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Comparison of Machine Learning Models for Classification of Gait Patterns in Children with Autism

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Extended Abstract

Children diagnosed with autism spectrum disorder (ASD) exhibit distinct gait patterns compared to neurotypical controls [1-3]. Previous studies have suggested that leveraging machine learning (ML) methodologies to classify ASD in children can contribute to a deeper understanding of gait mechanics and the development of optimised treatment strategies [4-6]. The aim of this study was to: 1) compare various ML algorithms for classification of gait patterns in children with ASD using 3D kinematic and kinetic biomechanical gait data; and 2) examine classification performance from combining multiple predictive models into an ensemble model. Twenty-six (n=26) children diagnosed with ASD (age=9.15±2.68 years; height=1.37±0.16 m; weight=35.47±14.59 kg) and twenty-six (n=26) age-, gender-, BMI matched neurotypical controls (age=9.38±2.57 years; height=1.40±0.17 m; weight=35.03±10.99 kg) participated in the study. A 12-camera Vicon T160 system (Oxford Metrics Group Ltd., UK), sampling at 100 Hz, was used to track 36 retro-reflective markers (9 mm diam.) placed on the tibia and foot landmarks with a modified 5-segment MSF model [7]. Six force plates (Kistler Instruments, Winterthur, Switzerland) sampling at 1000 Hz, were used to measure 3D forces and moments and identify key gait events. Participants walked at their preferred speed. Temporal-spatial (TS) features, multisegment foot (MSF) angles, lower extremity joint angles and kinetics were computed for each gait cycle. Features extracted from the gait waveforms included max/min values, range of motion, and magnitudes at key gait events and served as input to various ML models, including Linear Discriminant Analysis (LDA), radial basis function-based Support Vector Machine (SVM), k-Nearest Neighbour (KNN), Random Forest (RF), and multilayer perceptron (MLP). A forward sequential feature selection algorithm was applied to identify a set of most contributing features for each model. Subsequently, hyper-parameter optimization was conducted for each model to determine the optimal parameters. To streamline the feature selection process, only the feature sets with classification accuracy exceeding 80% were retained. As a result, six feature sets, containing the most contributing features, were finalised and validated based on clinical meaningfulness. An ensemble of these six feature sets was generated for each ML model and validated using stratified 10-fold cross validation. A majority voting strategy was employed for model ensembling, where the final prediction was based on the majority vote of base model predictions. The results showed that the SVM-based ensemble model demonstrated the highest classification performance (97% accuracy), followed by MLP with 95% accuracy. The remaining models achieved accuracy scores of 88% for LDA, 91% for KNN, and 90% for RF. The study also demonstrated the effectiveness of ensembling multiple base models to enhance overall model robustness and classification performance. For instance, the six base models on SVM had an average accuracy score of 90.21%, while its ensemble model showed an accuracy score of 97.1%. Similar improvements were observed for other models included in the study. The current study demonstrated that utilising ML models can improve the understanding of biomechanical gait patterns in children with ASD, potentially leading to more effective treatment protocols and a better quality of life. Moreover, this research direction could lay the groundwork for automated gait classification across diverse clinical populations.

References

[1] D. Kindregan, L. Gallagher, J. Gormley, "Gait deviations in children with autism spectrum disorders: A Review," *Autism Res. Treat*., 741480, 2015.

[2] N. Zakaria, N. Tahir, R. Jailani, "Experimental Approach in Gait Analysis and Classification Methods for Autism Spectrum Disorder: A Review," *Int. J. Emerg. Trends Eng. Res.*, vol. 9, pp. 3995–4005, 2020.

[3] M. Calhoun, P. Longworth, V. Chester, "Gait patterns in children with autism*," Clin. Biomech*., vol. 26, pp. 200–206, 2011.

[4] S. Ilias, N. Tahir, R. Jailani, C. Hasan, "Classification of autism children gait patterns using neural network and support vector machine," in *Proceedings of the IEEE Sym. on Comp. Applic. & Indust. Electr. (ISCAIE)*, Penang, Malaysia, 2016, pp. 52-56.

[5] C. Hasan, R. Jailani, N. Tahir, "Automated classification of gait abnormalities in children with autism spectrum disorders based on kinematic data," *Int. J. Psychiatry Psychother.*, vol. 2, pp. 10–15, 2017.

[6] A. Pradhan, V. Chester, K. Padhiar, "Classification of Autism and Control Gait in Children Using Multisegment Foot Kinematic Features," *Bioengineering*, 9, 552, 2022.

[7] A. Leardini, MG. Benedetti, L. Berti, D. Bettinelli, R. Nativo, S. Giannini, "Rear-foot, mid-foot and fore-foot motion during the stance phase of gait," *Gait Posture,* vol. 25, no. 3, pp. 453-62. 2007.