SYNCHRONOUS STEREO-VIDEO AND BIOSIGNAL RECORDING - A BASIC SETUP FOR HUMAN-COMPUTER-INTERFACE APPLICATIONS

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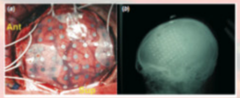
INTRODUCTION

We report on the development of a data acquisition system intended to be used in Human-Computer-interfacing applications to synchronously record upper limb movement and corresponding biosignals. Ultimately, this aims at the clinical recording of ECoG signals from awake patients undergoing tumor resection.

In addition to the standard cortical mapping performed by strip electrodes , the awake patient could perform an easy movement task, while at the same time his local cortical field potentials are recorded [1] .

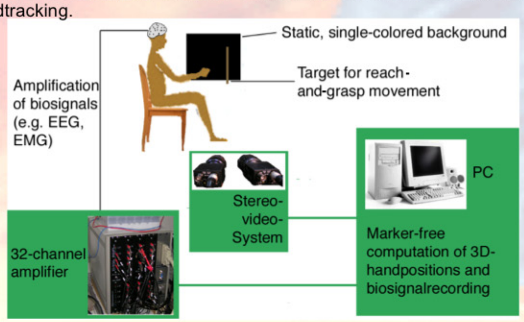


The paradigm under investigation is the correlation between hand-grasp movements and its generating brain activity.

For that purpose stereo-video camera frames are used to detect and triangulate hand and finger positions in three dimensions with high precision and least possible disturbance for the following surgery, while at the same time a DSP-based 32-channel board acquires wideband biosignals.

SETUP

In order to achieve the least disturbance possible in the actual clinical setting, we developed a stereo-camera based, markerfree system for handtracking.



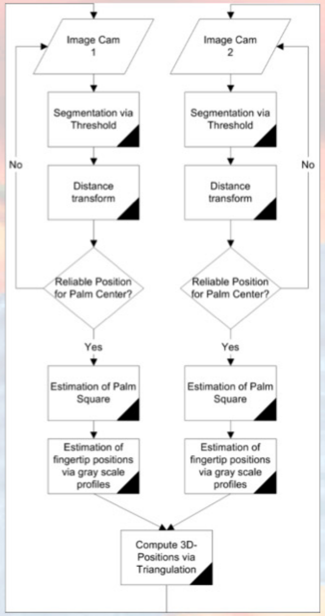
Biosignal-Recording [3]
M67 DSP-Board (Innovative Integr.)
- TI C6701 DSP
- Two AD16 OMNIBUS-Modules (A/D-Conv.)
- Custom made 32 channel amplifier

Stereo-Video-System
- Sony XC-ST50CE CCD-Cameras
- Pentax H612A-TH Lenses
- PC2Vision Framegrabber (Coreco Imaging)

Both, stereo-video and biosignal recording system reside in the same industrial PC-chassis, equipped with an Intel Pentium IV, 3.06 GHz CPU and 1 GB SDRAM

HAND DETECTION

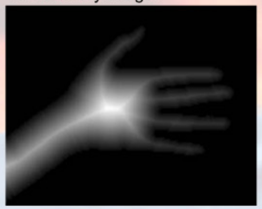
Due to the limitations given by the intended application in the operating room we chose to avoid marker-based hand detection. Therefore we used markerfree handtracking based on hand segmentation in real time. We currently restrict the camera background to a static single colored one. Additionally we search for the palm in a plane parallel to the image plane of the cameras.



Distance transfom

$$D(q) = \min_{p \in O} \left(\| p, q \| \right) q \notin O,$$

where O is the set of all marked pixels in the binary image.

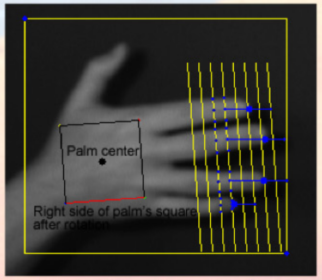


The maximum locates the center of the palm and a registered square, estimating the orientation of the hand [2]

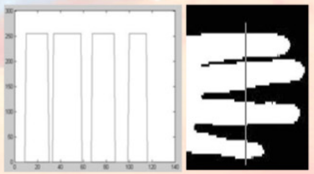
Rotation of the palm's square

$$\alpha = \arg\min_{\beta} \left(Std(S_\beta) \right)$$

where S_β is the set of all pixels on the right side of the square (see red line in the bottom picture).



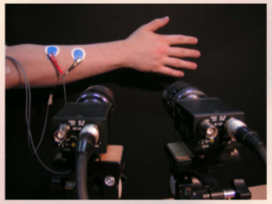
Small blue dots: edges of the fingers, middle of the fingers. Big blue dots: estimation of fingertips



Cross section trough binary image defines finger positions.

Estimation of fingertips:
Peaks in the grayscale profile's derivative give the location of the finger's edge, whereas a position in between belongs to the finger itself. A line connecting central finger positions of two profiles directs to the fingertip position.

RESULTS

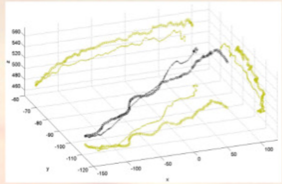


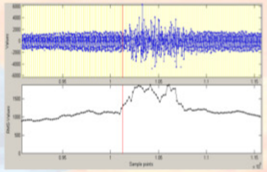
As proof of concept we recorded EMG signals (digital flexor muscle) correlated to a hand-grasp movement. The EMG signals of the volunteers main arm muscles were intercepted by self adhesive electrodes.

The recordings are synchronized via high resolution system timestamps..

Precision of hand detection depends on the optical and geometrical setup and as well on the speed of the movement. In our case we reached a precision of approximately 8 mm^3 in a volume of about 50x40x20 cm^3 at 25 Hz.

An exemplary 3D-trajectory of a hand movement can be seen in the figure on the right.





Time of disappearance of visible fingers in the video corresponded very well to an increase in EMG activity on the digital flexor muscle. This increase is apparent by a clear rise in EMG signal variation as detected by the rms-value of the signal.

Top: EMG signal of the digital flexor muscle (downsampled)
Bottom: rms-value of the EMG signal.
Red line: video detected closing of the hand

CONCLUSION

Conclusion

This project was intended to develop a single-computer system to synchronously record markerfree hand-arm-movements and its corresponding biosignals. We showed the validity of this concept by detecting hand-grasp movements and EMG signals at the same time with high temporal and local precision.

Outlook

We are now able to measure upper limb trajectories with a patient safe video system and will report on the clinical results elsewhere.

Improvements of the system aim to avoid the current constraints of the hand detection.

LITERATURE

[1]Ball, T., et al., *Towards an implantable brain-machine interface based on epicortical field potentials.* Biomedizinische Technik, 2004. 49(E2/2): p. 756-759.
[2] K. Abe, H. Saito, and S. Ozawa, "3d drawing system via hand motion recognition from two cameras," in *IEEE International Conference on Systems, Man and Cybernetics*, 2000.
[3] U. G. Hofmann, A. Folkers, F. Mösch, D. Höhl, M. Kindlundh, and P. Norlin, "A 64(128)-channel multisize neuronal recording system," *Biomedizinische Technik*, vol. 47, no. E1, pp. 194–197, 2002.