Video-EEG monitoring systems and automated analysis tools

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Hercules Consortium Meeting
2-3 September 2010
Heraklion, Crete
A) Video-EEG monitoring systems – setting the requirements for the unit to be installed

- Deliverable 1.4: Technological review and market search for video-EEG monitoring systems
  - Video analysis in epilepsy
  - EEG analysis in epilepsy
  - SOTA: 32 video-EEG devices from 27 manufacturers
    - Technical features
    - Data management
    - Usability
    - EEG analysis tools
    - Video capture
  - Consolidation with clinician Mrs. Vorgia
- Discussions with Greek dealers
Framework of demands

- Standard routine long-term monitoring
- Data acquisition (video, EEG) for research purposes within and beyond the project
- Fusion with other Hercules objectives (e.g. EHR)
- Versatility (e.g. ICU)
- Budget: 45000 €

=> Requirements
=> Rating criteria
Requirements (technical)

- Digital synchronized acquisition of video and EEG
- Long-term monitoring
- Event button
- Wired amplifier connection
- 64 EEG channels extendable to 128, with the possibility of also using less (e.g. 32)
- Polygraphy (EMG, ECG, EOG)
- Impedance check indicator
- Photic stimulator
Requirements (data management)

- Data saving on local drive, CD and DVD
- Data archiving on a central networked location with a minimum of 4TB storage, expandable
- Open format for audio, video and EEG (ASCII or EDF(+))
- Connectivity to HIS via HL7
Requirements (usability)

- Visible, audible alarm
- Printer
- Remote patient monitoring
- Report generator
- Mobility
Requirements (EEG analysis)

- Measurement tools (amplitude, frequency etc.)
- Filter change
- Montage change
- Event marker
Requirements (video capture)

- 2 video cameras
- Minimum resolution of 0.45 MPx
- Frame rate at 50 fps progressive scan
- Possibility of using only one camera
- Possibility of recording at a lower resolution and frame-rate
- Day- and night-recording
- Advanced video compression techniques
Requirements (safety)

- Intended for clinical use
- According to European safety standards
  (EN 60601-1 Medical Electrical Devices - General Requirements for Safety; EN 60601-1-1 - Collateral Standard – Systems; EN 60601-1-2 - Collateral Standard – Electromagnetic Compatibility; EN 60601-1-4 - Collateral Standard - Programmable Systems (if programmable); EN 60601-2-26 - Specific requirements for electroencephalographs)
- CE XXXX certified
Requirements (consumables)

- Everything needed for the application of all functionalities of the unit on neonates from 0 – 2 and children from 3 – 14 years of age (cap, electrodes, adhesive etc.).
Requirements (warranty)

- 2 years
- 5 years for spare parts supply
Rating criteria (technical)

- Usage in the ICU
- Wireless amplifier connection
- Small size and weight of amplifier or electrode connection pack
- Polysomnography
- Pulse oximetry
- ADC resolution: 16 bits
- Bandwidth: 1100 Hz
- Noise: <1.5 µV
- Input impedance: 100 MΩ
- CMRR: 100 dB
- Amplifier sample rate per channel: 2000 Hz
Rating criteria (data management)

- Patient database
- Report management system
- Patient calendar
- Data-sharing
Rating criteria (usability)

- Nurse station for central monitoring
- Customizable menu
- Two monitors
- Split screen view
- Stand-alone video-EEG viewer
- Multiple user profiles and access levels
Rating criteria (EEG analysis)

- Artifact rejection
- Brain mapping
- Coherence analysis
- Compressed spectral analysis
- Dipole localization
- Event detection / analysis (sharp waves etc.)
- Seizure detection / analysis
- Spectral analysis (fourier analysis)
- Spectral mapping
- Spike detection / analysis
- Statistics (averaging, burst suppression, tending)
Rating criteria (video capture)

- Resolution of 1920 x 1080 pixels
- IP, USB or Firewire supported cameras
- Digital video zoom
- Manual switchover between day- and night recording
- Camera technical properties:
  - Active sensor dimensions (W x H). The higher the area of the active sensor, the more light can reach each sensor cell.
  - Sensor ISO (12232). At high ISO values the sensor is more sensitive to lightning, which offers lower noise, especially during bad lightning conditions.
  - Lens characteristics: Maximum aperture (f/x.x) and focal length (zoom, fixed or variable).
  - Horizontal and vertical field of view.
To do…

- Setup
- Measurement protocol
  - Natural activities/motion
  - Large field of view
- Calibration procedures
- Patient priority
B) Automatic analysis tools: vision-based motion analysis

a) Deliverable 1.4: Technological review and market search for video-EEG monitoring systems: *Video analysis in epilepsy*

b) ITAB 2010 accepted paper: “*Vision-Based Human Motion Analysis in Epilepsy – Methods and Challenges*”

c) Overview to be submitted soon: “*Vision-based human motion analysis and seizure recognition in epilepsy: An overview*”
Clinical domain: motion in epileptic syndromes

Ranking:

1. **Extremities**: myoclonic jerks and posturing (tonic/dystonic and falling). The upper limbs are slightly more often affected.

2. **Eyes**: deviations, eyeball upwards roll, myoclonia, mydriasis, miosis.

3. **Head**: deviation, nodding, bobbing.

4. **Eyelid**: myoclonia/fluttering, closure.
   - **Facial expressions**: clonic convolutions, starring.

5. **Mouth and lips**: rhythmic protrusion of the lips, twitching of the corners of the mouth, jaw jerking.
   - **Fingers**: myoclonia, automatisms, abduction.
   - **General body motion**: flexion/extension in infants, stiffening, rotation, axial tonic posturing.

6. **Shoulders**: shrug-like movement, jerks.
   - **Eyebrows**: myoclonia.
   - **Trunk**: axial bending.
   - **Toes**: myoclonia.
   - **Hands**: automatisms.
Challenges

- Global approach missing
- More levels of detail: whole body, extremities, face
  - Higher resolutions
  - Higher frame-rates (myoclonic events, duration <100 ms)
  - Data storage bottlenecks and longer video processing duration
- Clinically useful information needed
  - Correct movement frequencies and duration
  - Synchronous vs. asynchronous characteristics
  - Nocturnal video recording is inevitable, as many ictal events occur only during night.
  - Lateralizing characteristics of motion (generalized vs. focal myoclonic seizures)
  - Symmetrical vs. asymmetrical motion.
  - Order of each clinical manifestation during a seizure is also very important.
  - Context (knowledge weather a seizure occurs during sleep, on awakening, during drowsiness etc.)
- Intra-, inter-class variations
- Temporal variations
- Environment and recording settings (dealing with occlusions)
Advantages of marker-free motion analysis

- According to evolution in the domain
- No artifacts due to laboratory constraints
- No relative skin-to-bone-movement
- Do not impede natural motion patterns
- Usage in clinical routine possible
  - Acceptable usage efforts in combination with video-EEG
  - Time and costs required for data collection, processing, interpretation
A more detailed overview based on 28 journal articles, conference papers and abstracts

- Main objectives:
  - Motion detection (for monitoring)
  - Analysis (motion quantification)
  - Recognition (interpretation of motion to a seizure type)

- Equal distribution between marker-based and marker-free approaches

- Majority: model-free (capturing of features in the absence of an a priori human model)
Algorithmic tools used so far

- **Optical flow**, using the velocity field for feature extraction by thresholding or clustering (e.g. the area change of a percentage of maximum vectors)
- **Spatiotemporal sub-band decomposition** of the image sequence, focusing on the sub-band containing motion and clustering into foreground and background
- **Frame differencing and pixel clustering** for background-foreground segmentation
Algorithmic tools used so far

- **Kanade-Lucas-Tomasi** algorithm for site selection and tracking, for extraction of motion trajectories
- **Pixel-block-matching** using various block motion models for extraction of motion trajectories
- Seizure recognition: **Artificial Neuronal Networks** to distinguish between specific seizure types and normal movement
Evolution

Motion in the scene with manual labeling
Motion of detected body parts
Behavior

Context

Clinically meaningful knowledge

Today

Extremities (L/R, U/L)
Head
Face
Eyes
Other

Analysis/quantification
Recognition
Possible solutions within the Hercules project: Model-based

An a priori human model with relevant anatomic and kinematic information is tracked or matched to 2D image planes or 3D representations.

- Once fitted, it provides all needed information at once (body part, laterality etc.)
- Most commonly used in the VBHMA community
- Long-lasting developing period
- A priori knowledge and assumptions might not correlate with complex motion patterns in epilepsy
Possible solutions within the Hercules project: Model-free example

- Body part detector (e.g., face detection)
  - Region/body part specific Optical Flow
    - Velocity field for each body part
  - Use vector orientation for clustering
    - Analysis/Classification

+ A “natural” development of existing methods in the domain of epilepsy (less risky)
+ Usage of already available tools
+ Less time consuming development
- Limited information extraction
- Possibly not extendable to cover more demanding tasks (behavioral analysis)
To do…

- Next month: considering the time-pressure, investigate the versatility and applicability of other model-free methods from other disciplines (surveillance etc.)
- Until January 2010: prepare and test the system using freely available video datasets not related to epilepsy until own videos become available
- Until project end: obtain initial results using own video datasets
- Beyond project end:
  - Continue our analysis with an increased dataset
  - Design and execute a clinical evaluation study.
Thank you!