

Parkinson's Disease Detection Using Spiral Drawing Analysis with 12-Feature Support Vector Machine Classification in MATLAB

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Abstract:

Parkinson's disease (PD) is a progressive neurological disorder that affects motor control, hand movement, coordination, and fine motor skills. Spiral drawing analysis provides a non-invasive image-based approach for studying variations in motor control. This study presents a computer-aided Parkinson's disease detection system based on spiral drawing images and Support Vector Machine (SVM) classification implemented in MATLAB. The dataset used in the experiment contained 528 spiral images, comprising 280 healthy samples and 248 Parkinson's disease samples. Twelve handcrafted image features were extracted from each drawing: Area, Perimeter, Eccentricity, Circularity, Solidity, Extent, Major Axis Length, Minor Axis Length, Mean Intensity, Standard Deviation, Entropy, and Edge Density. The images were converted to grayscale, filtered, thresholded, cleaned using morphological operations, and reduced to the largest connected component before feature extraction. The feature vectors were standardized and classified using an RBF-kernel SVM. Hyperparameter optimization was performed using BoxConstraint and KernelScale values. The best reported optimization accuracy was 97.73%. A MATLAB GUIDE graphical interface was developed for image upload, feature extraction, prediction, and display of feature-level information. The results indicate that the proposed handcrafted-feature SVM framework is a promising computer-aided screening approach for the analyzed dataset. However, the reported 97.73% value should be interpreted according to the exact validation procedure used in the final code and should not be considered a clinical diagnostic accuracy.

Keywords: Computer-Aided Detection, Handcrafted Features, Image Processing, MATLAB, Parkinson's Disease, Spiral Drawing, Support Vector Machine

1. Introduction

Parkinson's disease (PD) is a progressive neurological disorder associated with motor impairments such as tremor, rigidity, bradykinesia, and impaired coordination. Clinical diagnosis is primarily based on neurological examination and observed motor symptoms. Because changes in hand movement can influence handwriting and drawing, spiral tasks have been investigated as a non-invasive source of quantitative information for Parkinson's disease screening [1], [2].

Spiral drawing requires continuous and coordinated hand movement. Variations in the shape, boundary, intensity, and edge structure of a drawing can therefore provide measurable characteristics for computational analysis. Previous research has shown that geometric and kinematic features extracted from spiral drawings can be useful for distinguishing Parkinson's disease from healthy controls [3], [4].

Machine-learning approaches are attractive for this task because they can learn decision boundaries from extracted drawing characteristics. SVM classifiers, in particular, are well suited to feature-based classification problems. More

recent studies have also investigated deep-learning and hybrid approaches, including a ResNet-50 plus SVM model that reported 98.45% accuracy on a small hand-drawing dataset [5].

The present study develops a conventional image-processing and SVM framework using twelve handcrafted features extracted directly from spiral images. The complete system is implemented in MATLAB and integrated with a MATLAB GUIDE graphical interface.

The main objectives are: (i) to preprocess spiral drawing images; (ii) to extract twelve handcrafted image features; (iii) to standardize the extracted feature vectors; (iv) to optimize an RBF-kernel SVM classifier; and (v) to provide an interactive MATLAB GUI for automated prediction.

2. Literature Review

Research on Parkinson's disease detection from handwriting and spiral drawings has progressed from manually designed geometric and kinematic indicators to machine-learning and deep-learning models. Chandra et al. investigated geometric characteristics of digitized Archimedean spirals and showed that interpretable spiral features can provide strong discrimination between Parkinson's disease and control groups [3]. Their work also emphasized the usefulness of sparse, interpretable features when datasets are relatively small.

Lamba et al. developed a systematic Parkinson's disease diagnosis approach using kinematic features from handwritten spiral drawings. Their study extracted 29 kinematic features and evaluated SVM, random forest, AdaBoost, and XGBoost. The best reported combination used mutual-information feature selection with AdaBoost and achieved 96.02% accuracy using ten-fold cross-validation [4].

Other studies have explored static spiral image characteristics using image processing and machine learning. The use of drawing-derived features supports the broader concept that motor impairment can be quantified through handwriting and spiral tasks [2], [3].

Varalakshmi et al. evaluated machine-learning, deep-learning, pretrained, and hybrid models on hand-drawing images. Their ResNet-50 plus SVM hybrid approach achieved 98.45% accuracy, with reported sensitivity of 99% and specificity of 98% [5]. This result is higher than the present 97.73% result, but the approaches are not directly equivalent because the hybrid model uses deep features and a different dataset and experimental procedure.

The present work is therefore positioned as a lightweight handcrafted-feature approach. Instead of learning thousands of deep features, the proposed system extracts twelve explicit image characteristics covering shape, intensity, information content, and edge structure and applies an RBF-SVM classifier.

3. Case and Methodology

3.1 Dataset

The experimental dataset contained 528 spiral drawing images. The images were organized into two classes, Healthy and Parkinson's disease. The Healthy class contained 280 images and the Parkinson's class contained 248 images. The images were read from the corresponding class folders using MATLAB file-directory operations.

Class	Number of Images	Percentage
Healthy	280	53.03%
Parkinson's Disease	248	46.97%
Total	528	100%

The exact source of the 528-image image collection must be stated in the final manuscript. If the collection was derived from a public repository, the repository and original dataset publication must be cited. The UCI Parkinson Disease Spiral Drawings dataset is one established public dataset used in related research [6]. Do not identify the 528 images as the UCI dataset unless that is actually how the images were obtained.

3.2 Image Preprocessing

Each input image is first converted from RGB to grayscale when required. The grayscale image is converted to double precision and median filtering with a 3×3 neighborhood is applied to reduce noise. The image is then converted into a binary representation using Otsu thresholding through `graythresh` and `im2bw`. The binary image is inverted so that the drawing becomes the foreground.

Small connected components are removed using `bwareaopen` with a minimum area threshold of 50 pixels. Hole filling is then applied using `imfill`. Morphological closing with a disk-shaped structuring element of radius 2 and opening with a disk-shaped structuring element of radius 1 are used to refine the segmented drawing. Finally, connected-component analysis is performed and the largest connected component is retained for feature extraction.

3.3 Twelve-Feature Extraction

The feature-extraction function computes twelve handcrafted descriptors from the processed spiral image. Seven shape-related descriptors are obtained from MATLAB region props, while intensity, entropy, and edge information are computed directly from the grayscale image.

No.	Feature	Description
1	Area	Area of the segmented spiral region.
2	Perimeter	Boundary length of the segmented region.
3	Eccentricity	Elongation of the segmented region.
4	Circularity	Closeness of the shape to a circular form.
5	Solidity	Proportion of region area relative to its convex hull.
6	Extent	Ratio of region area to bounding-box area.
7	Major Axis Length	Length of the major principal axis.
8	Minor Axis Length	Length of the minor principal axis.
9	Mean Intensity	Average grayscale intensity.
10	Standard Deviation	Variation in grayscale intensity.
11	Entropy	Image information/complexity measure.
12	Edge Density	Proportion of detected Canny edge pixels.

The circularity feature is calculated as $4\pi A/P^2$, where A is the segmented area and P is the perimeter. Edge Density is calculated as the number of detected Canny edge pixels divided by the total number of image pixels. These features form a 528×12 feature matrix for the reported dataset.

3.4 Feature Standardization

The extracted feature vectors are standardized before SVM training. Standardization is important because the twelve features have different numerical scales. In the MATLAB implementation, the SVM is trained with the Standardize option enabled so that the classifier operates on standardized feature values.

3.5 SVM Classification

Support Vector Machine is used to classify the feature vectors into Healthy and Parkinson's classes. An RBF kernel is selected because the relationship between handcrafted image features and class labels may be nonlinear. The RBF kernel is expressed as $K(x_i, x_j) = \exp(-\|x_i - x_j\|^2 / (2\sigma^2))$, where σ controls the kernel width.

3.6 Hyperparameter Optimization

The classifier parameters BoxConstraint and KernelScale are varied over predefined candidate values. The MATLAB program trains an RBF-SVM for each parameter combination and selects the configuration producing the highest measured accuracy. The best reported configuration for the experiment produced an accuracy of 97.73%.

For publication, the exact evaluation procedure used to obtain 97.73% must be retained and reported consistently in the code and manuscript. If the cross-validation step is removed from the final code, 97.73% should not be described as an independently validated accuracy unless an unseen test set is used. A training-set or optimization accuracy can be inflated because the same observations influence model fitting and evaluation.

3.7 MATLAB GUIDE Interface

The trained model is integrated into a MATLAB GUIDE graphical interface. The GUI enables the user to select a spiral image, display the image, perform feature extraction, compare feature values with healthy reference ranges, and obtain the final SVM prediction. The trained model and reference statistics are stored in svm_model.mat for use by the prediction interface.

The overall system workflow is: Spiral Image Input → Grayscale Conversion → Noise Removal → Binary Segmentation → Morphological Processing → Largest Component Selection → 12-Feature Extraction → Feature Standardization → RBF-SVM Classification → Prediction Display.

4. Results & Analysis

4.1 Dataset and Model Summary

Parameter	Value
Total images	528
Healthy images	280
Parkinson's disease images	248
Feature matrix	528×12
Number of features	12
Classifier	Support Vector Machine
Kernel	RBF
Hyperparameters	BoxConstraint, KernelScale

Best reported accuracy	97.73%
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The optimized RBF-SVM produced a best reported accuracy of 97.73% during the parameter search. The result indicates that the twelve handcrafted features contain discriminative information for the two classes in the analyzed image collection.

4.2 Comparison with Previous Studies

Study	Approach	Classifier / Model	Reported Result
Lamba et al. [4]	29 kinematic features + feature selection	AdaBoost	96.02% accuracy
Chandra et al. [3]	Geometric/spiral features	Random Forest	AUC 0.999
Varalakshmi et al. [5]	Hand-drawing images + deep features	ResNet-50 + SVM	98.45% accuracy
Proposed method	12 handcrafted image features	RBF-SVM	97.73% best reported accuracy

The proposed 97.73% result is higher than the 96.02% accuracy reported by Lamba et al. for the best feature-selection/AdaBoost configuration [2]. It is lower than the 98.45% reported by Varalakshmi et al. using a ResNet-50 and SVM hybrid model [5]. Chandra et al. reported an AUC of 0.999 using geometric spiral features and random forest on the ParkinsonHW dataset [3]. These values should not be treated as direct head-to-head comparisons because the datasets, features, preprocessing, validation procedures, and classifiers differ.

4.3 Discussion

The proposed approach has the advantage of using a compact and explicitly defined feature representation. The twelve descriptors cover geometric shape, region properties, grayscale intensity, information content, and edge structure. This makes the processing pipeline easier to inspect than an end-to-end deep-learning model.

The result also demonstrates the importance of reporting the evaluation protocol together with accuracy. A single accuracy value is not sufficient to establish clinical usefulness, particularly when model selection and evaluation are performed on the same observations. Independent testing, subject-level separation, and external validation are needed to determine generalizability.

Accordingly, the 97.73% value is reported here as the best measured result from the stated optimization experiment, rather than as a clinical diagnostic accuracy. The system is intended as a research and screening aid and does not replace neurological assessment.

5. Conclusion

This study presented a MATLAB-based computer-aided Parkinson's disease detection framework using spiral drawing images, twelve handcrafted image features, and an RBF-kernel Support Vector Machine classifier. The preprocessing pipeline includes grayscale conversion, median filtering, thresholding, binary inversion, removal of small objects, hole filling, morphological refinement, and largest-component selection.

The final feature representation consists of Area, Perimeter, Eccentricity, Circularity, Solidity, Extent, Major Axis Length, Minor Axis Length, Mean Intensity, Standard Deviation, Entropy, and Edge Density. The reported best optimization accuracy was 97.73% on the analyzed dataset of 528 images.

The MATLAB GUIDE interface provides a practical implementation for image upload, feature extraction, classification, and result display. Future work should use an independent unseen test set, subject-level validation, larger and more diverse datasets, and comparisons with additional machine-learning and deep-learning methods.

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Author Contributions

Dharshana V.: conceptualization, methodology, software development, image preprocessing, feature extraction, SVM implementation, hyperparameter optimization, analysis, visualization, and manuscript preparation. Project Guide: supervision, methodological guidance, review, and validation of the study, if applicable. Individuals should be listed as authors only if they meet the journal's authorship criteria.

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Disclosure Statement

The author declares no conflict of interest related to this study.

Data Availability

The exact source of the 528 spiral images should be stated by the author before submission. If the images were obtained from a public repository, the repository and original dataset citation should be provided. The UCI Parkinson Disease Spiral Drawings dataset is available through the UCI Machine Learning Repository [6].

Ethical Statement

The ethical status of the dataset must be reported according to its actual source and acquisition procedure. No claim of institutional ethical approval or exemption should be made unless supporting documentation exists.

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