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Real-time intraoperative functional brain mapping using a RGB camera

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Introduction

Context: Non invasive functional brain mapping is an imaging technique used before brain tumor resection to localize the functional areas of the patient brain. f-MRI and electrical brain stimulation are two complementary clinical tests realized before neurosurgery.

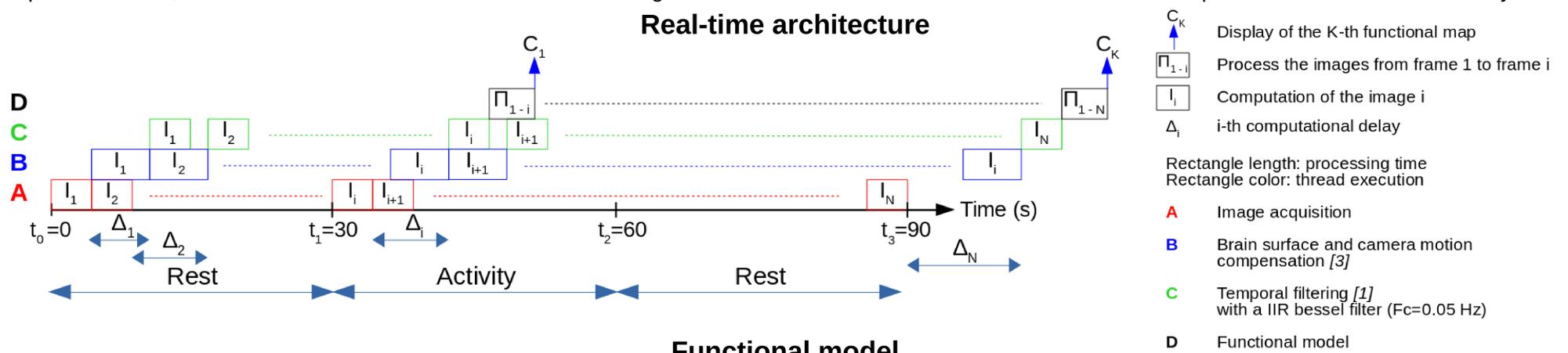
f-MRI tests are realized before the patient craniotomy. Electrical brain stimulation tests are realized once the patient cortex is exposed.

Background: Optical imaging can be used to monitor the brain activity [1] with the measure of hemoglobin concentration changes ($\Delta[HbO_2]$ and $\Delta[Hb]$). A device consisting of a continuous wave white light illumination and a RGB camera is a suitable approach [2].

Objectives: We propose to realize a real time intraoperative localization of brain functional areas using a RGB camera with the analysis of $\Delta[HbO_2]$ and $\Delta[Hb]$ time courses which is closely linked with the Bold contrast in f-MRI studies.

Material & methods

Experimental paradigm: After the patient craniotomy and before the brain tumor resection surgery, the patient was awakened and functional tests have been realized. The stimulation of the motor cortex was achieved through a repetitive and alternative hand opening and closing at ≈ 1 Hz. The paradigm consisted of 3 steps : 30s of rest, 30s of stimulation and 30s of rest. The neurosurgeon realized electrical brain stimulations to localize the patient brain motor and sensory areas.



Functional model

1 - Correction of the collected intensity slope

The slow drift of the collected intensity (cortical desiccation) was corrected through a linear regression subtracted to the original data.

2 - Modified Beer-Lambert law [4]

$$\begin{bmatrix} \Delta A_R(t) \\ \Delta A_G(t) \\ \Delta A_B(t) \end{bmatrix} = \begin{bmatrix} E_{R,Hb} & E_{R,HbO_2} \\ E_{G,Hb} & E_{G,HbO_2} \\ E_{B,Hb} & E_{B,HbO_2} \end{bmatrix} \times \begin{bmatrix} \Delta[Hb](t) \\ \Delta[HbO_2](t) \end{bmatrix}$$

$$\text{with } E_{i,n} = \int \epsilon_n(\lambda) \times D_i(\lambda) \times S(\lambda) \times L(\lambda) d\lambda.$$

A global mean path length L is calculated with Monte-Carlo simulations [5].

D_i : spectral sensitivity of the camera detector i (R,G,B). S: light source spectrum

ϵ_n : chromophore n(Hb, HbO₂) molar absorption coefficient ($L \cdot Mol^{-1} \cdot cm^{-1}$)

3 - Selection of activated areas

For each camera pixel, the Hb or HbO₂ concentration changes time courses are obtained by matrix inversion. The time courses which best fit the expected patient hemodynamic response [6] are considered (the Pearson correlation coefficient threshold is set to 0,5).

4 - Functional quantitative maps

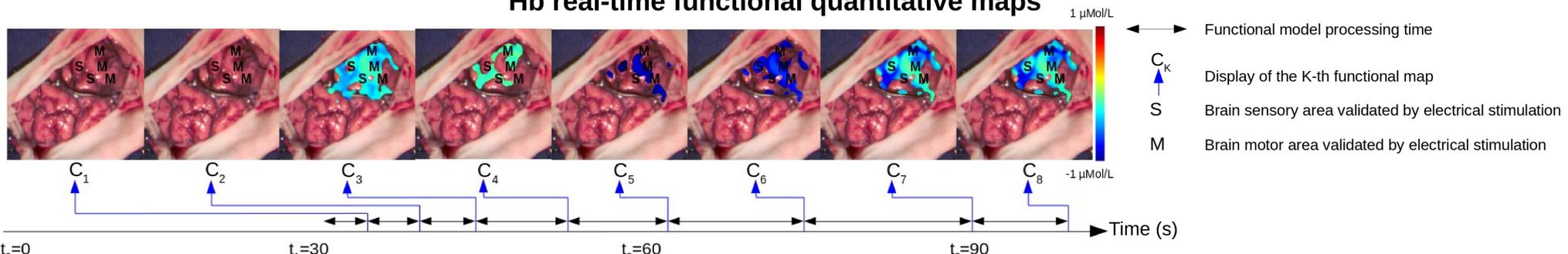
Hb or HbO₂ concentration changes are averaged over the duration of the patient cortical activity.

$$QMap_C(x, y) = \frac{\sum_{t=t_1}^{t_2} \Delta C(t, x, y)}{t_2 - t_1}$$

C represents either [Hb] or [HbO₂]. (x,y) is the position of an image point.

Results

Hb real-time functional quantitative maps



✓ The Hb functional quantitative maps correspond to the motor and sensory areas validated by the neurosurgeon.

✓ Relevance of the functional quantitative maps as soon as the patient activity is established.

Discussion & conclusion

↗ A global mean path length is calculated for all camera pixels. A pixel-wise computation of the mean path length is required.

↗ The correction of the collected intensity slope is not optimal for the first maps (from C₁ to C₆). This problem will be investigated in a future work.

↗ The functional quantitative maps processing time depends on the amount of pixels contained in the region of interest. CPU and GPU optimization code is required.

References

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