Wavelet and Unsupervised Learning Techniques for Experimental Biomedical Data Processing

Matteo Cacciola, Department of Civil Engineering, Energy, Environment and Materials, "Mediterranea" University of Reggio Calabria, Reggio Calabria, Italy

Salvatore Calcagno, Department of Civil Engineering, Energy, Environment and Materials, "Mediterranea" University of Reggio Calabria, Reggio Calabria, Italy

Filippo Laganà, Department of Civil Engineering, Energy, Environment and Materials, "Mediterranea" University of Reggio Calabria, Reggio Calabria, Italy

Francesco Carlo Morabito, Department of Civil Engineering, Energy, Environment and Materials, "Mediterranea" University of Reggio Calabria, Reggio Calabria, Italy

Diego Pellicanò, Department of Civil Engineering, Energy, Environment and Materials, "Mediterranea" University of Reggio Calabria, Reggio Calabria, Italy

Isabella Palamara, Department of Civil Engineering, Energy, Environment and Materials, "Mediterranea" University of Reggio Calabria, Reggio Calabria, Italy

Mario Versaci, Department of Civil Engineering, Energy, Environment and Materials, "Mediterranea" University of Reggio Calabria, Reggio Calabria, Italy

Biagio Cammaroto, Department of Civil Engineering, University of Messina, Messina, Italy

ABSTRACT

Learning theories and algorithms for both supervised and unsupervised Neural Networks (NNs) have already been accepted as relevant tools to cope with difficult problems based on the processing of experimental electromagnetic data. These kinds of problems are typically formulated as inverse problems. In this paper, in particular, the electrical signals under investigations derive from experimental electromyogram interference patterns measured on human subjects by means of non-invasive sensors (ElectroMyoGraphic, sEMS surface data). The monitoring and the analysis of dynamic sEMG data reveal important information on muscles activity and can be used by clinicians for both preventing dramatic illness evolution and improving athletes performances. The paper proposes the use of the Independent Component Analysis (ICA), an unsupervised learning technique, in order to process raw sEMG data by reducing the typical "cross-talk" effect on the electric interference pattern measured by the surface sensors. The ICA is implemented by means of a multi-layer NN scheme. Since the IC extraction is based on the assumption of stationarity of the involved sEMG recording, which is often inappropriate in the case of biomedical data, we also propose a technique for dealing with non-stationary recordings. The basic tool is the wavelet (time-frequency) decomposition, that allows us to detect and analyze time-varying signals. An auto-associative NN that exploits wavelet coefficients as an input vector is also used as simple detector of non-stationarity based on a measure of reconstruction error. The proposed approach not only yields encouraging results to the problem at hand, but suggests a general approach to solve similar relevant problems in some other experimental electromagnetics applications.

Keywords: *Biomedical Data Processing, Electromyography Surface (sEMG), Independent Component Analysis (ICA), Neural Networks (Nns), Wavelets*

DOI: 10.4018/ijmtie.2012070105

1. INTRODUCTION

Most relevant medical problems are today faced by processing (by visual inspection or some automatic means) electrical signals detected on the human body. The evaluation of patient populations often includes the use of ancillary tests for diagnosis and/or prognosis. Data sets collected from these diagnostic tests, such as the Electroencephalogram (EEG), the Electromyogram (EMG), the Electrocardiogram (ECG) and, more recently, the functional Magnetic Resonance Imaging (fMRI), tend to be complex, large and high-dimensional. The trend towards the digitization of the traditionally analog EEG, EMG and ECG signals has coincided with the development of computing power and multivariate signal processing techniques capable of manipulating and analyzing such large data sets (Akay, 1997).

The use of Independent Component Analysis (ICA), an unsupervised learning technique which generalizes the Principal Component Analysis (PCA), commonly implemented through Neural Network (NN) schemes, is proposed in this study to process experimental biomedical data. Applied to sEMG (ElectroMyoGraphy surface) data, ICA results in numerous spatially- independent patterns, each associated with a unique time-course, providing a way to separate different electrical signals coming from different muscle activities (Junk et al., 2000). In contrast to the variable nature of the EMG surface recorded from a single muscle in isolation, the ICA of the sEMG from several muscles simultaneously allows the detection of highly reproducible components for example in the sEMG of the face and the throat during swallowing, and in the sEMG of arm muscles during the movements reaching (McKeown, Torpey, & Gehm, 2002).

The researchers in the present work show important applications in the study of some neurological diseases, and in the monitoring of athletic activities to improve significantly the potential of the athletes as well as the capabilities of normal subjects in daily actions, since it makes it possible, in principle, to enhance motor coordination. Also, musculo-skeletal disorders are the first cause of patient-physician encounters in the industrialized countries (McKeown, 2001). This paper is organized as follows. In Section 2 the type of data coming from electrical activity of muscles will be discussed. In Section 3 we shall propose the McKeown's idea of motion through integration of sub-movements (McKeown, 2000). The computational model incorporating sub- movements will be presented in Section 4. Section 5 is devoted to the proposal of NN schemes to implement ICA. Section 6 will report the results achieved by processing the experimental data. The assumption of stationarity of the electrical signals will be relaxed in Section 7, where the wavelet approach will be proposed. Finally, some conclusions are drawn.

2. THE ELECTRO-MYOGRAPHIC (EMG) SIGNALS

When skeletal muscle fibers contract, they conduct electrical activity (action potentials, APs) that can be measured by electrodes affixed to the surface of the skin above the muscles (Akay, 1997). As the APs pass by the electrodes, spikes of electrical activity are observed and pulses of muscle fiber contractions are produced. Small functional groups of muscle fibers, termed motor units (MUs), contract synchronously, resulting in a motor unit action potential (MUAP). To sustain force, a MU is repeatedly activated by the central nervous system several times per second. The repetition's, or average, firing rate is often between 5 and 30 times per second (or faster). The amplitude of the signal varies in the range 20 - 2000 uV. The electromyographic (EMG) signal is widely used as a suitable means to have access to physiological processes involved in producing joint movements. The EMG surface (sEMG) measures the electrical potential resulting from the superposition of single muscle fibers action potentials. The use of sEMG simplifies the acquisition of the signals not only due to the non-invasiveness of

Related Content

Mixed-Mode Surveys with Netservey

S. Papagiannidis (2007). *Handbook of Research on Electronic Surveys and Measurements (pp. 224-231).*

www.irma-international.org/chapter/mixed-mode-surveys-netservey/20234

Learning by Doing: Four Years of Online Assessments in Engineering Education Research

John C. Wise, Sang Ha Leeand Sarah E. Rzasa Zappe (2006). *Online Assessment, Measurement and Evaluation: Emerging Practices (pp. 306-315).*

www.irma-international.org/chapter/learning-doing-four-years-online/27713

Automatic Home Floor Cleaner Robot

Felix Gerald Masomera, Confidence Z. Gweeraand John Batani (2020). *International Journal of Electronics, Communications, and Measurement Engineering (pp. 1-16).*

www.irma-international.org/article/automatic-home-floor-cleaner-robot/258313

A New Approach to Evaluate Defects in Metallic Plates Based on Computing with Words and Fuzzy Entropy

Matteo Cacciola, Salvatore Calcagno, Filippo Laganà, Francesco Carlo Morabito, Diego Pellicanò, Isabella Palamaraand Mario Versaci (2012). *International Journal of Measurement Technologies and Instrumentation Engineering (pp. 20-28).*

www.irma-international.org/article/new-approach-evaluate-defects-metallic/74697

Development of Near-Diffraction Limited, Low-Cost and High-Resolution CCD Camera System for Imaging Coulter Orifices: Performance Analysis Using Zemax

Sami D. Alaruri (2014). *International Journal of Measurement Technologies and Instrumentation Engineering (pp. 54-61).*

www.irma-international.org/article/development-of-near-diffraction-limited-low-cost-and-high-resolution-ccd-camera-system-for-imaging-coulter-orifices/126909