EEG, ECG, EMG

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What is Signal?

- A signal is defined as a fluctuating quantity or impulse whose variations represent information. The amplitude or frequency of voltage, current, electric field strength, light, and sound can be varied as signals representing information.

- A signal can be simply defined as a function that conveys information.

- Signals are represented mathematically as functions of one or more independent variables.

- Examples: voltage, current, electric field strength, light, sound, etc.
Biomedical signals

• Biomedical signals means the bio-signals which are generated in biological systems only.

• Biomedical signals are observations of physiological activities of organisms, ranging from gene and protein sequences, to neural and cardiac rhythms, to tissue and organ images.

• Examples of biomedical signals:
  ECG (Electrocardiogram) signal,
  EEG (Electroencephalogram) signal, etc.
How biomedical signals are generated?

• Biomedical signals are electrical or magnetic signals generated by some biological activity in the human body.

• Human body is composed of living tissues that can be considered as a power station.

• Action of living tissues in terms of bioelectric potentials generate multiple electric signals from two internal sources- muscles and nerves system.
What are biopotentials

- An electric potential that is measured between points in living cells, tissues, and organisms, and which accompanies all biochemical processes.
- Also describes the transfer of information between and within cells
Classification of Biomedical Signals

- Bioelectric Signal
- Bioacoustics Signal
- Biomechanical Signal
- Biochemical Signal
- Bio-magnetic Signal
- Bio- optical signal
Bioelectric signal

• The electrical signals which we can measure mainly on the surface of the body is known as bioelectric signal.

• It is generated by muscle cells and nerve cells.

• Basic source is the cell membrane potential.

• Examples: ECG, EEG, EMG, EOG
Electrocardiography (ECG)

- Measures galvanically the electric activity of the heart
- Well known and traditional, first measurements by Augustus Waller using capillary electrometer (year 1887)
- Very widely used method in clinical environment
- Very high diagnostic value

1. Atrial depolarization
2. Ventricular depolarization
3. Ventricular repolarization
Electrocardiography

- The heart is an electrical organ, and its activity can be measured non-invasively
- Wealth of information related to:
  - The electrical patterns proper
  - The geometry of the heart tissue
  - The metabolic state of the heart
- Standard tool used in a wide-range of medical evaluations
ECG principle
Cardiac Electrical Activity

- SA node (Pacemaker)
- AV node (delay)
- AV bundle & branches (Insulated)
- Purkinje fibers (activation)
- Fibro-fatty atrioventricular groove (separates atrial and ventricular tissue)

- Black: Contractile
- Green: Conductive
- Pink: Nonconductive
ECG basics

- Amplitude: 1-5 mV
- Bandwidth: 0.05-100 Hz

- Largest measurement error sources:
  - Motion artifacts
  - 50/60 Hz powerline interference

- Typical applications:
  - Diagnosis of ischemia
  - Arrhythmia
  - Conduction defects
12-Lead ECG measurement

- Most widely used ECG measurement setup in clinical environment
- Signal is measured non-invasively with 9 electrodes
- Lots of measurement data and international reference databases
- Well-known measurement and diagnosis practices
- This particular method was adopted due to historical reasons, now it is already rather obsolete

Goldberger augmented leads: \( V_R, V_L & V_F \)

Precordial leads: \( V_1-V_6 \)

Einthoven leads: I, II & III
EINTHOVENS TRIANGLE
Why is 12-lead system obsolete?

• Over 90% of the heart’s electric activity can be explained with a dipole source model
  → Only 3 orthogonal components need to be measured, which makes 9 of the leads redundant
• The remaining percentage, i.e. nondipolar components, may have some clinical value

• 12-lead system does, to some extend, enhance pattern recognition and gives the clinician a few more projections to choose from
  …but....
• If there was no legacy problem with current systems, 12-lead system would’ve been discarded ages ago
Origination of the QRS - Signal
ECG - applications

- Diagnostics
- Functional analysis
- Implants (pace maker)
- Biofeedback (Heart rate variability, HRV)
- Peak Performance Training, Monitoring
Normal sinus rhythm

Sinus Tachycardia—Rate 122

Sinus Bradycardia—Rate 48

V₁
RATE

• P wave rate 60 - 100 bpm with <10% variation - Normal

• Rate < 60 bpm = Sinus Bradycardia
  - Results from:
    - Excessive vagal stimulation
    - SA nodal ischemia (Inferior MI)

• Rate > 100 bpm = Sinus Tachycardia
  - Results from:
    - Pain / anxiety
    - CHF
    - Volume depletion
    - Pericarditis
    - Chronototropic Drugs (Dopamine)
Electroencephalography (EEG)

• An electrophysiological monitoring method to record electrical activity of the brain.

• Typically noninvasive, with the electrodes placed along the scalp, although invasive electrodes are sometimes used in specific applications.

• EEG measures voltage fluctuations resulting from ionic current within the neurons of the brain.

• In clinical contexts, EEG refers to the recording of the brain's spontaneous electrical activity over a period of time, as recorded from multiple electrodes placed on the scalp.

• Diagnostic applications generally focus on the spectral content of EEG, that is, the type of neural oscillations (popularly called "brain waves") that can be observed in EEG signals.
The Electroencephalogram (EEG) is a recording of electrical activity originating from the brain.

- It is recorded on the surface of the scalp using electrodes, thus the signal is retrievable non-invasively.
- Signal varies in terms of amplitude and frequency
- Normal frequency range: 0.5Hz to 50 Hz.
EEG Electrode – cap

locations of the 10/20 system
Electroencephalogram (EEG)

- The 10-20 system of electrode placement for EEG recording.
Electroencephalogram (EEG)

• The commonly used terms for EEG frequency range:
  – Delta (0.5-4 Hz): deep sleep
  – Theta (4-8 Hz): beginning stages of sleep
  – Alpha (8-13 Hz): principal resting rhythm
  – Beta (>13 Hz): background activity in tense and anxious subjects
Electroencephalogram (EEG)

- (a) delta
- (b) theta
- (c) alpha
- (d) beta
- (e) blocking of alpha rhythm by eye opening
- (f) marker 50 μV, 1 sec
EEG - applications

- Diagnostics (Epilepsy, Oncology, ..)
- Cognitive Sciences
- Sleep Analysis
- Human Computer Interfaces (BCIs)
- Pharmacology
- Intensive Care, Monitoring
Electromyography (EMG)

- Electromyography (EMG) is a technique for evaluating and recording the activation signal of muscles.
- EMG is performed by an electromyograph, which records an electromyogram.
- Electromyograph detects the electrical potential generated by muscle cells when these cells contract and relax.
ELECTRODE TYPES

Intramuscular - Needle Electrodes

Extramuscular - Surface Electrodes
EMG PROCEDURE

• Clean the site of application of electrode;
• Insert needle/place surface electrodes at muscle belly;
• Record muscle activity at rest;
• Record muscle activity upon voluntary contraction of the muscle.
EMG Contd.

- Muscle Signals are Analog in nature.

- EMG signals are also collected over a specific period of time.
EMG Contd.

EMG processing:

- Signal pick up
- Amplification & Filtering
- Conversion of Analog signals to Digital signals
- Computer
Factors Influencing Signal Measured

• Geometrical & Anatomical Factors
  – Electrode size
  – Electrode shape
  – Electrode separation distance with respect to muscle tendon junctions
  – Thickness of skin and subcutaneous fat
  – Misalignment between electrodes and fiber alignment

• Physiological Factors
  – Blood flow and temperature
  – Type and level of contraction
  – Muscle fiber conduction velocity
  – Number of motor units (MU)
  – Degree of MU synchronization
## Factors That Influence the Signal Information Content of EMG

<table>
<thead>
<tr>
<th>Factor</th>
<th>Influence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neuroactivation</td>
<td>- firing rate of motor unit AP’s</td>
</tr>
<tr>
<td></td>
<td>- no. of motor units recruited</td>
</tr>
<tr>
<td></td>
<td>- synchronization of motor units</td>
</tr>
<tr>
<td>Muscle fiber physiology</td>
<td>- conduction velocity of fibers</td>
</tr>
<tr>
<td>Muscle anatomy</td>
<td>- orientation &amp; distribution of fibers</td>
</tr>
<tr>
<td></td>
<td>- diameter of muscle fibers</td>
</tr>
<tr>
<td></td>
<td>- total no. of motor units</td>
</tr>
<tr>
<td>Electrode size/orientation</td>
<td>- no. of fibers in pickup area</td>
</tr>
</tbody>
</table>
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<tbody>
<tr>
<td>Electrode-electrolyte interface with</td>
<td>- type of material and site</td>
</tr>
<tr>
<td></td>
<td>- electrode impedance decreases increasing frequency</td>
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<tr>
<td>Bipolar electrode configuration</td>
<td>- distance between electrodes</td>
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<td></td>
<td>- orientation of electrodes relative to the axis of muscle fibers</td>
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What can be learned from an EMG?

- Time course of muscle contraction
- Contraction force
- Coordination of several muscles in a movement sequence
  - These parameters are DERIVED from the amplitude, frequency, and change of these over time of the EMG signal

- **Field of Ergonomics**: from the EMG conclusions about muscle strain and the occurrence of muscular fatigue can be derived as well
APPLICATION OF EMG

• EMG can be used for diagnosis of Neurogenic or Myogenic Diseases.
• Rehabilitation
• Functional analysis
• Active Prothetics, Orthesis
• Biomechanics, Sports medicine
Assignment

• Write short notes on ECG ? [5]
• Write short notes on EEG ? [5]
• Write short notes on EMG ? [5]
Useful Links

- https://www.youtube.com/watch?v=RYZ4daFwMa8
- https://www.youtube.com/watch?v=JSxd0UTt5gQ