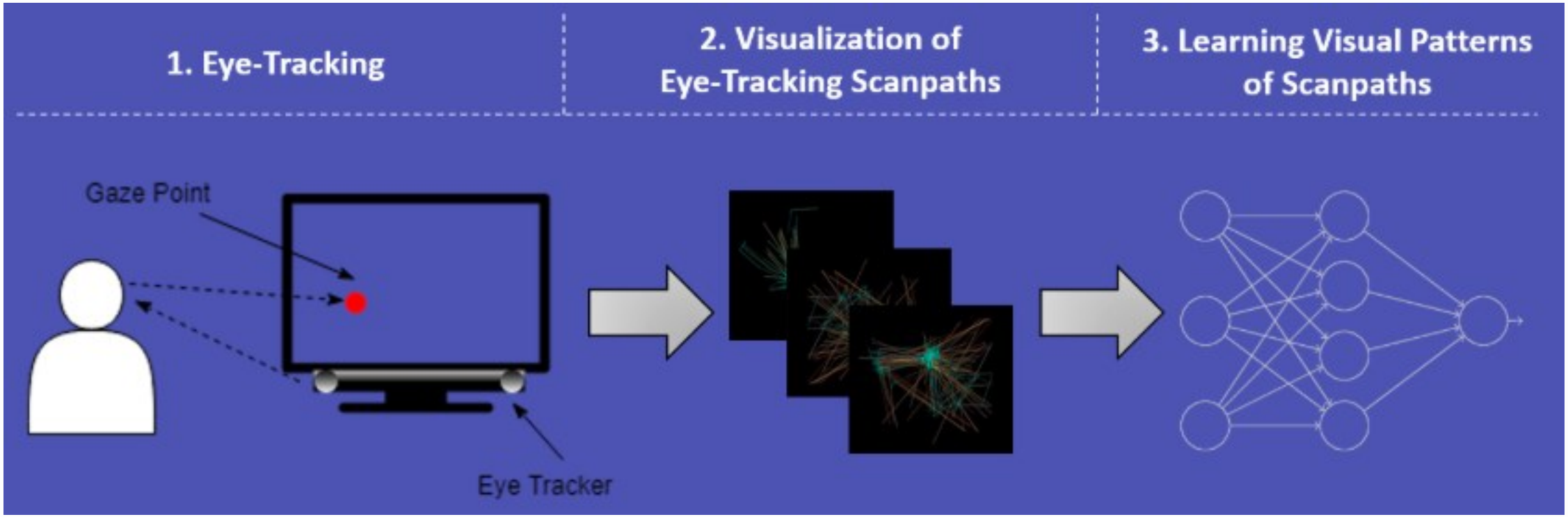
Key Idea:
Learning the Visual Patterns of Eye-Tracking Scanpaths



Motivational Questions

- Would the visual patterns of eye-tracking scanpaths indicate an underlying structure of clusters?
- If so, could the clusters discovered reveal possible connections related to the dynamics of gaze behavior (e.g. velocity, acceleration)?
- Further, how would clusters vary with respect to the characteristics of participants (e.g. age)?

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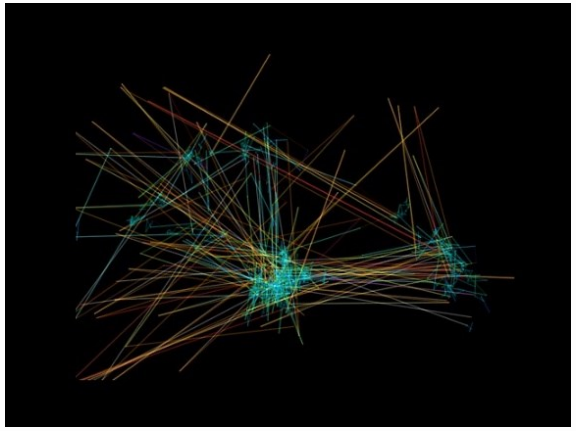
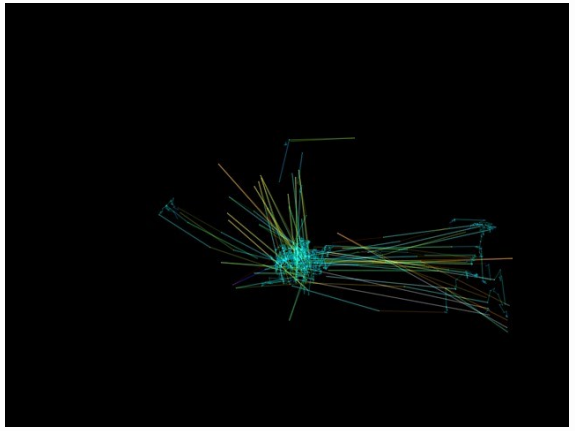
Data Description

- 59 participants.
- Avg age 7.88 years old.
- 547 images: 328 (Non-ASD), 219 (ASD)
- Image dimensions: 640x480



ASD



Non-ASD

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Feature Extraction Using Autoencoder

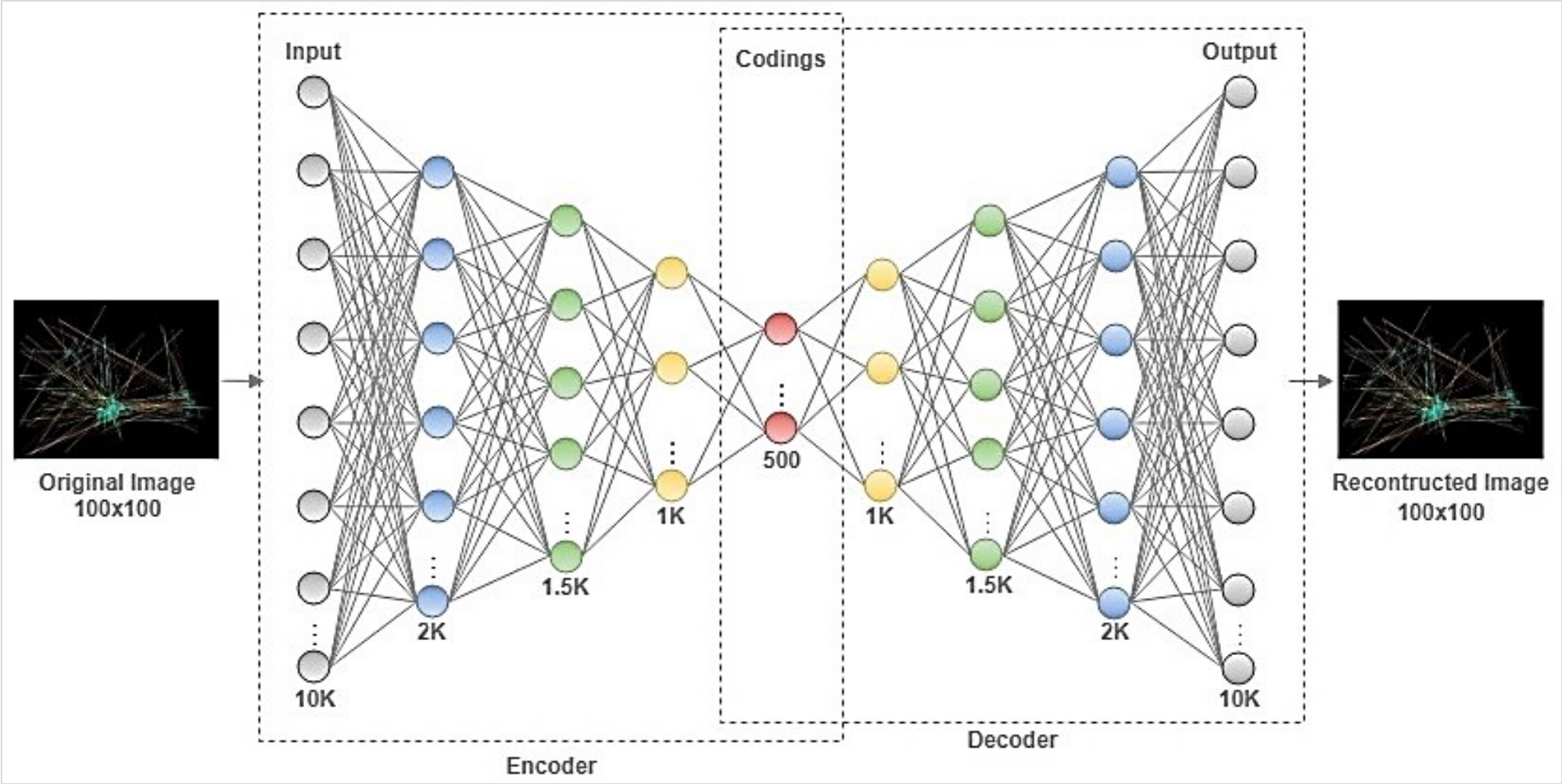
- A multi-layered ANN performs the functionality of encoding and decoding of images as follows.

Encoding:

- The encoder takes an image (100x100) at the input layer.
- The compression process is conducted over four hidden layers.
- The concentration of neuros continues to gradually decrease down to 500 units, which contain the final image codings.

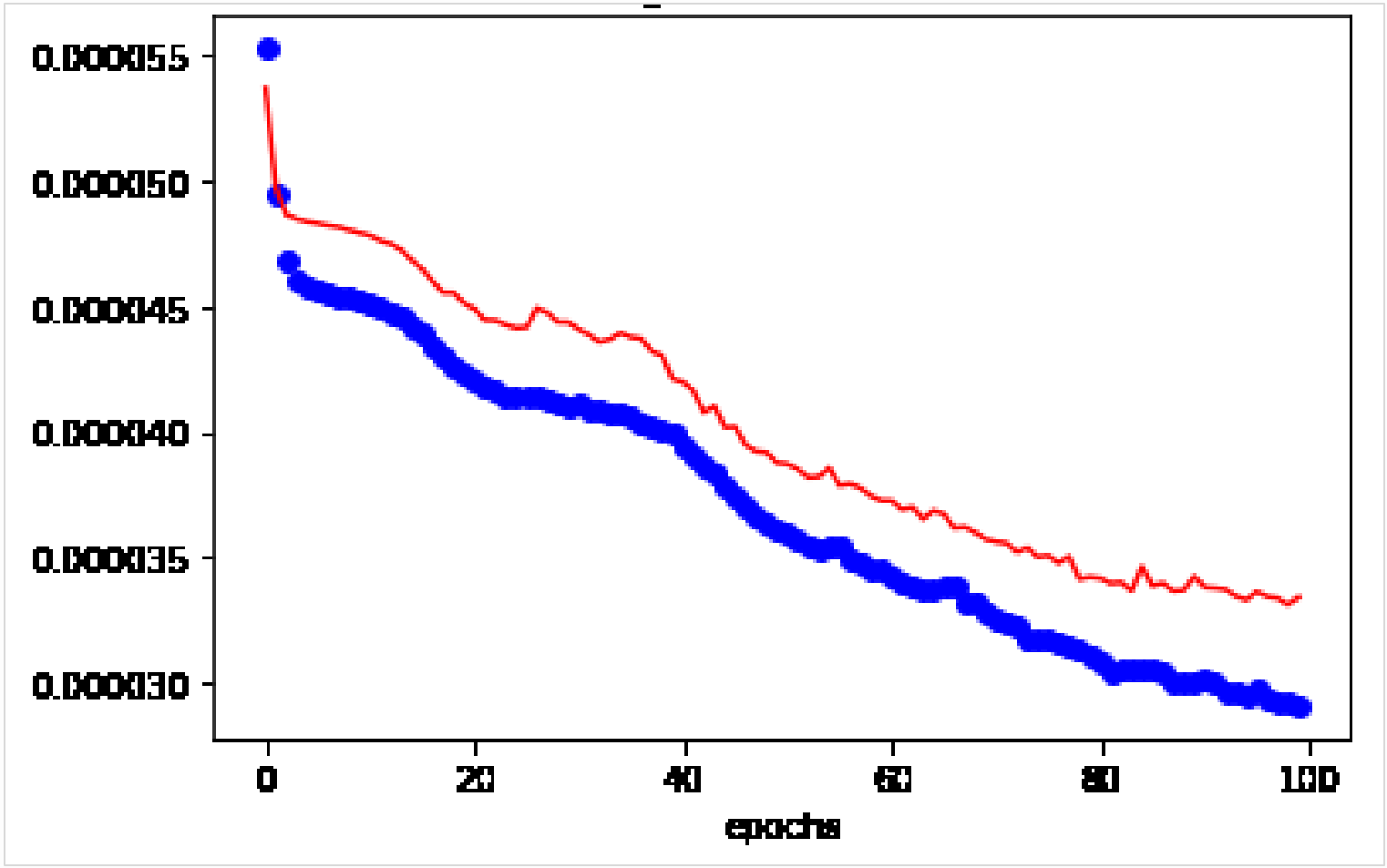
- **Decoding:**
  - The decoder is a flipped copy of the encoder.
  - In an inverse fashion, the number of neurons progressively increased all the way back to the original dimension (i.e. 10k units).

Feature Extraction Using Autoencoder (cont'd)



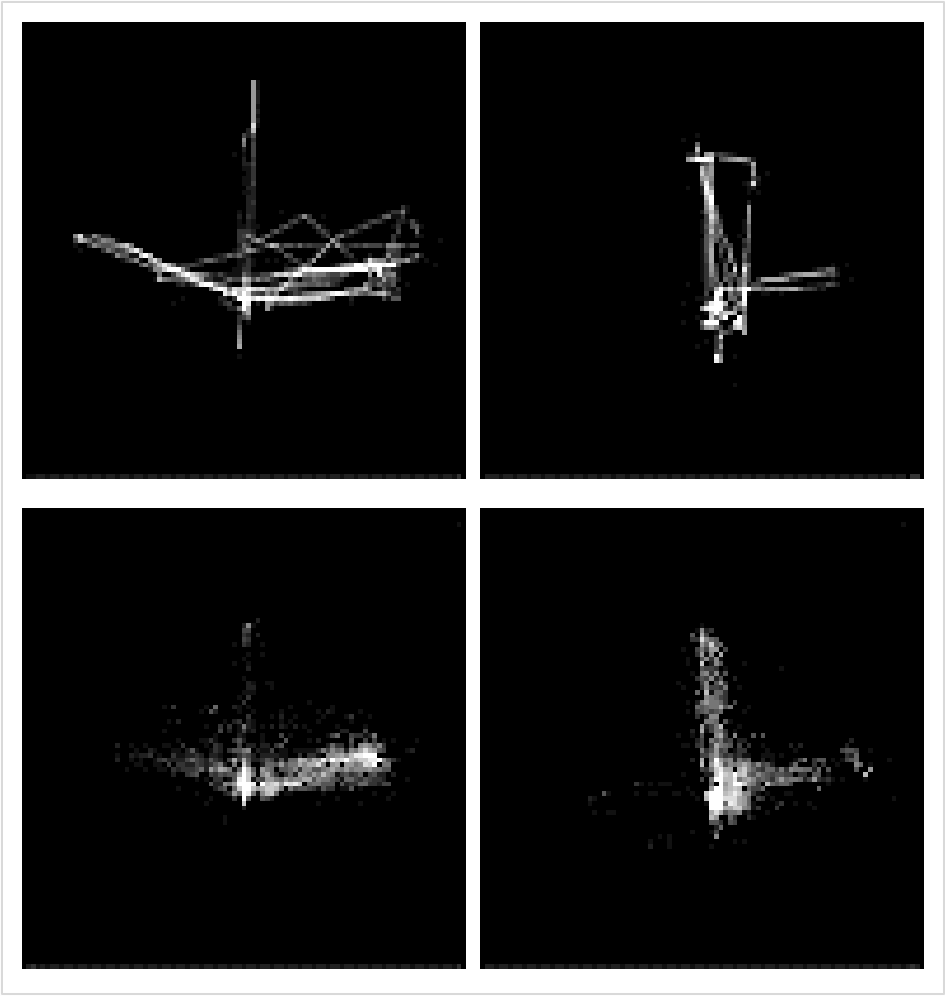
The autoencoder architecture.

Autoencoder Accuracy



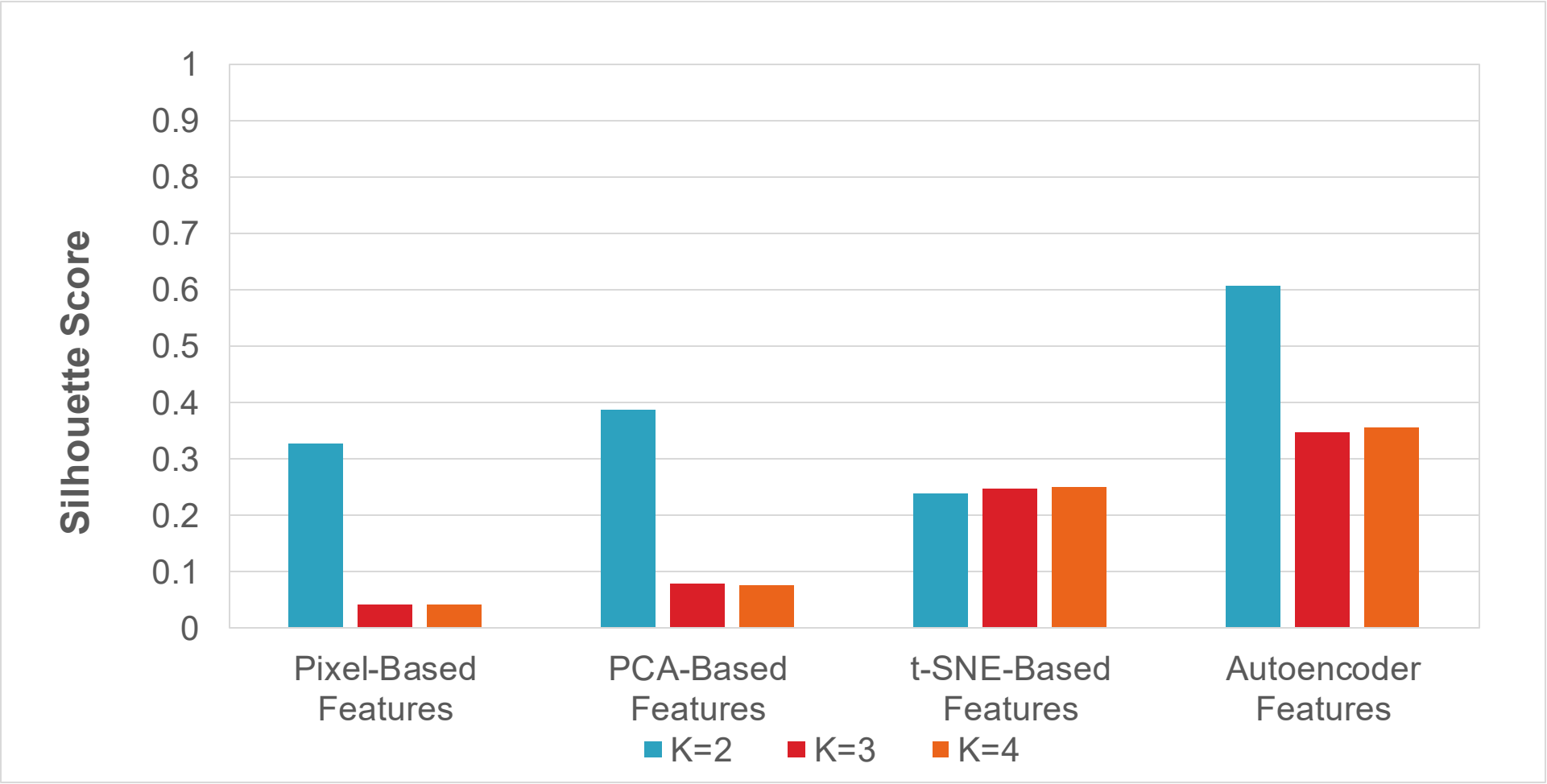
Training loss (blue) and validation loss (red) over 100 epochs.

Autoencoder Accuracy (cont'd)



Sample images produced by the autoencoder.
The first row gives the original images, while below are the reconstructed images by the autoencoder.

K-Means Clustering Experiments



Quality of clusters based on the Silhouette score.

Cluster Analysis

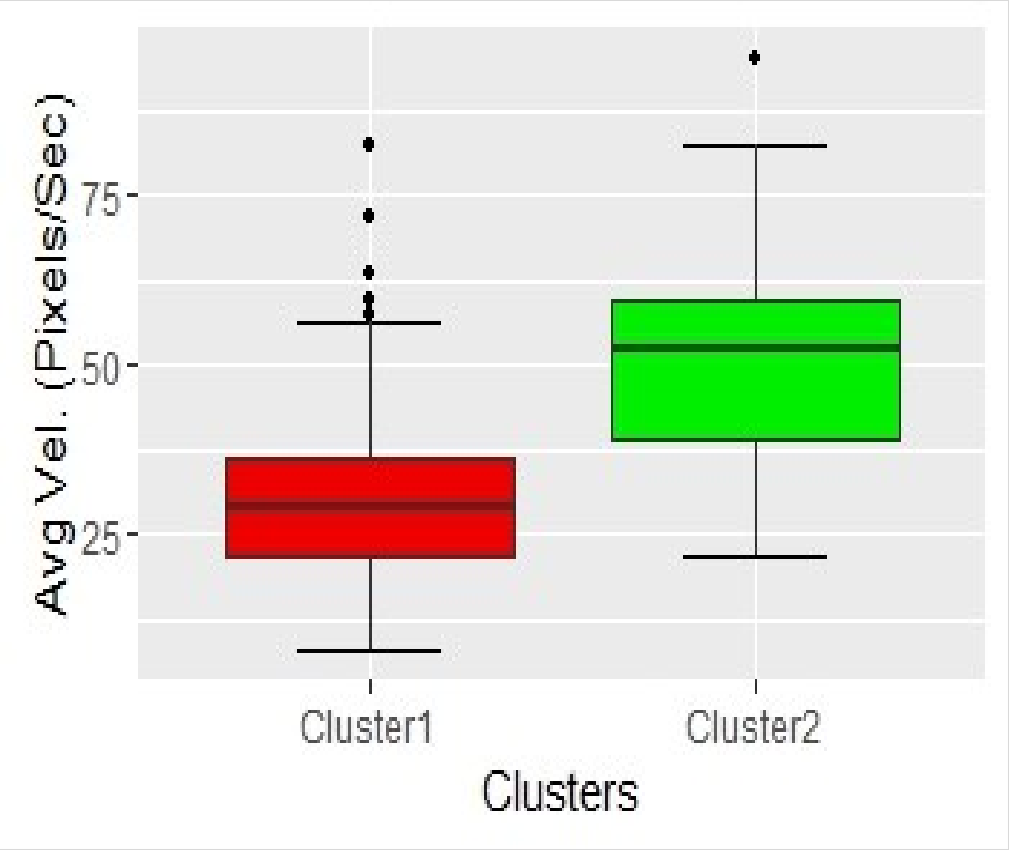
Summary of Clusters (K=2)

Cluster	Percentage of ASD Participants	Avg. Age (years)
Cluster 1	33%	8.2
Cluster 2	85%	8.7

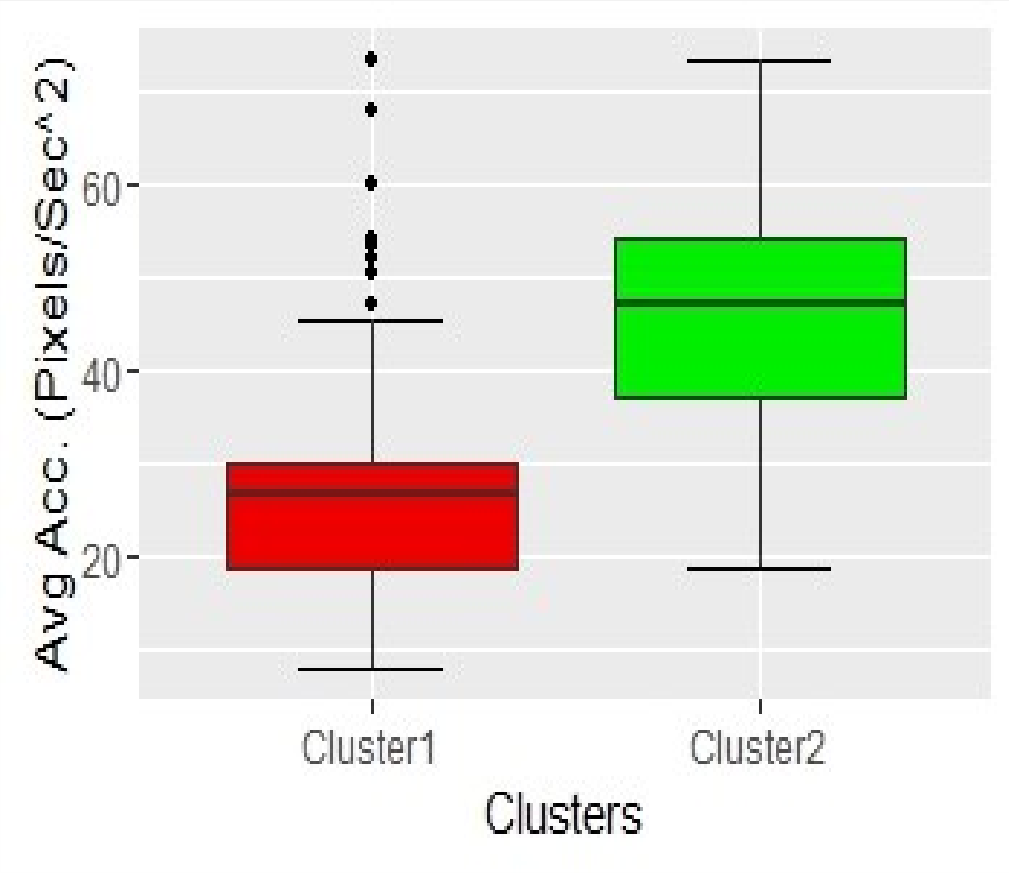
Summary of Clusters (K=3)

Cluster	Percentage of ASD Participants	Avg. Age (years)
Cluster 1	28%	7.95
Cluster 2	49%	8.76
Cluster 3	94%	9.02

Cluster Analysis (cont'd)

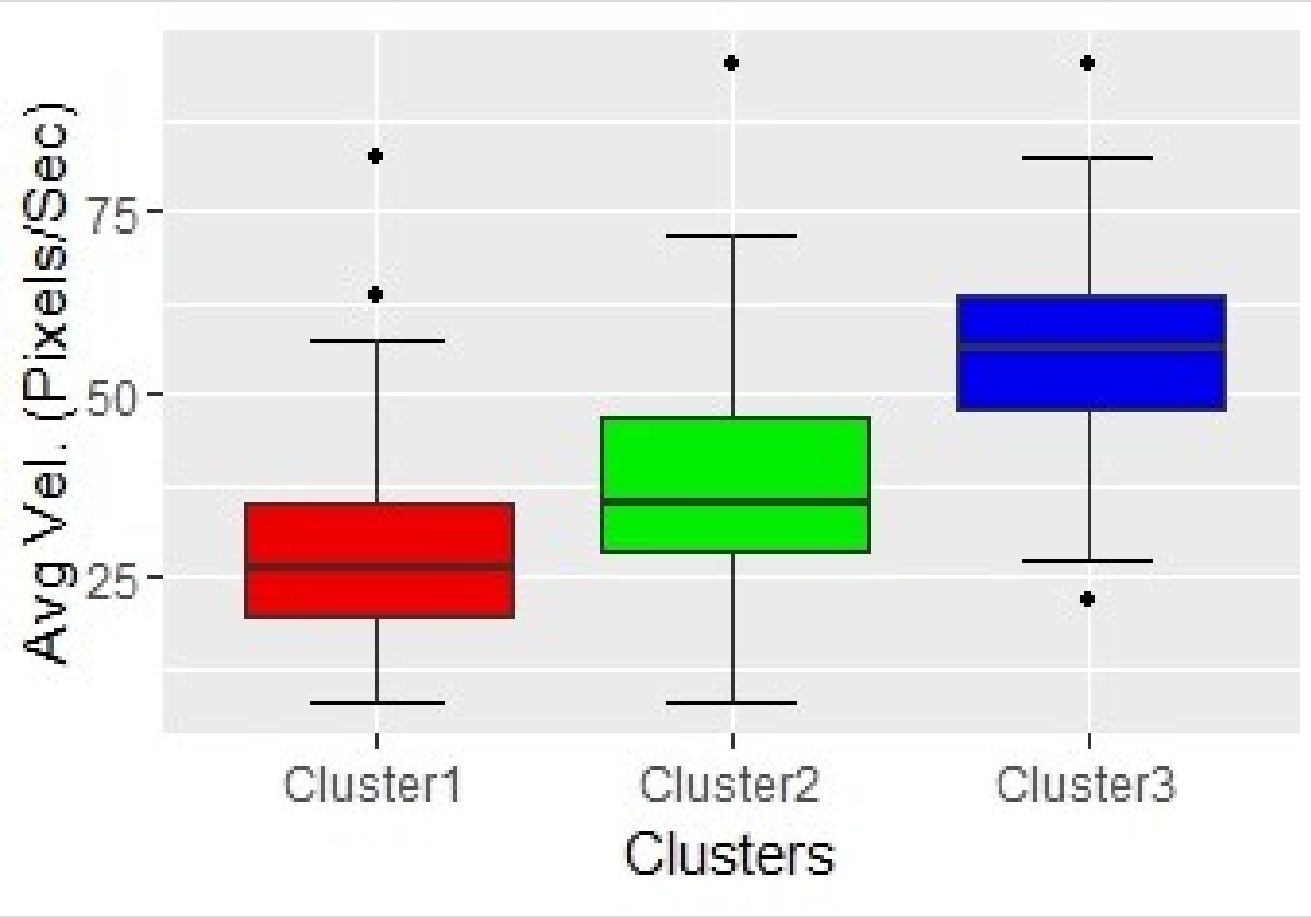


The variation of gaze velocity in clusters (K=2).



The variation of gaze acceleration in clusters (K=2).

Cluster Analysis (cont'd)



The variation of velocity in clusters (K=3).

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Conclusions

- The clustering experiments confirmed the applicability of the image-based clustering using eye-tracking scanpaths.
- This could translate into that scanpath visualizations could largely discriminate the ASD-diagnosed samples from others.
- Furthermore, the cluster analysis could reveal potential connections between the dynamics of gaze behaviour and autism.
- From a practical standpoint, the deep autoencoder played a key role in learning efficient compressed representations of images.
- The study gives promising prospects for employing such visual patterns for developing assistive diagnostic tools including classification models.

Thank You!

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Find the original publication on:

- https://ieeexplore.ieee.org/document/8856904

Dataset available on Figshare:

- https://figshare.com/articles/Visualization_of_Eye-Tracking_Scanpaths_in_Autism_Spectrum_Disorder_Image_Dataset/7073087

Project Website:

- https://mahmoud-elbattah.github.io/ML4Autism/
- https://www.researchgate.net/project/Predicting-Autism-Spectrum-Disorder-Using-Machine-Learning-and-Eye-Tracking