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FUZZY LOGISTIC REGRESSION WITH TRIANGULAR AND GAUSSIAN FUZZY NUMBERS

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This thesis presents a comprehensive exploration of fuzzy methods for binary classification problems, focusing on addressing the critical challenges of class imbalance, complete separation, multicollinearity, seasonality and efficiency. The particular areas of focus for the application in each chapter are varied, including environmental problems, chemical studies, clinical studies, credit card fraud detection and wildfire event prediction.

Initially, fuzzy logistic regression (FLR) is introduced with an extensive simulation and benchmarking against traditional machine learning on five real-world datasets. The results indicate that FLR outperforms machine learning methods, which tend to be significantly impacted by imbalance problems. The FLR framework is then applied to an extensive set of clinical studies, and balancing techniques are considered for the machine learning methods used for benchmarking. FLR shows greater classification performance, even considering balancing techniques to help improve machine learning models under imbalance. The FLR framework is also applied to a real-time problem for credit card fraud detection. The aim is to showcase a high-performing fuzzy framework for detecting fraudulent activity in transactions in an online environment. This application shows strong classification performance and an online application with FLR.

One key challenge with FLR is the extensive tuning required to find optimal parameters due to the Markov chain Monte Carlo approach. The fuzzy-Bayesian logistic regression (FBLR) framework is developed in the second half of this thesis to specifically handle the tuning inefficiency, while also contributing to the integration

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of FLR into the Bayesian domain and working with Gaussian fuzzy numbers (GFN) for greater flexibility. GFN arithmetic is first defined mathematically, providing generalised equations that can be used on any statistical method. This is shown by benchmarking GFNs against triangular fuzzy numbers in fuzzy linear regression, showcasing significant improvement in classification performance. FBLR with GFNs is then applied to the same datasets and benchmark machine learning methods with FLR, showcasing substantial improvements in both efficiency and classification performance.

Lastly, the FBLR framework is applied for wildfire event prediction on 16 unique forest locations, using data from Google Earth Engine on environmental features. The framework is also expanded to incorporate handling of temporal patterns due to seasonality in wildfire data, and the new model is called time-series fuzzy-Bayesian logistic regression, showing strong classification performance for wildfire event activities.

In conclusion, this thesis advances the field of fuzzy modelling by developing and applying robust, adaptable and generalisable frameworks tailored for real-world binary classification challenges.

Some of this research has appeared in [1–5].

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