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Real time intraoperative functional brain mapping using a RGB camera

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ABSTRACT

We demonstrate that a RGB camera and a continuous wave white light illumination is a suitable approach to intraoperatively localize in real time the sensory and motor areas of the patient brain. The analysis of the reflectance spectra of the acquired light and Monte Carlo simulations allow us to measure the concentration changes of oxygenated and deoxygenated hemoglobin during the video acquisition. These measures are compared to the expected hemodynamic response to precisely localize the functional areas of the patient brain.

Keywords: hemodynamic response, functional brain mapping, Monte-Carlo simulations, intraoperative imaging, RGB camera, real time

1. INTRODUCTION

Non-invasive functional brain mapping is an imaging technique used to localize the functional areas of the brain. This technique is used before brain tumor resection surgery to indicate to the neurosurgeon the cortical tissues which should not be removed without cognitive impairment. MRI-f is widely used to localize patient sensory or motor areas. However, after patient craniotomy, a brain shift invalidates the relevance of neuro-navigation to intraoperatively localize the functional areas of the patient brain. For this reason, the localization of cortical motor or sensory areas is achieved through electrical stimulation but this technique suffers from limitations.

Chance et al. have demonstrated that optical imaging can be used to monitor brain activity with the determination of concentration changes of oxygenated hemoglobin $\Delta[HbO_2]$, deoxygenated hemoglobin $\Delta[Hb]$, blood volume $\Delta[Hb] + \Delta[HbO_2]$ and oxygenated cytochrome-oxidase.¹ It also has been demonstrated that a device consisting of a continuous wave white light illumination and a RGB camera is a suitable approach.^{2,3}

The objective of this work is to supply the methodological tools for the real time construction of quantitative functional brain maps based on the analysis of the cortical reflectance spectra acquired by a digital RGB camera. The motivation for this paper is derived from the necessity to analyze the hemoglobin time courses in brain tissue following neuronal activation which are closely linked to the BOLD (blood oxygenation level dependent) contrast used in functional MRI studies.⁴ Concentration changes of oxygenated hemoglobin and deoxygenated hemoglobin can be measured for each camera pixel using the modified Beer-Lambert law.⁵ This law is computed with an estimated mean path length calculated by Monte-Carlo simulations.⁶ Finally, the concentration changes time courses are compared to the expected hemodynamic response of the patient brain which allow us to precisely localize the functional tissues of the patient brain.

2. MATERIAL AND METHODS

2.1 Experimental setup

The instrumentation consisted of a digital RGB CMOS camera (BASLER acA2000- 165uc), a continuous wave white light source (OSRAM Classic 116W 230V Light bulb) and a laptop (processor: Intel Core i5 - 7200U, 2.50GHz \times 4, ram: 15.3GiB). The RGB camera was used with an Edmund Optics camera lens ($f = 16mm$, $f\# = 1 : 1 : 4$). The sensor provided 8 bits RGB images every 33 ms.

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2.2 Patient inclusion and experimental paradigm

The video acquisition was realized before a brain tumor resection surgery. The patient was awakened and functional tests have been realized. Stimulation of the motor cortex was achieved through successive fist clenching and relaxing. The paradigm consisted of 3 steps: 30s of rest, followed by 30s of stimulation and 30s of rest. The neurosurgeon realized electrical brain stimulation to localize patient brain motor and sensory areas.

2.3 Data pre-processing

Once an image is acquired, several steps are processed in parallel. First, the image is registered to compensate the brain repetitive motion. The algorithm developed by *Sdika et al.*^{7,8} was implemented to ensure that each camera pixel corresponds to the same cortical area all along data acquisition. The RGB intensities of the acquired image are then independently filtered with a low-pass IIR Bessel temporal filter.¹

2.4 Model

A functional model is applied to assess Hb and HbO_2 concentration changes for each camera pixel.

- **Data correction:** The slow drift of the collected intensity due to cortical tissue desiccation during the video acquisition⁹ was corrected through a linear regression subtracted to the original data.
- **Functional model:** The assessment of the concentration changes through the modified Beer-Lambert law⁵ depends on the determination of the mean path length of the detected photons. Monte-carlo simulations⁶ were processed to estimate a global mean path length which was applied to all camera pixels. The computed concentration changes times courses are compared to the expected hemodynamic response with the Pearson correlation coefficient. A quantitative functional map is then computed for each pixel whose correlation coefficient is superior to a threshold value. These maps correspond to the Hb or HbO_2 concentration changes averaged over the patient cortical activity.

2.5 Real time processing

These processing steps are implemented in a soft real-time architecture. The pre-processing steps (see Sec. 2.3) and the model (see Sec. 2.4) are executed in different parallel threads. An intermediate buffer is placed between each computational step allowing the data storage. These buffers are required in our soft real-time architecture since the processing times are different for each computational step. The thread corresponding to the model is computed as soon as the cortical activity started. This thread is recursively called while images are pre-processed.

3. RESULTS AND DISCUSSION

In Fig. 1, the real time Hb quantitative functional maps (see Sec. 2.4) which are best correlated with the expected hemodynamic response are plotted (correlation threshold sets to 0.5). The highest Hb mean concentrations are localized on blood vessels surrounding motor and sensory areas. The highest correlation coefficient are localized on these blood vessels and on motor and sensory areas. The computed functional maps become significant as soon as the patient activity is established, see Fig. 1-C. *Pichette et al.*¹⁰ proposed to mask the blood vessels in order to render more clearly the smaller hemodynamic changes in grey matter. The measurement of the correlation coefficient between the concentration change time courses and the expected hemodynamic response allows us to visualize the activated cortical areas without masking the blood vessels. A global mean path length is used for each camera pixels in the modified Beer Lambert law.⁵ A pixel-wise determination of the mean path length could be implemented to assess more precisely the Hb concentration changes. However it would require a lot of Monte Carlo simulations and cause an increase of the processing time of the model (see Sec. 2.4). The slow drift of the collected intensity is corrected each time the model is executed (see Sec. 2.4) which cause an increase of the processing time. In addition, the estimation of the collected intensity slope is not optimal for the first maps (from Fig. 1-A to Fig. 1-F). This problem will be investigated in a future work.

4. CONCLUSION

In conclusion, a RGB camera and a continuous wave white light illumination seem to be a suitable setup to intraoperatively monitor the sensory and motor areas of the patient brain in real time. These results indicate that our setup could complement the actual intraoperative gold standard for the localization of patient functional areas.

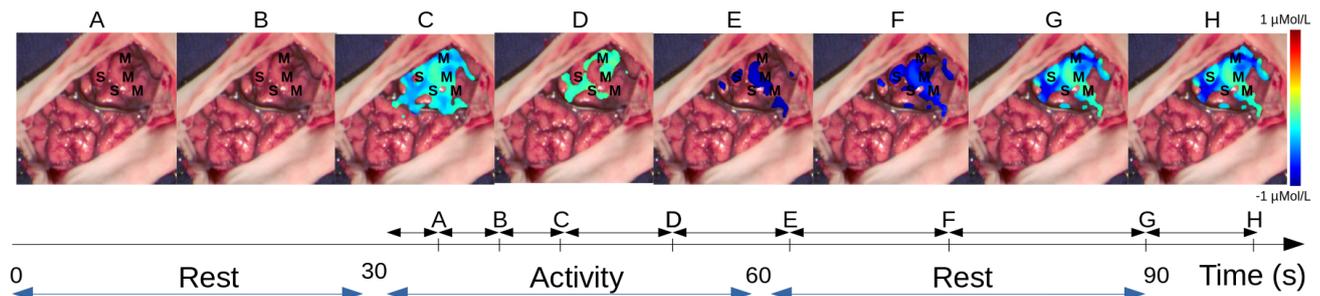


Figure 1. *Hb* concentration changes maps emitted during the video acquisition. The correlation threshold is set to 0.5. The horizontal axis represents the acquisition time of the RGB camera. The experimental paradigm is represented under this axis. The vertical lines represent the display time of the computed functional maps (images from A to H). The double black arrows represent the processing time of the model, see Sec. 2.4. The markers **M** and **S** designate respectively the motor and the sensory areas which have been validated by the neurosurgeon through electrical stimulation. The colorbar represents the scale of variation of *Hb* mean concentration in $\mu\text{Mol/L}$.

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REFERENCES

- [1] Chance, B., Zhuang, Z., UnAh, C., Alter, C., and Lipton, L., “Cognition-activated low-frequency modulation of light absorption in human brain.,” *Proceedings of the National Academy of Sciences* **90**, 3770–3774 (Apr. 1993).
- [2] Malonek, D. and Grinvald, A., “Interactions between electrical activity and cortical microcirculation revealed by imaging spectroscopy: Implications for functional brain mapping,” **272**, 551–4 (05 1996).
- [3] Steimers, A., Gramer, M., Ebert, B., Füchtmeier, M., Royl, G., Leithner, C., Dreier, J. P., Lindauer, U., and Kohl-Bareis, M., “Imaging of cortical haemoglobin concentration with RGB reflectometry,” 736813 (July 2009).
- [4] Veldsman, M., Cumming, T., and Brodtmann, A., “Beyond BOLD: Optimizing functional imaging in stroke populations: Optimizing BOLD Imaging in Stroke,” *Human Brain Mapping* **36**, 1620–1636 (Apr. 2015).
- [5] Kohl-Bareis, M., Ebert, B., Dreier, J. P., Leithner, C., Lindauer, U., and Royl, G., “Apparatus for measuring blood parameters,” (11 2012).
- [6] Fang, Q. and Boas, D. A., “Monte Carlo simulation of photon migration in 3d turbid media accelerated by graphics processing units,” *Optics express* **17**(22), 20178–20190 (2009).
- [7] Sdika, M., Alston, L., Rousseau, D., Guyotat, J., Mahieu-Williams, L., and Montcel, B., “Repetitive motion compensation for real time intraoperative video processing,” *Medical Image Analysis* **53**, 1 – 10 (2019).
- [8] Sdika, M., Alston, L., Mahieu-Williams, L., Guyotat, J., Rousseau, D., and Montcel, B., “Robust real time motion compensation for intraoperative video processing during neurosurgery,” in *[2016 IEEE 13th International Symposium on Biomedical Imaging]*, 1046–1049, IEEE, Prague, Czech Republic (Apr. 2016).
- [9] Oelschlägel, M., Meyer, T., Wahl, H., Sobottka, S. B., Kirsch, M., Schackert, G., and Morgenstern, U., “Evaluation of intraoperative optical imaging analysis methods by phantom and patient measurements,” *Biomedizinische Technik/Biomedical Engineering* **58** (Jan. 2013).
- [10] Pichette, J., Laurence, A., Angulo, L., Lesage, F., Bouthillier, A., Nguyen, D. K., and Leblond, F., “Intraoperative video-rate hemodynamic response assessment in human cortex using snapshot hyperspectral optical imaging,” *Neurophotonics* **3**, 045003 (Oct. 2016).