Early Detection of Alzheimer's Disease and Related Disorders Using Deep Learning-Based 3D Pose Estimation, Gait Analysis, and Machine Learning

Presented by

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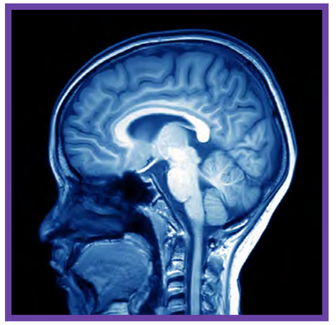
What is Alzheimer's Disease(AD) and Mild Cognitive Impairment(MCI)?

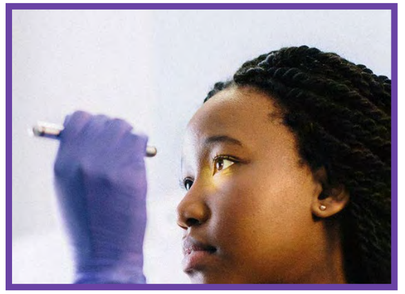
- **What is Alzheimer's Disease(AD)?**
  - Progressive **neurodegenerative** disorder and most common cause **of dementia**.
  - Onset Age: Typically, **65+**, early-onset in **30s**.
  - Effect: There is **no cure** of Alzheimer's Disease
  - Symptoms: Cognitive **decline**, memory **loss**, and **difficulty** with daily tasks.

- **What is Mild Cognitive Impairment(MCI)?**
  - **Minor** memory and cognitive **decline**.
  - Effect: **Increased risk** of developing **Alzheimer's Disease**(not all individuals with MCI progress to dementia or Alzheimer's Disease)
  - Symptoms: Forgetfulness, trouble making decisions, challenges with complex tasks, and difficulty following conversations
  - Common Cause: Age-related changes, genetic factors, cardiovascular diseases, etc.

Current Clinical Diagnoses of MCI, their Challenges, and Solution to Challenges

- **Clinical Diagnosis of MCI**:
  - Brain Imaging
  - Lab Test
  - Neurological Exam
  - Neuropsychological Test





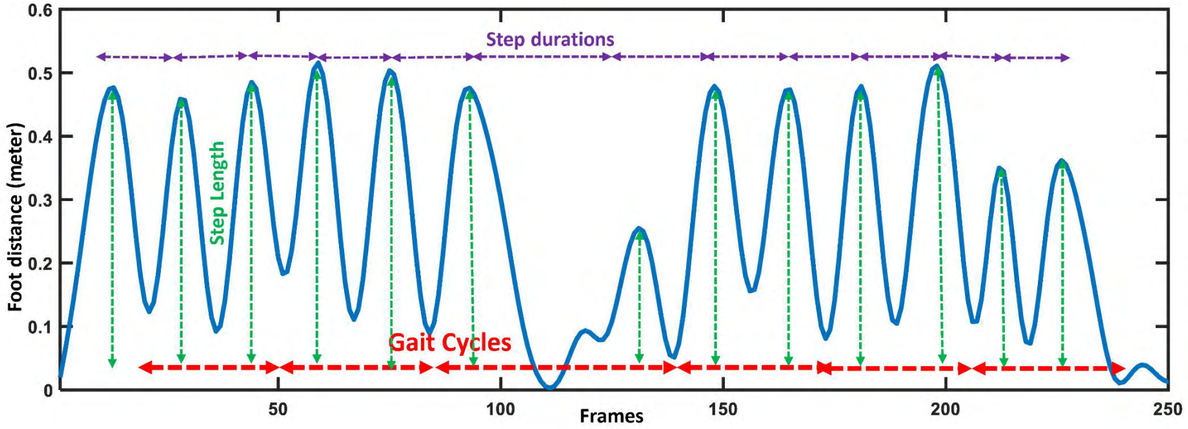
- **Clinical Diagnosis Challenges**:
  - Time consuming
  - Complicated Setting
  - High Cost
  - Subjective

- **Solution**:
  - **Gait Analysis** – Assess walking patterns
  - **3D Pose Estimation-** Capture and analyze joint movements
  - **Machine Learning-** Classify MCI vs healthy on gait data

Main Steps for Gait Analysis and Processing to Detect MCI

•Feature extraction

- A total of 36 gait features were extracted
- 6 macro features
- 12 micro temporal features
- 12 micro spatial features
- 6 micro Spatio-temporal features



•Feature selection using statistical analysis

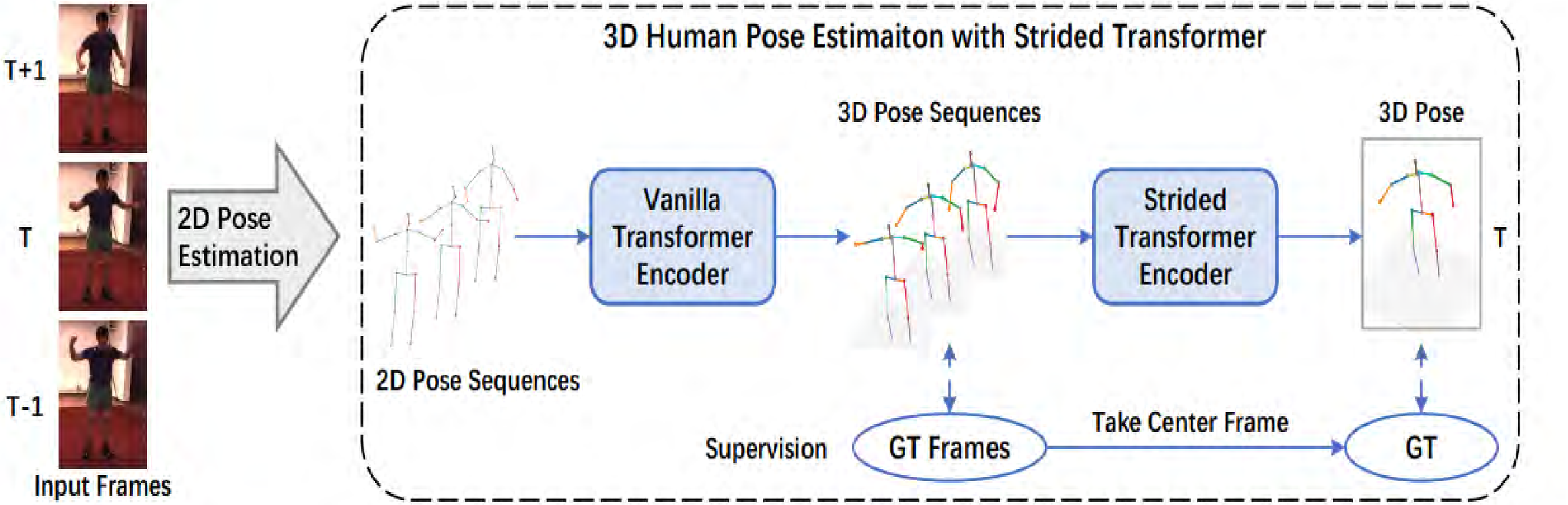
- Finding features with significant differences
- Selecting the unique features with the highest power for discrimination of MCI and HC

•Classification of MCI vs. Healthy Control (HC)

- Support Vector Machine (SVM)
- K-Fold cross-validation
- Finding the best hyperparameters and kernels using the grid search

Main Steps for Gait Analysis and Processing to Detect MCI (continued)

3D Pose Estimation Model



Yan, J., Zhao, X., Liu, Y., Ni, B., Zhao, Q., Ma, J., & Yang, X. (2021). Anchor DETR: Query Design for Transformer-Based Object Detection. arXiv preprint arXiv:2103.14304.

What was the demographical and clinical information of the two study groups, MCI vs. HC?

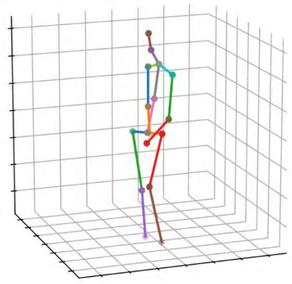
Characteristic	HC (N=27)	MCI (N=26)
Age *(years)*	68.33 ± 2.15	69.76 ± 6.45
BMI (kg/m^2)	24.51 ± 2.67	26.67 ± 2.62
Education *(years)*	13.53 ± 2.38	11.56 ± 3.00
MMSE	28.50 ± 1.17	25.60 ± 1.29
MoCA	27.13 ± 2.05	22.76 ± 1.69
GDS	1.43 ± 1.33	3.52 ± 1.29

Mean ± Standard deviation was shown. N = Number of participants; HC = Healthy Cognitive Control Group; MCI = Mild Cognitive Impairment; BMI = Body Mass Index; MMSE = Mini-Mental State Examination (maximum score, 30); MoCA = Montreal Cognitive Assessment (maximum score, 30); GDS = Geriatric Depression Scale (maximum score, 15), * shows the significant difference for the level of $p < 0.05$.

Samples of body joint detection using 3D Pose Estimation Model on our dataset

Input

Reconstruction



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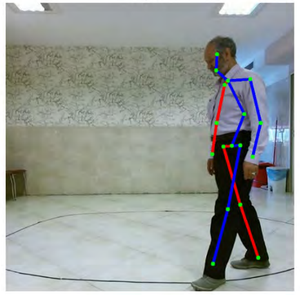

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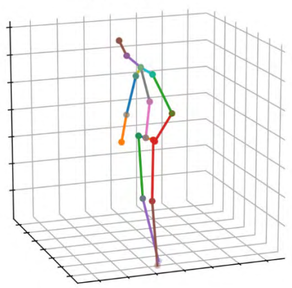

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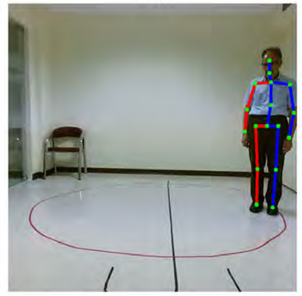

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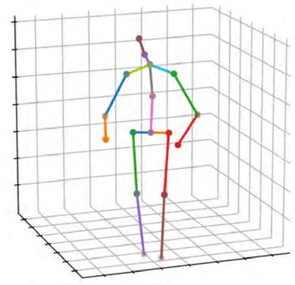

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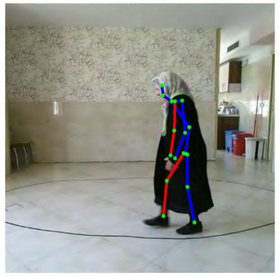

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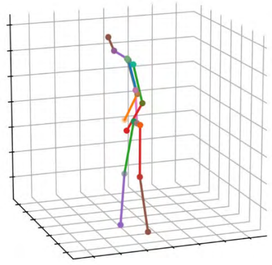

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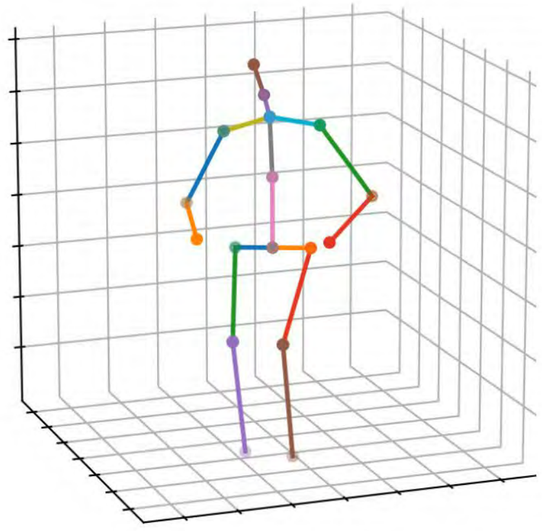
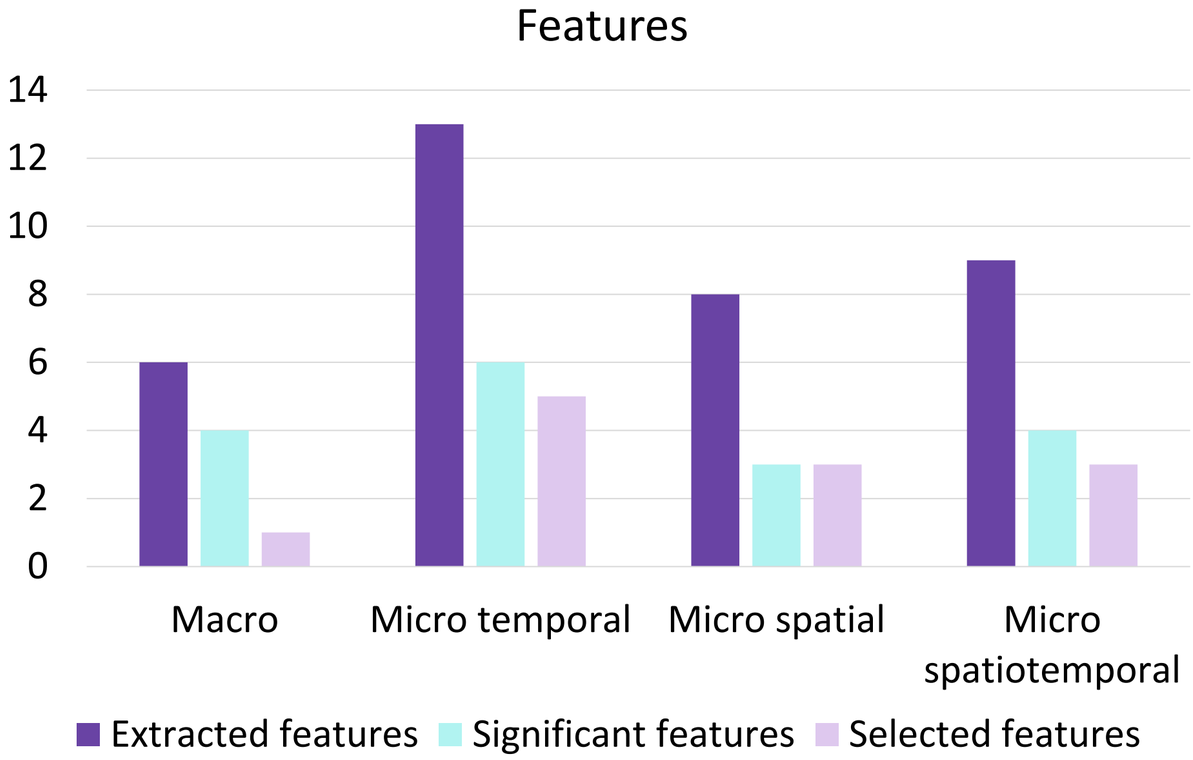


How was the performance of MCI and HC participants significant and selected gait features?

A. Comparison of gait features between MCI and HC participants

- **Stride Length**: MCI patients have shorter strides than healthy controls.
- **Gait Speed**: MCI individuals walk slower than healthy individuals.
- **Gait Variability**: MCI patients show more variability in steps and stride time.

B. Distributed of extracted, significant and selected gait features



Was the Machine Learning Model of SVM Successful in MCI Detection via Gait Features, and What Were the Results?

Number of Folds (K-Fold)	Evaluation metrics (%)				
	Accuracy	Sensitivity	Precision	Specificity	F-Score
K=3	66.10	69.23	64.28	62.96	66.67
K= 5	75.36	69.23	78.26	81.48	73.47
K= 10	69.73	65.38	70.83	74.07	68.00

- **K=5 Folds**: **Highest performance** with **75.36%** accuracy, **78.26%** precision, and **81.48%** specificity.

Conclusion

- In summary, comprehensive analysis of curved-path gait using standard cameras, pose estimation via deep neural networks, signal processing, descriptive statistical analysis, and ML can be used as a complementary tool for MCI detection.

- Suitable for widespread use in clinical and non-clinical settings to assist in frequent cognitive decline assessments

- Promoting healthy aging by increasing the chance of in-time MCI diagnosis at early stage and related disorders before conversion to AD

Thank You!

- Link to LinkedIn