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A Novel Tensor Similarity Score for the Classification of Cardiac Index from ECG Signals

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Introduction

Main goal:

Building a real-time clinical decision support system that predicts potential complications and recovery trends for post-cardiac patients

Benefits:

Early post-surgical intervention, efficient resource allocation, detect/avoid secondary complications, avoid re-admittance

Monitoring Post-Surgical Cardiac Patients

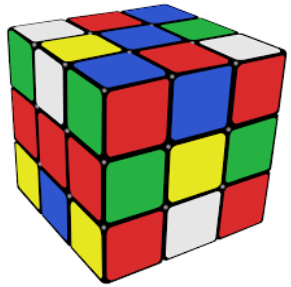
BIOMEDICAL & CLINICAL INFORMATICS LABORATORY

Motivation

- Current monitors inadequate for early detection of hemodynamic instability
- Need better comprehensive analysis of interactions/correlations of multimodal time-series data
- Personalized to patient
- Humans inherently poor judge of multiple data streams

Tensors to Represent Biomedical Data

- Rapid growth in quantity and variety of biomedical data exceeds the capacity of matrix based data representations



- One of the highest challenges in biomedical data processing is the analysis of multidimensional and multi-modal data

- Tensors provide often a natural and compact representation for such massive multidimensional data

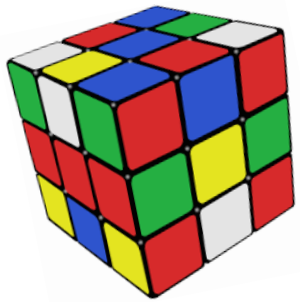


Figure: Rubik's cubes. In Wikipedia. Chris Buckleys. (6 March, 2008). Retrieved August 18, 2018 from https://en.wikipedia.org/wiki/File:Rubik%27s_cube_scrambled.svg

What is a tensor?

A tensor is a multi-dimensional array

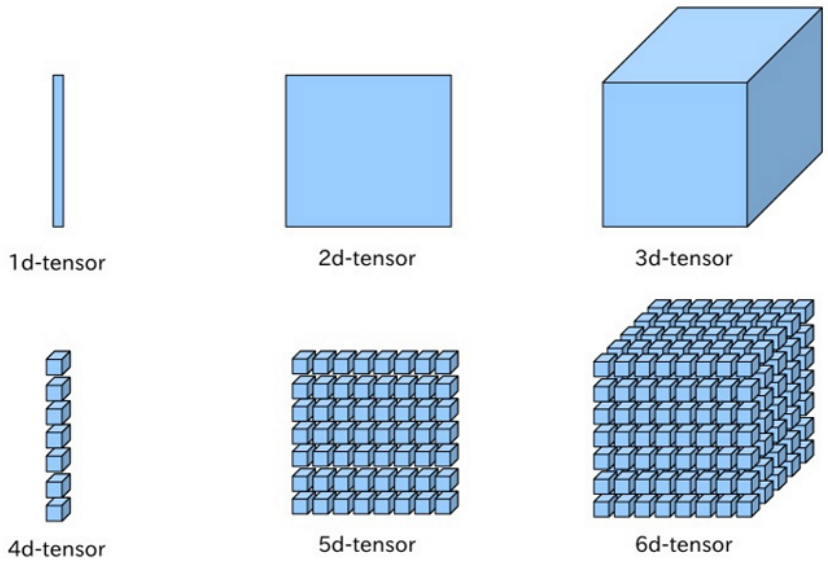
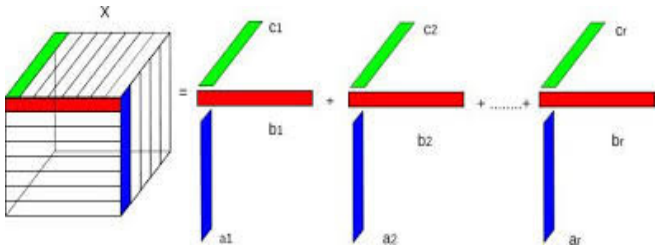


Figure: Examples of n-dimensional tensors, image by https://leonardoaraujosantos.gitbooks.io/artificial-inteligence/content/linear_algebra.html

Decomposition of tensors

A tensor can be written as a sum of outer product of vectors.



Why tensor decomposition ?

- For feature extraction
- For dimension reduction
- To exploit the structure of the data
- To reduce the computational complexity

Comparing Tensors: Similarity Score

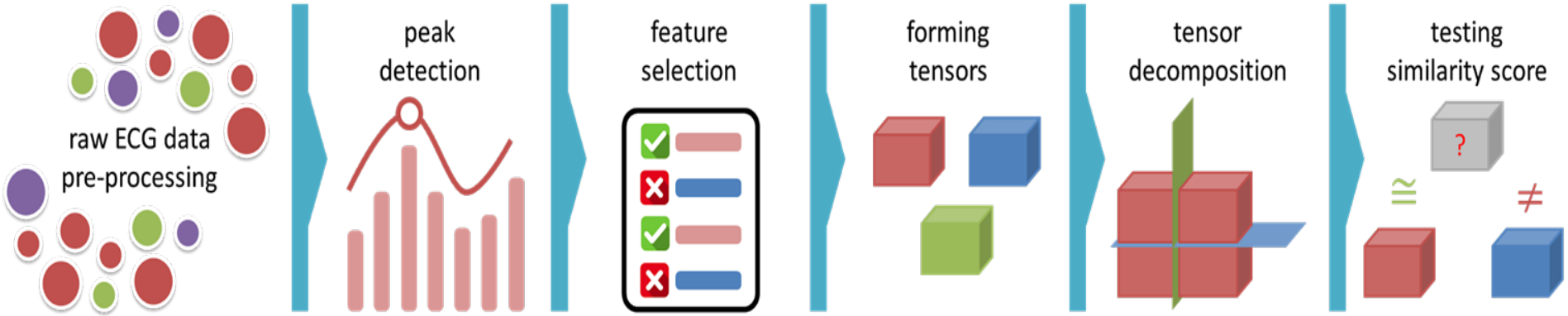
Similarity score for comparing tensors have been useful for various medical applications:

- Matching of diffusion tensors (DT) MRIs of the human brain
- For the analysis of large amounts of EEG data
- To identify the location of the epileptic seizure origin

Limitations :

The utility of established tensor similarity measures is limited to tensors having the same dimension.

Pipeline


raw ECG data
pre-processing
peak
detection
feature
selection
forming
tensors
tensor
decomposition
testing
similarity score
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Tensor Similarity Score

Let $T \in R^{p \times q \times r}$ be a third-order tensor with the following decomposition

$$T = \sum_{i=1}^{R} a_i \circ b_i \circ c_i$$

Let $D \in R^{p \times (q+a) \times r}$, $a \geq 0$ be another tensor. In order to check the similarity in two modes, we solve the following convex problem

$$\min_{\tilde{B}} \|D - \sum_{i=1}^{R} a_i \circ \tilde{b_i} \circ c_i\| \text{ where } \tilde{B} = [\tilde{b_1}, \tilde{b_2}, \ldots, \tilde{b_r}]$$

Let $F_2 = \sum_{i=1}^{R} a_i \circ \tilde{b_i} \circ c_i$, then the similarity score of T and D can be given as

$$1 - \frac{\|F2 - D\|}{\|D\|}$$

Experimental Results

Data

- MIT- BIH Arrhythmia Database
- Extract windows of 90 consecutive “Normal heartbeats” and “Abnormal heartbeats”, 12 windows for each heartbeat type

Applied Tensor Similarity Score with 3-Fold Cross Validation

Results

- Sensitivity: 0.67
- Specificity:1.00
- Accuracy: 0.83

The results indicate that the tensor similarity score shows promise for an effective binary classification, with an average accuracy of 83%.

Limitations and Future Work

Limitations

This study include a small sample size and limited feature sets for patient data. Potential modifications to this approach could incorporate features derived from other real-time physiological signals, such as arterial or peripheral oxygen saturation.

Goal

- Utilizing the similarity score to develop a tensor-based classification method
- Using this classification method with patient monitoring systems to detect changes in the waveform that are indicative of adverse events