UNIVERSITI PUTRA MALAYSIA

ADAPTIVE RESONANCE THEORY-BASED HAND MOVEMENT CLASSIFICATION FOR MYOELECTRIC CONTROL SYSTEM

HESSAM JAHANI FARIMAN

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By

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Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in fulfillment of the requirements for the Degree of Master of Science

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July 2014

Chairman : Siti Anom Ahmad, PhD

Faculty : Engineering

Electromyography (EMG) also referred to as the Myoelectric, is a biomedical signal acquired from skeletal muscles. Skeletal muscles are attached to the bone responsible for the movements of the human body. In case of prosthetic hand, an EMG based control system known as Myoelectric Control System (MCS) has been widely attracted research in the field. Despite there has been a great development in prosthetic hand industry during the last decade, it is considerably needed to investigate an effective control algorithm for affordable prosthetic hand. This thesis investigates a pattern recognition approach for MCS that classifies hand movements accurately and computationally efficient to actuate different functions of a prosthetic hand. Five distinct hand movements are classified with an Adaptive Resonance Theory (ART) based neural network implemented, as it uses a combination of features extracted from four EMG signals.

In order to prove the contribution of the proposed MCS approach, two different evaluation processes have been done. First evaluation considers the investigation of feature extraction method; where the proposed multi-feature consisting of Mean Absolute Value (MAV), Zero Crossing (ZC), Waveform Length (WL), Slope Sign Change (SSC), Root Mean Square (RMS), and Mean Frequency (MNF) has been compared to 2 well-known high accuracy and simple multi-feature methods. The second evaluation is included comparing ART-based methods versus Linear Discriminant Ananlysis (LDA) and k-Nearest neighbor (KNN) as two accurate and simple implementing classifiers.

The study outcome reveals that the proposed multi-feature has better extraction performance in terms of class separability and accuracy; while the performance for the proposed multi-feature (82.51%) is at least 6% better than the other 2 methods. Classification results obtained by using the proposed multi-feature have shown better performance of ART-based methods; considering average accuracy of 89.09% for the ART method, 83.98% for the KNN and 82.52% for the LDA. Further investigation has been done on a computation time evaluation between proposed ART-based methods, LDA and KNN. Regarding training time (75.69ms), classification time (49.57 ms) and elapsed time (3.77s), evaluation showed significantly less computation time of ART-based methods than LDA : training time

(153.65ms), classification time (344.2 ms) and elapsed time (7.92 s) and KNN: training time (165.42 ms), classification time (230.91 ms) and elapsed time (6.58 s). At last, an accurate and computationally efficient hand movements' classification approach for Myoelectric Control System (MCS) has achieved.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains.

TEORI RESONAN SUAI BERASASKAN PENGELASAN PERGERAKAN TANGAN BAGI SISTEM KAWALAN MIOELEKTRIK

Oleh

HESSAM JAHANI FARIMAN

Julai 2014

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Elektromiografi (EMG) juga dikenali sebagai Mioelektrik, adalah isyarat bioperubatan yang diperoleh daripada otot rangka. Otot rangka ialah otot yang melekat pada tulang dan bertanggungjawab untuk pergerakan tubuh manusia. Merujuk kepada tangan palsu, sistem kawalan EMG yang dikenali sebagai Sistem Kawalan Myoelectric (MCS) telah menarik pelbagai bidang penyelidikan. Walaupun terdapat pembangunan yang hebat dalam industri tangan palsu pada sedekad yang lalu, ia masih diperlukan bagi mengkaji algoritma kawalan yang berkesan untuk tangan palsu yang mampu milik.Tesis ini bertujuan mengkaji pendekatan pola pengenalan untuk Sistem Kawalan Mioelektrik (MCS) yang mengklasifikasikan pergerakan tangan dengan tepat dan pengiraan yang efisyen untuk menggerakkan fungsi tangan yang berbeza bagi tangan palsu. Lima pergerakan tangan yang berbeza dikelaskan melalui Adaptive Resonance Theory (ART) menggunakan rangkaian neural, pengkelasan ini berdasarkan gabungan ciri-ciri yang diekstrak daripada empat isyarat EMG.

Dalam usaha untuk membuktikan sumbangan pendekatan MCS yang dicadangkan, dua proses penilaian yang berbeza telah dilakukan. Penilaian pertama ialah penilaian terhadap kaedah pengekstrakan; di mana pelbagai kaedah yang terdiri daripada Mean Absolute Value (MAV), Zero Crossing (ZC), Waveform Length (WL), Slope Sign Change (SSC), Root Mean Square (RMS), dan Mean Frequency (MNF) telah dibandingkan dengan 2 kaedah yang terkenal, yang mempunyai ketepatan yang tinggi dan mudah. Penilaian kedua ialah membandingkan kaedah berasaskan ART dengan Linear Discriminant Analysis (LDA) dan K-nearest Neighbor (KNN) sebagai dua pengklasifikasi yang tepat dan mudah.

Hasil kajian menunjukkan bahawa pelbagai kaedah mempunyai prestasi pengekstrakan lebih baik berdasarkan pemisahan kelas dan ketepatan; manakala prestasi bagi pelbagai ciri yang dicadangkan (82.51%) adalah sekurang-kurangnya 6% lebih baik daripada 2 kaedah yang lain. Hasil pengelasan yang diperolehi dengan menggunakan pelbagai ciri yang dicadangkan telah menunjukkan prestasi yang lebih baik apabila kaedah berasaskan ART digunakan ; dengan mempertimbangkan ketepatan purata 89.09 % untuk kaedah pemilihan ART yang terbaik atau Best-ART,

83.98 % bagi kaedah KNN dan 82.52 % bagi kaedah LDA. Siasatan lanjut telah dilakukan ke atas penilaian masa pengiraan antara kaedah berasaskan ART, LDA dan KNN. Penilaian dijalankan mengenai masa latihan (ms) , masa pengelasan (ms) dan masa berlalu (s). Penilaian menunjukkan masa pengiraan yang singkat bagi kaedah berasaskan ART jika dibandingkan dengan LDA dan KNN . Mengenai masa latihan (75.69ms), masa pengelasan (49,57 ms) dan masa yang diambil (3.77s), penilaian menunjukkan masa pengiraan yang kurang daripada kaedah berasaskan ART berbanding LDA: masa latihan (153.65ms), masa pengelasan (344.2 ms) dan masa yang diambil (7.92 s) dan KNN: masa latihan (165,42 ms), masa pengelasan (230,91 ms) dan masa yang diambil (6.58 s). Di akhir kajian, pendekatan klasifikasi yang mudah, tepat dan pengiraan yang efisyen bagi pergerakan tangan yang cekap untuk Sistem Kawalan Mioelektrik (MCS) akan tercapai.

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I certify that a Thesis Examination Committee has met on ……. To conduct the final examination of Hessam Jahani Fariman on his thesis entitled "hand movements' classification for myoelectric control system using Adaptive Resonance Theory" in accordance with the Universities and University Collages Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U. (A) 106] 15 March 1988. The committee recommends that the student be awarded the Master of Science.

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