ABSTRAK

Muhammad Athan Amrullah
UPPER LIMB EXOSKELETON BERBASIS MACHINE LEARNING UNTUK MENDETEKSI POLA EMG PADA WRIST DAN BERBASIS FORCE PADA ELBOW MENGGUNAKAN RASPBERRY PI
xvi + 71 Halaman + 4 Tabel + 1 Lampiran

Stroke merupakan salah satu penyebab utama disabilitas fisik di dunia, terutama akibat dampaknya terhadap sistem saraf motorik. Gangguan ini dapat menyebabkan penurunan kontrol otot, melemahnya kekuatan lengan, serta hilangnya koordinasi antara pergelangan tangan dan siku. Rehabilitasi pasca-stroke membutuhkan intervensi berkelanjutan yang mampu menstimulasi pergerakan secara bertahap dan adaptif. Penelitian ini bertujuan mengembangkan prototipe exoskeleton lengan atas untuk mendukung rehabilitasi pasca-stroke, dengan dua sistem kendali: exoskeleton pergelangan tangan berbasis machine learning, dan exoskeleton siku berbasis sensor sudut dan tekanan. Pengujian dilakukan pada lima orang responden laki-laki dengan kondisi fisik normal berusia 22–23 tahun. Sinyal EMG dikumpulkan menggunakan Sensor Analog EMG by OYMotion, sedangkan sudut gerak dideteksi oleh MPU6050 dan tekanan diukur menggunakan load cell. Tiga algoritma machine learning—Random Forest (RF), Support Vector Machine (SVM), dan K-Nearest Neighbors (KNN)—digunakan untuk mengklasifikasikan sinyal EMG antara kondisi kontraksi dan relaksasi otot, dengan ciri ekstraksi RMS, WL, dan MAV. Hasil penelitian menunjukkan bahwa kombinasi ciri secara signifikan memengaruhi performa klasifikasi, dengan RF dan KNN mencapai akurasi, presisi, recall, dan F1-score hingga 99,53%, serta waktu prediksi tercepat oleh RF sebesar 0,044 detik. Sistem siku berhasil mendeteksi sudut gerak dan memberikan respons motor yang adaptif terhadap perubahan tekanan tanpa algoritma machine learning. Kesimpulannya, sistem kendali gabungan berbasis sinyal EMG dan sensor gerak-tekanan menunjukkan kinerja tinggi dalam mendukung gerakan lengan secara adaptif. Prototipe ini berpotensi menjadi alat bantu rehabilitasi pasca-stroke yang efisien dan responsif terhadap kondisi pasien.

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Kata kunci: Stroke, rehabilitasi pasca-stroke, Elektromiografi (EMG), *Forest* (RF), *Support Vector Machine* (SVM), *K-Nearest Neighbors* (KNN), RMS, WL, MAV, MPU6050, *Sensor load cell*, Akurasi, Presisi, *recall*, F1-score.
Daftar Pustaka: 35 jurnal, 1 buku(2016-2024)

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xvi + 71 Pages + 4 Tables + 1 Appendices

Stroke Stroke is one of the leading causes of physical disability worldwide, primarily due to its impact on the motor nervous system. It often results in reduced muscle control, weakened arm strength, and impaired coordination between upper limb segments such as the wrist and elbow. Post-stroke rehabilitation requires continuous intervention capable of gradually and adaptively stimulating movement. This study aims to develop an upper-limb exoskeleton prototype to support post-stroke rehabilitation, consisting of two control systems: a wrist exoskeleton powered by machine learning, and an elbow exoskeleton controlled by motion angle and pressure sensors. Experiments were conducted on five healthy male participants aged 22–23 years. EMG signals were acquired using an Analog EMG Sensor by OYMotion, joint angles were measured using an MPU6050, and pressure was detected using a load cell. Three machine learning algorithms—Random Forest (RF), Support Vector Machine (SVM), and K-Nearest Neighbors (KNN)—were evaluated for classifying EMG signals between muscle contraction and relaxation states, using RMS, WL, and MAV feature extractions. The results show that feature combination significantly affects classification performance, with RF and KNN achieving up to 99.53% in accuracy, precision, recall, and F1-score, and the fastest prediction time recorded by RF at 0.044 seconds. The elbow system successfully detected arm motion angles and adjusted motor responses based on pressure changes without the use of machine learning algorithms. In conclusion, the integrated control system based on EMG signals and motion-pressure sensors demonstrates high performance in adaptively supporting upper-limb movements. This prototype shows potential as an efficient and responsive assistive tool for post-stroke rehabilitation.

Keywords: Stroke, post-stroke rehabilitation, Electromyography (EMG), Random Forest (RF), Support Vector Machine (SVM), K-Nearest Neighbors (KNN), RMS, WL, MAV, MPU6050, load cell sensor, accuracy, precision, recall, F1-score.
Referance:35 journal, 1 book (2016-2024)