Capturing Waveforms in Polysomnography

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Abstract

Winter cityside, crystal bits of snowflakes all around my head in the wind, I had no illusions that I've ever find the glimpse of summer heatwaves in your eyes. You did what you did it to me now its history i can see here's my comeback on the road again, things will happen when they can, I will wait here for my man tonight, its easy when you are Big In Japan. Neon on my naked skin, passing silhouettes of strange illuminated mannequins, shall i stay here at the zoo, or shall i go to change my point of view for other ugly scene.

Keywords: SIFT, EEG, waveform

1. Introduction

Bidimensional images can be interpreted as bidimensional signals. Instead of having amplitude values for a time series, they can be interpreted as having amplitude values for two varying independent variables (height and width).

This method proposed a different approach, where EEG signals are studied based on the shape of their waveforms, graphoelements that conceive cognitive meaning, or that represent medical conditions. Having such a method, allows a mapping quantitive mapping of EEG signals and components which at the same time conceive meaning to the practicioners clinician, technician or physician that is studying these signals. Like a common language.

This work expands the method presented here, here and here. It establishes

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their modeling and extend their usage to the study of polysomnographic signals, which are particularly suitable to be analyzed in this way.

This work unfolds as follows. The first section provides the general layout of the model. Section II presents a brief section and an accompanying software that can be used to obtain descriptors from images and that can be integrated into other projects to perform this analysis. For the experiment section we analyzed a database of Sleep Research, and in the Results section we proved how this method can be used to identify slow waves. Conclusions and future research directions are outlined in the last section.

2. Converting images

Once the regularization procedure, the size and the scale of the image are defined, a binary image $\mathcal{I}^{(c)}$ can be constructed from a variant of the method specified in Equation **??** according to

$$\mathcal{I}^{(c)}(z_1, z_2) = \begin{cases} 255 & \text{if } z_1 = \gamma_t \; n \quad \text{and} \quad z_2 = \lfloor \gamma \; \tilde{x}(n,c) \rceil + z(c) \\ 0 & \text{otherwise} \end{cases} \tag{1}$$

where $1 \leq c \leq C$ and $1 \leq n \leq N$. The amplitude scale factor γ and time scale factor γ_t are used to determine the image size and at the same time the image resolution. This scheme produces a black-and-white plot of the signal with 255 being white and 0 black. There is one image per channel per segment.

A Digitalization Procedure.

Resolution and Precision.

3. The SIFT: Histogram of Gradient Orientations

The basic procedure is composed of,

1. Keypoints kp are located on an image of a signal plot.

2. A region of an image, a patch, is established using keypoints as centers. Each patch has a horizontal St and vertical scale Sv, which determines the size in pixels Sx and Sy, along the horizontal and vertical axis respectively.
3. From each patch, a descriptor d is derived which is used as a representation of the graphical information contained within the patch.

On the image generated by the procedure detailed in previous Chapter, a keypoint kp is placed on a pixel (x_{kp}, y_{kp}) over the image plot and a window around the keypoint is considered. A local image patch of size $Sx \times Sy$ pixels is constructed by dividing the window in 16 blocks. It is arranged in a 4×4 grid and the pixel kp is the patch center. Figure **??**(a) shows a plot of a signal, a keypoint in red at the center and the surrounding patch.

Pixel intensity gradients can be obtained from an image by applying the Sobel filter [**?**] and using finite differences to obtain pixel differences on the x and y direction. Composing them as vectors, oriented gradients on each pixel can be calculated. Figure **??**(b) and (c) show vector field of oriented gradients.

A local representation of the signal shape within the patch can be described by obtaining the gradient orientations on each of the 16 blocks and creating a histogram of gradients. In order to calculate the histogram, the interval $[0-360]$ of possible angles is divided in 8 bins, each one at 45 degrees. Figure **??**(d) shows a sample histogram obtained for eight orientations.

Hence, for each spatial bin $i, j = \{0, 1, 2, 3\}$, corresponding to the indexes of each block $B_{i,j}$, the orientations are accumulated in a 3-dimensional histogram h through the following equation:

$$h(\theta, i, j) = \sum_{\mathbf{p}} \omega_{\text{ang}}(\angle J(\mathbf{p}) - \theta)\, \omega_{ij}\, (\mathbf{p} - \mathbf{kp})\, \|J(\mathbf{p})\| \qquad (2)$$

where $\mathbf{p}$ is a pixel from within the patch, θ is the angle bin with $\theta \in \{0, 45, 90, 135, 180, 225, 270, 315\}$, $\|J(\mathbf{p})\|$ is the norm of the gradient vector in the pixel $\mathbf{p}$, computed using finite differences, and $\angle J(\mathbf{p})$ is the angle of the gradient vector. The scalar $\omega_{\text{ang}}(\cdot)$ and vector $\omega_{ij}(\cdot)$ functions are linear interpolations used by [**?**] and [**?**] to provide a weighting contribution to eight adjacent bins. They are calculated as

$$\omega_{ij}(\mathbf{v}) = \omega\left(\frac{5\ v_x}{\Delta s\ St} - x_i\right)\omega\left(\frac{5\ v_y}{\Delta s\ Sv} - y_i\right) \tag{3}$$

$$\omega_{\text{ang}}(\alpha) = \sum_{r=-1}^{1} \omega\left(\frac{8\alpha}{2\pi} + 8r\right) \tag{4}$$

where x_i and y_i are the spatial bin centers located in $x_i, y_i \in \{-\frac{3}{2}, -\frac{1}{2}, \frac{1}{2}, \frac{3}{2}\}$. The function parameter $\mathbf{v} = (v_x, v_y)$ is a vector variable and α a scalar variable. The value of Δs is the unit length of the patch, which is described in the section **??**. On the other hand, r is an integer that can vary freely in the set $\{-1, 0, 1\}$ and allows the argument α to be unconstrained in terms of its values in radians. The interpolating function $\omega(\cdot)$ is defined as:

$$\omega(z) = \max(0, 1 - |z|). \tag{5}$$

These binning functions conform a trilinear interpolation that has a combined effect of sharing the contribution of each oriented gradient between their eight adjacent bins in a tridimensional cube in the histogram space, and zero everywhere else. This procedure is important to avoid quantization issues that may appear with the histogram (i.e. elimination of intermediate values).

Lastly, on Equation 3 the values of $\frac{5}{\Delta s\ St}$ and $\frac{5}{\Delta s\ Sv}$ allow a unit conversion from pixel to units-of-patch. As the patch has 16 blocks and 8 bin angles are considered, a feature d called *descriptor* of 128 dimension is obtained. This technique is a modification of Lowe's SIFT Descriptor method.

In Figure **??** the possible orientations on each patch are illustrated. The first eight orientations of the first block $B_{1,1}$, are labeled from 1 to 8 clockwise. The orientations of the second block $B_{1,2}$ are labeled from 9 to 16. This labeling continues left-to-right, up-down until the eight orientations for all the sixteen blocks are assigned. They form the corresponding **kp**-descriptor of 128 coordinates.

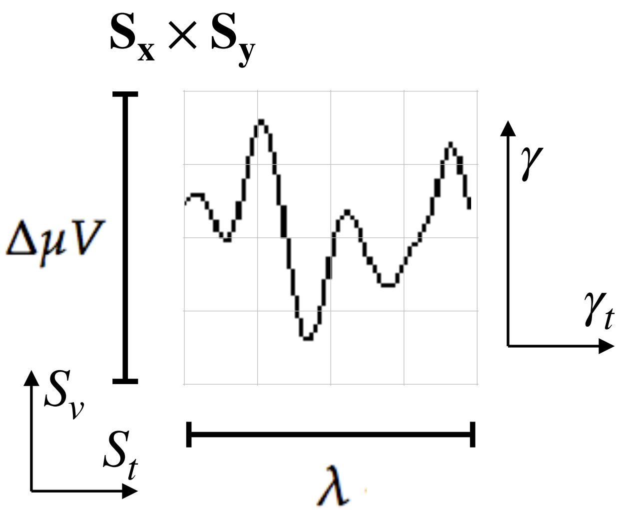

Figure 1:

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Here are two sample references: [**?** **?**].

4. Mapping between Signal Features and Patch Descriptor

5. Slow Wave and KComplex identification

Sleep Research is devoted to understand the inner workings of the brain during sleep and its strong connection with memory. The traditional approach to glimpse what is happening inside the brain while sleeping has been the Electroencephalography, which received a particular term when it is used for this purpose: Polysomnography (PSG). Sleep research studies rely heavily on EEG graphoelements (CITE) like K-Complexes, Slow Waves, and they are key components used to determine sleep stage. BLA BLA BLA

This makes PSG signal analysis particular relevant for this methodology, because it can be used to derive a metric that can describe quantitative the similarities between signal shape components. Sleep research requires long hours of data analysis hence, it will benefit from automation tools that at the same speak the same language than those who traditionally analyze these signals.

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Dataset. The dataset used is THIS. It contains EEG data for 10 subjects. More information can be obtained from HERE.

References