# UNDERSTANDING EPILEPSY SEIZURE STRUCTURE USING TENSOR ANALYSIS

By

Evrim Acar Ataman

An Abstract of a Thesis Submitted to the Graduate

Faculty of Rensselaer Polytechnic Institute

in Partial Fulfillment of the

Requirements for the Degree of

DOCTOR OF PHILOSOPHY

Major Subject: Computer Science

The original of the complete thesis is on file
in the Rensselaer Polytechnic Institute Library

Examining Committee:

Bülent Yener, Thesis Adviser
Rasmus Bro, Member
Kristin Bennett, Member
Petros Drineas, Member
Mukkai Krishnamoorthy, Member
Mohammed Zaki, Member

Rensselaer Polytechnic Institute
Troy, New York

April 2008
(For Graduation May 2008)

# ABSTRACT

Data in many disciplines are arranged as two-way datasets; in other words, matrices. However, matrices may not be enough to fully represent the information content of the data and two-way analysis techniques may fail in terms of capturing and interpreting the underlying structure in a dataset. Tensors, on the other hand, represent datasets by preserving their multi-modal structures and tensor decomposition methods, which are mostly based on generalizations of two-way factor models to higher-order datasets, can extract the true underlying structures of the data. In this thesis, we introduce mathematical models based on multi-modal data construction and analysis with a goal of understanding epilepsy seizure dynamics and developing automated and objective approaches for the analysis of large amounts of scalp electroencephalogram (EEG) data.

In the first part of this study, we address the problem of identification of a seizure origin through an analysis of ictal EEG, which is proven to be an effective standard in epileptic focus localization. We rearrange multi-channel ictal EEG data as a third-order *Epilepsy Tensor* with modes: time samples, scales and channels, through continuous wavelet transform. Then we demonstrate that multiway analysis techniques, in particular Parallel Factor Analysis, can successfully model the complex structure of an epilepsy seizure, localize an epileptic seizure origin and extract artifacts. Furthermore, we introduce an approach for removing artifacts using multilinear subspace analysis.

In the second part, we focus on seizure recognition and aim to automatically differentiate between seizure and non-seizure periods. We represent multi-channel EEG data using a set of features. These features expected to have distinct trends during seizure and non-seizure periods include features from both time and frequency domains. First, we rearrange multi-channel EEG signals as a third-order tensor called an *Epilepsy Feature Tensor* with modes: time epochs, features and channels. Second, we model the epilepsy feature tensor using a multilinear regression model, i.e., Multilinear Partial Least Squares, which is the generalization of Partial Least

Squares regression to higher-order datasets. This two-step approach facilitates EEG data analysis from multiple channels represented by several features from different domains. We develop patient-specific as well as patient non-specific seizure detection models and obtain promising performance in both approaches.

In summary, this thesis demonstrates how multi-channel epileptic EEG signals can be rearranged as multi-modal datasets and how tensor decompositions can be used to mark the seizure period or localize the seizure origin. Nevertheless, in order for these methodologies to be clinically applicable, the performance of the proposed techniques should be tested and enhanced on large datasets containing heterogeneous epileptic patterns and patients.