Using Multiobjective Evolutionary Algorithms to Understand Parkinson's Disease

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ABSTRACT

The incidence of neurodegenerative diseases such as Parkinson's is increasing rapidly around the world, yet the symptoms and pathology of these diseases remain incompletely understood. As a consequence, it is challenging for clinicians to provide patients with accurate diagnoses or prognoses. In this work, we use multi-objective evolutionary algorithms to explore recordings of patients drawing neurological assessment figures, with the aim of identifying patterns of cognitive and motor signals that discriminate different disease states. As a proof of principle, we demonstrate how this approach can be used to explore the trade-off between predicting clinical measures of motor and cognitive deficit.

Categories and Subject Descriptors

I.2.8 [**Artificial Intelligence**]: Problem Solving, Control Methods, and Search; I.5.2 [**Pattern Recognition**]: Design Methodology; J.3 [**Computer Applications**]: Life and Medical Sciences

Keywords

Multi-objective evolutionary algorithms; Predictive modelling; Parkinson's disease; Polynomial regression

1. INTRODUCTION

Over the next 10–20 years, neurodegenerative diseases (NDDs) are predicted to become a major social and economic problem in countries with aging populations. All NDDs lead to degeneration of neural tissue, though the biological pathways through which this occurs varies considerably between diseases. For most NDDs, these pathways remain poorly understood. However, regardless of their underlying biology, most NDDs lead to widespread damage, affecting diverse regions of the brain. As a consequence of this, there is considerable overlap at the symptomatic level. This, in turn, can make it challenging to perform a differential diagnosis. There is also considerable heterogeneity within diseases [1]. Parkinson's disease (PD), for example, has both motor and cognitive variants. People with motor variants develop characteristic symptoms such as tremor, slowing of movement, and an unstable gait. People with cognitive variants also experience cognitive impairment [2], in many cases developing dementia. At the onset of the disease, it is unclear which variant a patient will develop, meaning that most patients do not receive an accurate prognosis.

In this work, we are looking at how multi-objective evolutionary algorithms (MOEAs) can help us to understand the ontology of PD. MOEAs allow us to explore a space of predictive models that make different trade-offs. In this paper, we focus on the trade-off between models that predict motor and cognitive elements of PD, describing how an MOEA is used to optimise a Pareto front of polynomial regression models.

2. CLINICAL DATA

Data collection took place at the Leeds Teaching Hospitals NHS Trust[1]. Fifty-eight patients and twenty-nine age-matched controls were recruited and underwent standard clinical assessments of their motor and cognitive abilities. In this paper, we use the composite score of the MoCA (Montreal Cognitive Assessment) cognitive screening test, and the composite score of the motor section of the MDS-UPDRS (Movement Disorder Society sponsored revision of the Unified Parkinson's Disease Rating Scale) assessment as measures to be predicted by regression models. The subjects were asked to carry out a series of neurological figure copying tasks, which are designed to emphasise motor and cognitive impairments.

In this paper, we analyse data from a single drawing task which required the subject to trace, using an inking pen, a pentagon spiral figure (see Figure 1) that was overlaid on a

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[1]Permission to use this data was granted by the South Central - Oxford C NHS REC (ref: 15/SC/0365). Other data generated during this research is available at the following DOI: 10.17861/958af07e-d336-4202-854e-12188211873a.

Wacom digitising tablet, capturing their pen position at a rate of 200 times per second. To characterise each drawing, we extracted a range of features that capture both motor and cognitive characteristics: the accuracy of the drawing (in terms of distance from the template), the total drawing time, the total time spent in each triangular segment of the drawing, the distance travelled by the pen, how often the pen was lifted from the tablet, total time spent not moving, and total time spent not accelerating.

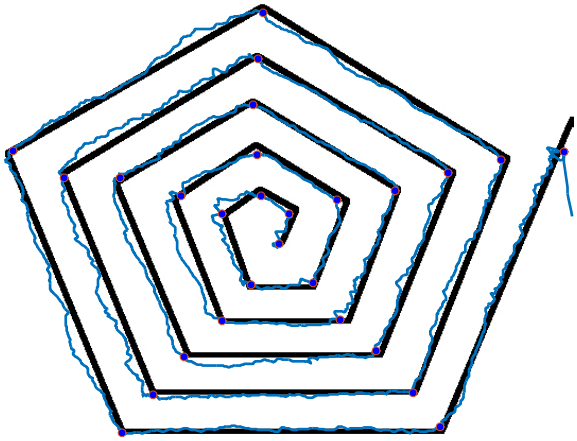

Figure 1: Example of a patient's spiral pentagon trace overlaid on the template.

3. METHODS

Polynomial regression models were used to predict each patient's motor and cognitive assessment scores. Both the features used in these models, and their polynomial degrees (or powers), were optimised using a modified version of the Pareto Archived Evolution Strategy (PAES) [4], a simple yet effective multi-objective evolutionary algorithm. The regression coefficients were not optimised using PAES; rather, they were fitted to the data using the Ordinary Least-Squares (OLS) method [3]. For each evolved solution (i.e. set of features and powers) coefficients were fitted for both motor and cognitive scores, giving two measures of regression error. The aim was to minimise both these objectives, using 10-fold cross validation to measure generality.

4. RESULTS

Fig. 2 shows the combined Pareto front of non-dominated solutions found over all runs. The shape of the front shows a clear trade-off between the two objectives. Models at the extremes of the front offer good predictive ability for motor or cognitive scores, but no models were found that offer good predictive ability for both of these regression scores. This highlights the lack of correlation between motor and cognitive symptoms in PD. Models that successfully predicted motor or cognitive scores used overlapping sets of features, with both making use of measures of time spent drawing and deviation from the target image. This is perhaps unsurprising, since both of these can capture elements of motor and cognitive dysfunction, e.g. deviation due to tremor, or deviation due to impaired visuospatial ability. Other features only appeared in solutions that successfully predicted a single regression target.

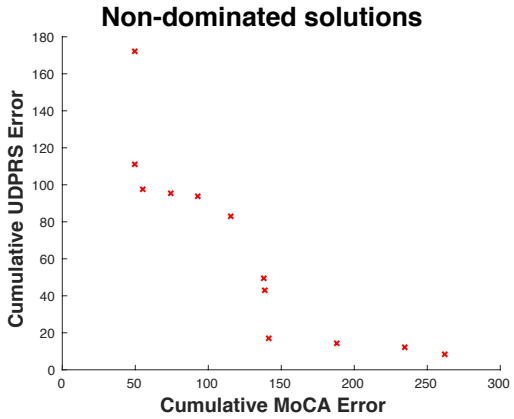

Figure 2: The non-dominated set of solutions found over all runs of PAES.

To explore the effect of model complexity on predictive ability, PAES was run with power limits from 1 (i.e. linear regression models) to 8. In general, we found that error rates reduced as the power limit was raised. Linear models had approximately twice the error rate of the best non-linear models, although they were more interpretable.

5. CONCLUSIONS

In this paper, we have shown that multi-objective evolutionary algorithms can be used to explore recordings of clinical assessment data, identifying groups of features that are particularly relevant for diagnosing and prognosing different variants of Parkinson's disease. In future work, we aim to extract a much larger group of features, to provide a more nuanced insight into the role of different factors in predicting disease characteristics. We will also consider a wider range of objectives, including other predictive variables, such as accuracy early in the disease, and non-predictive factors, such as minimising the complexity of the model.

6. ACKNOWLEDGEMENTS

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