Next-generation computational optical tomography for diffuse optical imaging

Information

Active discussion period: 15 July 2018 and 15 September 2018
Identifier: **RFI_BCI_002**
Contact: frl_academics@fb.com
Submissions: https://fbresearch.wufoo.com/forms/facebook-request-for-information-rfi_bci_002/

Summary

Facebook requests information about novel approaches to perform noninvasive optical sensing of brain activity. We seek opportunities for research and development in academic and industry to advance the field of optical brain computer interfaces. Facebook may use the information received in response to this RFI to guide our program for future research collaborations.

At Facebook we have performed a number of research and innovation projects in an open and collaborative manner. With this approach we hope to combine the respective strengths of Facebook and the academic community to advance research areas of interest to us. To make well informed decisions for our future research programs, we want to engage with the academic research community at the earliest possible stage, for which we use Requests For Information (RFI).

Relevant Keywords

Brain-computer interface, non-invasive, optics, diffuse optical tomography, random media, light diffusion, intrinsic optical signals, remote sensing, dynamic light scattering, diffuse correlation spectroscopy, computational optics, fluctuation analysis, intensity, phase, polarization

Scope of Request for Information

Background - coherent diffuse optical tomography

Diffuse optical sensing of the brain is a promising method for the non-invasive, real-time, information-rich quantification of brain function, including neural and vascular activity. In diffuse optical sensing, a light source that illuminates the scalp will be heavily scattered by the scalp, skull, and brain. As such, light from a point source will travel a large number of different pathways and be remitted at a wide range of distances from the location of illumination. The properties of remitted light at a specific location is a function of the paths travelled that end at that detector and the spatially-varying optical properties encountered along each path. If the scalp is illuminated at some large number of locations and, from each illumination location, light is collected at some large number of detectors, light from a wide range of overlapping paths is detected over a large number of source-detector pairs. Given the overlap, and given the large number of source-detector pairs, it is possible to pose an inverse problem: given a set of known illumination light properties, and given the measured light properties at spatially-indexed source-detector pairs, what are the spatially-varying optical properties of the scalp, skull, and brain? This inverse problem is called tomography. Most diffuse tomographic sensing methods use spatially incoherent light. For this kind of sensing, tomographic methods are relatively mature. On the other hand, next-generation diffuse tomographic sensing methods use spatially coherent laser light. The use of spatially coherent light results in an optoelectronic signal that contains significantly more information compared to the spatially-incoherent case. Because coherent laser light is used, however, the remitted optical field has a large degree of interference leading to strong intensity variations at a short length scale (i.e. speckle). As a consequence, the task of tomographic reconstruction of coherent, diffuse optical fields is notably more complex and correspondingly immature as a field of research. In sum, robust tomographic methods for coherent diffuse optical sensing methods of the brain is expected to improve these sensing methods to provide real-time, information-rich images of brain activity.

Background - next-generation computational optics

Traditional optical imaging systems rely on the optical hardware itself to generate an image (or the straightforward transform of an image) in physical space. This physical domain image is captured on film or at an optoelectronic detector. Over the past decade, it has become clear that the requirement to have image formation in the physical domain is overly-restrictive and, surprisingly, not always optimal in terms of maximizing information extraction from a detected optical field. Out of this realization has emerged a new paradigm for optical imaging called computational optics. Computational optics focuses on [i] maximizing information capture in the hardware domain without the formal requirement of image formation in the physical domain and [ii] using sophisticated computational methods in conjunction with vast computational power to generate information-rich images in the digital domain. There are several enabling concepts behind the computational optics revolution, including sparsity/compressed sensing, optimization-based methods for image reconstruction, and machine learning such as artificial neural networks and reinforcement learning. Some computational optics methods also exploit advances in the understanding of light propagation and scattering in random and disordered media. In all, computational optics has made dramatic advances in a relatively short period of time, and holds tremendous promise for dramatically improving the capabilities of diffuse optical imaging, including next-generation methods that use coherent laser light.

Goals and requirements of this RFI

In light of the potential of coherent diffuse optical tomography to quantify brain physiology, and given the recent dramatic advances in computational optics, this RFI seeks to solicit proposals for next-generation computational optics methods for <u>coherent</u> diffuse optical tomography of the brain. We have an explicit requirement that submitted proposals use or develop cutting-edges concepts and methods in computational optics. Additionally, we require that methods assume realistic conditions, in particular [i] there is no exact, instantaneous knowledge of the complete scattering medium; fluctuations happen faster than can be compensated, and [ii] only a small fraction of the total optical field can be collected.
We have an expectation that the developed computational optical methods have a robustly-argued

basis in the relevant fields of mathematics, computer science, physics, optics, and neuroscience. It is not an explicit requirement but it is strongly preferred if the performance of the proposed computational optics methods are compared to more traditional approaches (e.g. L2 norm-based linear reconstruction). Such comparisons can be made on simulated data and/or experimental data.

Submission Instructions

Submissions must not contain any Facebook, respondent, or third party (i) intellectual Property, or (ii) confidential, proprietary, or privileged information. It is the respondent's responsibility to ensure that all submitted information has been approved for public release by the information owner.

Respondents are free to choose whatever form most effectively conveys the intended information - examples include, but are not limited to, .pdf documents or .txt documents, and interactive web content (e.g. Jupyter Notebook, web postings such as https://andrewgyork.github.io/remote_refocus/). There is no formatting specification, nor limit on the amount of content that can be included. As a result, Facebook makes no assurances that submitted materials will be reviewed, nor that any feedback will be provided. Content that is excessive or of unclear relevance to the RFI topic are unlikely to be reviewed.

Submissions should be sent to frl_academics@fb.com with the identifier **RFI_BCI_002** in the subject line, or through https://fbresearch.wufoo.com/forms/facebook-request-for-information-rfi_bci_002/. Responses to this RFI will be reviewed between the dates of 15 July 2018 and 15 September 2018, during which time open discussions will be hosted on Workplace.

Disclaimers and Important Notes

This RFI and any submissions in response thereto are solely for Facebook's information and planning. This RFI is not a solicitation for proposals, bids, quotations, or an invitation to contract. Participation and submission of information is entirely voluntary. Responses to this RFI are not proposals and cannot be accepted by Facebook to form a binding contract. Submitting a response to this RFI is not a precondition to submission of a response to a Request for Proposal (RFP), should Facebook issue an RFP in the future. Facebook will not provide payment or reimbursement for any information submitted in response to this RFI or for any costs incurred in responding to this RFI.

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Respondents are advised that Facebook is under no obligation to acknowledge receipt of the information submitted or provide feedback to respondents with respect to any information submitted under this RFI. Respondents are further advised that materials submitted in response to this RFI will not be returned by Facebook except at Facebook's discretion.