Mareike Haug
Physiological Data Analysis for educational technologies

OBJECTIVE MEASURES, SENSORS AND COMPUTATIONAL TECHNIQUES FOR STRESS RECOGNITION AND CLASSIFICATION

Sharma & Gedeon (2012)
AGENDA

- Definition of Stress and Computed Stress
- Stress Measuring Methods
  - physiological methods
  - physical methods
- Feature Extraction
- Computational Techniques to build a model
STRESS

Response of the body to any demand for change

→ psychological, cognitive and behavioural components

→ Risk to health and social aspects of life

Computed Stress: Computationally derived from instantaneous measures of stress symptoms obtained by non-invasive methods
STRESS CHARACTERISTICS

- Stress Hormons
- Blood Pressure
- Heart Rate
- Pupil Diameter
- Breathing
- Galv. Skin Resp.
- Emotion
- Voice Intonation
- Body Pose
PRIMARY MEASURING METHODS

PHYSIOLOGICAL MEASURES

- Brain Activity
- Eye Gaze
- Pupil Diameter
- Blink Rates
- Electromyogram
- Blood Volume Pulse
- Skin Conductivity
- Voice
- Heart Activity
- Hand and Finger Movements
- Gesture
- Behaviour
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Physiological Measures

Autonomic Nervous System (ANS)

Sympathetic Nervous System (SNS)
- Dominates in stressful activities
- Eustress
- Distress

Parasympathetic Nervous System (PNS)
- Dominates in restful activities

Galvanic Skin Response
Heart Rate Variability
Brain Waves
HEART ACTIVITY

- Superior measurement for HRV: Electrocardiogram (ECG)

- Heart Rate Variability (HRV) detects cardiovascular conditions and ANS activities

- Frequency of HR reflects SNS and PNS activities

- Acute Stress: increased Frequency

https://www.elitehrv.com/what-is-heart-rate-variability

Physiological Measures
SKIN CONDUCTIVITY

- Flow of electricity through skin
- Stress → Increase in humidity on skin surface → Skin conductance is increased
- Measuring two electrical potentials between electrodes typically placed on hand, first and middle fingers
BRAIN ACTIVITY

- Neural activity produces electrical signals captured in waveforms by **Electroencephalography (EEG)**
- EEG signals are categorized by frequency
- Rapid beta wave frequencies indicate stress
- May contain more information than HRV because shows differences in relaxion
BLOOD PRESSURE & BLOOD VOLUME PULSE

Blood Pressure (BP)
- Pressure exerted on walls of blood vessels
- Varies between systolic (max) and diastolic (min)
- Stress: Increase in BP

Blood Volume Pulse (BVP)
- Amount of blood in a blood tissue during certain time interval
- Measured by amount of light reflected by skin surface
- Stress: Decrease in BVP
Electromyogram (EMG)
- shows electrical activity produced by active muscles
- electrodes placed on trapezius muscle

Skin Temperature (ST)
- Stress: ST decreases

Respiration
- Rate and volume
- Measured by belt around chest → intrusive
- Stress: Respiration Rate increases
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• Recognition requires techniques that consider degrees of freedom for **body configurations** and vast **variations in motion**

• Common method: human experts
Facial Expressions

- Human observers or systems that automatically determine facial features
- Stress: Increase in head and mouth movements

Eye Gaze

- Stress: Eyes focus on particular object on computer screen for greater period of time
PUPIL DILATION & BLINK RATES

Pupil Dilation

- Stress: Pupil diameter increases, pupil dilates at higher frequency → increasing mean values over time period
- Can be caused by negative and positive stimuli

Blink Rates

- Conflicting characteristics in different environments
- In real driving experiments stress correlated with higher frequency of blinks
- In task solving experiments on a computer stress correlated with lower frequency of blinks
- Higher Stress indicates faster eye closure
VOICE

- Nonverbal components reflect stress
- Stress: increases in range, rapid fluctuations in fundamental frequency, greater proportions of high frequency components
- Intelligent speech recognition and speaker identification systems
- Acoustic components: micro-muscle tremors caused by muscle tension → relation between physiological and physical characteristics of stress
# EVALUATION OF PRIMARY MEASURES

<table>
<thead>
<tr>
<th>Rank</th>
<th>Primary Measure</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Heart Rate Variability (HRV)</td>
</tr>
<tr>
<td>2</td>
<td>Galvanic Skin Response (GSR)</td>
</tr>
<tr>
<td>3</td>
<td>Brain Activity (EEG)</td>
</tr>
<tr>
<td>4</td>
<td>Pupil Dilation (PD)</td>
</tr>
<tr>
<td>5</td>
<td>Voice</td>
</tr>
<tr>
<td>6</td>
<td>Eye Gaze</td>
</tr>
<tr>
<td>7</td>
<td>Facial Expression</td>
</tr>
<tr>
<td>8</td>
<td>Blood Pressure (BP)</td>
</tr>
<tr>
<td>9</td>
<td>Skin Temperature (ST)</td>
</tr>
<tr>
<td>10</td>
<td>Blood Volume Pulse (BVP)</td>
</tr>
<tr>
<td>11</td>
<td>Eye Blinks</td>
</tr>
<tr>
<td>12</td>
<td>Respiration</td>
</tr>
<tr>
<td>13</td>
<td>Electromyogram (EMG)</td>
</tr>
</tbody>
</table>
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FEATURE EXTRACTION TECHNIQUES

Fourier Transformation:

- Transform physiological signals from time to **frequency domain** to extract features

Wavelet Transformation:

- Transform physiological signals from time to frequency domain to extract features
- Allows data to be divided up into different frequency components
ENERGY RATIO

Energy Ratio = \frac{\text{Low Frequency}}{\text{High Frequency}}

High Energy Ratio: Predominance of sympathetic modulation \rightarrow \text{Stress}
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COMPUTATIONAL TECHNIQUES

- Software programs, tools, packages
- Exploring signal data
  - selection of appropriate computational techniques to model stress
  - detection of noisy, corrupted, missing data
- Computational model of stress: combination of stress symptom measures to produce a computed stress measure as instantaneous measure of stress at that point of time
DECISION TREES

- Classify stress based on characteristics in physiological measures and combinations
- Each node represents some criteria or test
- Each terminal leaf represents a target class
- Algorithms to generate decision trees
ARTIFICIAL NEURAL NETWORKS (ANN)

- Inspired by biological neural network → learning and reacting

- A neuron in an artificial neural network is
  - A set of input values ($x_i$) and associated weights ($w_i$).
  - A function ($g$) that sums the weights and maps the results to an output ($y$).

Recurrent ANN

- ANN that contains feedback connections

- Retaining information of how previous sample was processed
SUPPORT VECTOR MACHINES

- Classifying linear and non-linear primary measures
- Transforms training data to a higher dimension in which a linear separating hyper-plane is determined
- New examples are mapped into same space and predicted to belong to a category based on which side of the gap they fall on
MARKOV CHAINS AND HIDDEN MARKOV MODELS

Markov Chain

- Time-domain process
- probability distribution of the next state depends only on the current state, not on the sequence of events that preceded it

Hidden Markov Model

- States are hidden, only output dependent on state
- Each state has a probability distribution over the possible output tokens
- sequence of tokens generated by an HMM gives some information about the sequence of states

Figure 2

http://4.bp.blogspot.com/-ug9XsiQrACb8/VK7zCym3zOJ/AAAAAAAAAoj/DAxkKTcCKvc/s1600/markovdiag.png
# EVALUATION OF TECHNIQUES FOR MODELING STRESS

<table>
<thead>
<tr>
<th>Rank</th>
<th>Primary Measure</th>
<th>Accuracy</th>
<th>Inputs</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Support Vector Machines (SVM)</td>
<td>90.1%</td>
<td>GSR, HR, PD, ST, EMG, ECG, Respiration</td>
</tr>
<tr>
<td></td>
<td></td>
<td>79.3%</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Recurrent ANN (RANN)</td>
<td>MSE = 0.084</td>
<td>Voice</td>
</tr>
<tr>
<td>3</td>
<td>Adaptive neuro-fuzzy system (ANFS)</td>
<td>76.7%</td>
<td>EMG, ECG, Respiration, GSR</td>
</tr>
<tr>
<td>4</td>
<td>Adaptive neuronal network (ANN)</td>
<td>82.7%</td>
<td>EEG</td>
</tr>
<tr>
<td>5</td>
<td>Hidden Markov Models (HMM)</td>
<td>-</td>
<td>Voice</td>
</tr>
<tr>
<td>6</td>
<td>Decision Tree</td>
<td>88.02%</td>
<td>GSR, HR, PD, ST</td>
</tr>
<tr>
<td>7</td>
<td>Naive Bayesian network</td>
<td>78.65%</td>
<td>GSR, HR, PD, ST</td>
</tr>
</tbody>
</table>
SUMMARY

- Stress is a serious and growing issue on individuals and society
- Stress recognition and classification/prediction can lead to solving the problem
- Stress cannot be directly measured but determined by characteristics in primary measures
- Computational model of stress: combination of stress symptom measures to produce a computed stress measure as instantaneous measure of stress at that point of time
DEMO HR FEATURE: SDHR
STANDARD DEVIATION (SD)

- Amount of variation or dispersion of a set of data values
- Low SD: data points tend to be close to the mean of the set
- High SD: data points are spread out over a wider range of values
- Calculation:

\[
SD = \sqrt{\frac{1}{N} \sum_{i=1}^{N} (x_i - \mu)^2}
\]
MEANHR & SDHR [31.10.2016]
MEANHR & SDHR [05.11.2016]
MEANHR & SDHR [23.10.2016]
SDHR & STRESS
MEAN OF RR-INTERVALS (MEANRR)

- RR-Interval = Time between 2 Heartbeats
- Get meanRR from HR:

\[
meanRR[s] = \frac{60s}{\frac{x_i}{N}}
\]

- SDRR = Heart Rate Variability
MEANHR & MEANRR

98 BPM
Mean RR-Intervall: 0.4 s

50 BPM
Mean RR-Intervall: 1.2 s
STRESS AND SDHR [31.10.2016]
STRESS AND SDHR [31.10.2016]
STRESS AND SDHR [03.11.2016]


• What is Heart Rate Variability. EliteHRV. URL: [https://www.elitehrv.com/what-is-heart-rate-variability](https://www.elitehrv.com/what-is-heart-rate-variability)

• Miličević, G. (2005). Low to high frequency ratio of heart rate variability spectra fails to describe sympa-tho-vagal balance in cardiac patients. *Collegium antropologicum, 29*(1), 295-300.