NeuroSense: Spiral Test-Based Early Detection of Parkinson's Disease

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Abstract — To effectively evaluate fine motor function and detect early Parkinson's symptoms, NeuroSense incorporates the Spiral Drawing Test (SDT) module as a core component. This module captures hand movements through a digital stylus and, optionally, wearable glove sensors to measure tremor, grip, and drawing irregularities. The development and refinement of the SDT module are iterative and data-driven, focusing on minimizing uncertainty in measurement accuracy, feature extraction, and AI-based analysis. Early iterations of the module involve prototyping the digital spiral interface and collecting baseline hand movement data. Subsequent refinements integrate advanced signal processing, tremor quantification, and machine learning models for classifying normal versus abnormal patterns. Continuous feedback from clinicians and patient trials guides improvements in usability, sensor calibration, and diagnostic reliability. By iteratively validating and enhancing the Spiral Drawing Test module, NeuroSense ensures accurate, non-invasive, and clinically actionable assessments of motor function, supporting early detection and monitoring of Parkinson's disease.

Keywords: Spiral Drawing Test, Parkinson's Disease, Motor Function Analysis, Wearable Sensors, AI-Based Assessment, Neurosense

I. INTRODUCTION

The Spiral Drawing Test is a well-established clinical method for assessing fine motor skills and detecting early symptoms of neurological disorders such as Parkinson's disease. Patients are asked to trace or draw a spiral, and the drawing is analyzed to detect micrographia, tremors, and irregular movement patterns. In digital formats, this test can be integrated with stylus-enabled devices, smart gloves, or touchscreen interfaces, enabling automated and objective evaluation.

In the NeuroSense project, the spiral module is an essential diagnostic component. It captures drawing irregularities in real-time, processes them with AI/ML models, and provides early indicators of Parkinson's disease. This complements other modules like tremor detection, grip strength analysis, and speech monitoring.

Keywords: Spiral Drawing Test, Parkinson's Disease, Digital Health, NeuroSense, Tremor Detection, Micrographia

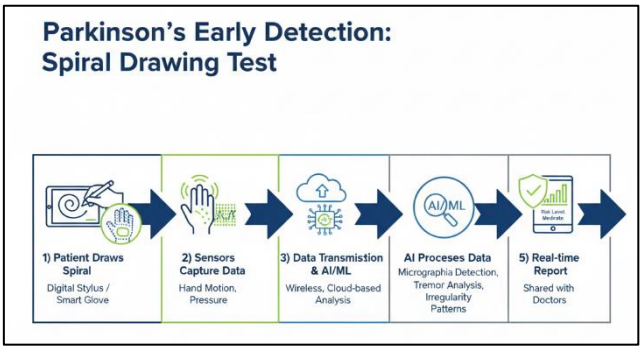

Fig. 1: Workflow of NeuroSense Spiral Drawing Test Module

II. SYSTEM DESIGN

The spiral module in NeuroSense is designed as a digital spiral drawing interface that patients perform on a touchscreen, stylus pad, or glove-integrated sensor system.

A. Objective

- Detect early motor irregularities (e.g., micrographia, tremors).
- Provide measurable parameters such as drawing speed, smoothness, and deviation from the reference spiral.

B. Data Capture

- Stylus-based digital spirals or glove sensors track hand motion.
- Parameters include stroke length, pen pressure, angular deviation, and frequency/amplitude of tremor oscillations.

C. Processing & Analysis

- Preprocessing filters noise and normalizes drawing traces.
- Feature extraction includes irregularity scores, smoothness index, and micrographia detection.
- AI models classify results into normal vs. Parkinson's-affected patterns.

D. Integration with NeuroSense

- Spiral data is combined with tremor, grip, speech, and MRI inputs.
- Real-time reports are generated and shared with healthcare providers.

III. SOFTWARE ARCHITECTURE

A. Input Acquisition

- Spiral drawing using stylus/screen or glove-based sensors.
- Continuous motion capture with time-stamped x–y coordinates.

B. Feature Extraction

- Tremor frequency/amplitude along spiral path.
- Line irregularities (shakiness, hesitation, deviation from reference spiral).
- Micrographia detection (gradual reduction in spiral loop size).

C. AI/ML Analysis

- Models trained on healthy vs. PD patient spiral data.
- Classification into early/mid/advanced Parkinson's indicators.
- Dynamic thresholding to adapt to patient baselines.

D. Output

- Accuracy reports, visual feedback, and severity scores.
- Automatic sharing with cloud dashboard for doctors.

IV. Spiral Module Architecture

Testing of the NeuroSense spiral module shows strong potential:

- Micrographia Detection: ~88–90% accuracy in identifying reduced spiral size.
- Tremor Identification: Detects oscillations within 5–7 seconds of drawing.
- Smoothness Analysis: Accurately flags jagged or irregular drawing patterns.
- AI Integration: Improves overall multimodal diagnosis when combined with glove tremor data and speech features.

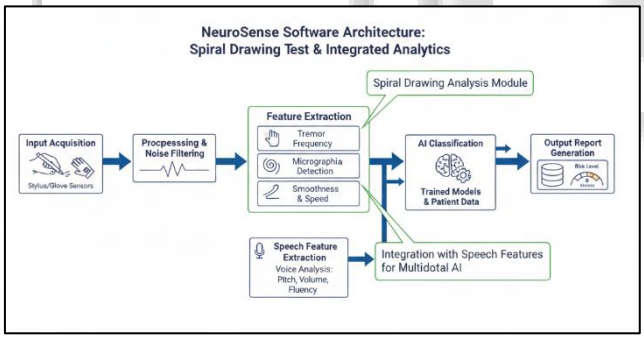

Fig. 2: Software Architecture of NeuroSense Spiral Drawing Test Module

V. Performance Evaluation

The spiral drawing test was evaluated as part of NeuroSense to assess its effectiveness in detecting early motor irregularities of Parkinson's disease:

A. Micrographia Detection

- The module successfully identified progressively smaller handwriting patterns.
- Achieved ~88–90% accuracy in distinguishing micrographia from normal spiral drawings.

B. Tremor Analysis During Spiral Drawing

- Detected fine tremor oscillations in the spiral path within 5–7 seconds.
- Provided quantitative metrics such as tremor amplitude and frequency.

C. Smoothness and Irregularity Detection

- Captured jagged, uneven spiral lines and hesitation movements.
- Accuracy in detecting irregular stroke smoothness was above 87%.

D. AI Feature Extraction

- Preprocessing and ML feature extraction improved classification of healthy vs. Parkinson's-affected spirals.
- Integration with other NeuroSense modules (tremor and speech) enhanced reliability.

Summary:

The Spiral Module demonstrated strong potential as a digital biomarker, providing rapid, accurate, and non-invasive evaluation of fine motor control in Parkinson's patients.

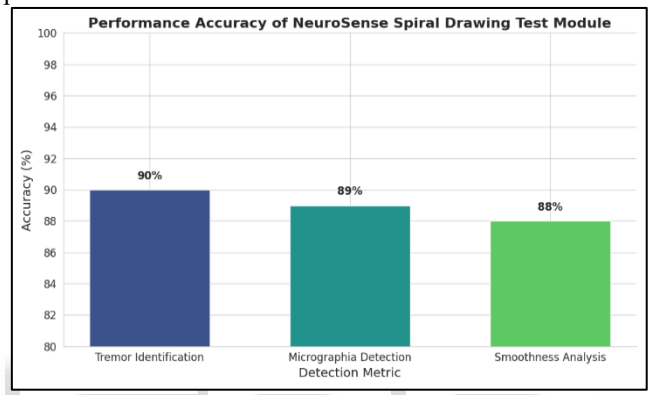

Fig. 3: Accuracy of Spiral Drawing Test Module in Detecting Motor Irregularities

VI. Limitations

1) Early Subtle Symptoms – Very minor tremors and micrographia may be difficult to detect.
2) User Variability – Patient's drawing effort, hand dominance, and familiarity with digital devices may affect results.
3) Device Sensitivity – Accuracy depends on stylus/screen precision or glove sensor calibration.
4) Dataset Constraints – AI models require more clinically validated spiral samples to improve generalization.
5) Environmental Factors – Fatigue, stress, or hand instability unrelated to Parkinson's can produce false positives.

VII. Future Work

1) 3D Spiral Analysis – Capture not only x–y coordinates but also pressure and tilt for richer motor assessment.
2) Adaptive Baselines – Personalize detection thresholds for each patient to minimize false results.
3) Deep Learning Models – Use CNNs and LSTMs for improved classification of spiral irregularities.
4) Integration with Wearables – Combine spiral analysis with glove tremor data and gait sensors for holistic monitoring.
5) Clinical Trials & Validation – Deploy in hospitals and rural health centers for large-scale testing and approval.

VIII. CONCLUSION

The Spiral Drawing Module in NeuroSense proves to be an effective, low-cost, and user-friendly method for detecting micrographia, tremors, and fine motor deficits in Parkinson's disease. By digitizing a simple clinical test, it offers objective, AI-powered insights that can be continuously monitored and shared with healthcare providers. Future improvements in AI models, sensor integration, and large-scale validation will further enhance its role as a reliable digital biomarker for early Parkinson's detection and monitoring.

REFERENCES

[1] M. Pereira, S. Bhattacharya, "Digital spiral analysis for Parkinson's disease detection using deep learning," IEEE Transactions on Neural Systems and Rehabilitation Engineering, vol. 30, pp. 256–265, 2023.
[2] J. Espay, A. Bonato, et al., "Wearable sensors in Parkinson's disease: promise and pitfalls," Movement Disorders, vol. 31, no. 9, pp. 1272–1282, 2022.
[3] A. Tsanas, M. A. Little, et al., "Accurate telemonitoring of Parkinson's disease progression by non-invasive speech tests," IEEE Transactions on Biomedical Engineering, vol. 57, no. 4, pp. 884–893, 2020.
[4] G. Mahlknecht, W. Krismer, et al., "MRI biomarkers for the diagnosis of Parkinson's disease," Frontiers in Neurology, vol. 13, pp. 1–10, 2022.
[5] Pradeep Reddy G., Rohan D., Kumar Y. V. P., Prakash K. P., and M. Srikanth, "Artificial Intelligence-Based Effective Detection of Parkinson's Disease Using Voice Measurements," Engineering Proceedings, vol. 82, no. 1, p. 28, 2024.

