Postdoctoral Position at IRIT Lab Toulouse

Super-resolution Image Reconstruction using Unsupervised Learning for Ultrasound Localization Microscopy (ULM)

- **Location**: Equipe MINDS, Laboratoire IRIT, Toulouse, France
- **Funding Duration** : 1 year renewable
- **Starting date:** as soon as possible.
- **Application Deadline:** Open until filled
- **Supervisors**:
  Duong Hung PHAM (duong-hung.pham@irit.fr)
  Denis KOUAME (denis.kouame@irit.fr)

1 General Context

This postdoctoral position is funded by an MIC (Mathematics and Computer Science) - INSERM grant, uniting three research groups in computational medical imaging from prominent institutions. These include the University of Toulouse (IRIT lab, Dr. Duong Hung PHAM and Pr. Denis Kouame), the University of Tours (iBrain, Inserm 1253, Dr. Jean-Pierre REMENIERAS), and the Institut d'Électronique de Microélectronique et de Nanotechnologie (IEMN, Prof. Olivier BOU MATAR). The postdoctoral research will be conducted at IRIT lab in Toulouse, in collaboration with Dr. Jean-Pierre REMENIERAS and Prof. Olivier BOU MATAR, involving regular meetings and visits between Toulouse, Tours and Lille.

2 Postdoctoral Description and Objectives

The recent introduction of Ultrasound Localization Microscopy (ULM) has effectively addressed the trade-off between ultrasound imaging's spatial resolution and penetration depth while maintaining high sensitivity through the interaction of sparse US contrast agents (UCA) and ultrafast imaging [1]. Similar to photoactivated localization microscopy (PALM), ULM utilizes UCAs as sensors to localize and accumulate thousands of UCA events using density-based techniques for imaging the region of interest. With its high framerates, ULM enables the reconstruction of UCA trajectories in the bloodstream and the imaging of vasculature and microvasculature at the microscopic scale, recently adapted for transcranial applications by Demene [2]. However, existing ULM algorithms primarily process frame-by-frame data (2D ULM), neglecting temporal information and thus limiting effectiveness. Moreover, current ULM approaches based on CNN require extensive ground-truth datasets for training, which may not always be available [3].

The first objective of this postdoctoral endeavor is to develop inverse problems for accurate and efficient ULM leveraging weakly or unsupervised machine learning (ML) techniques, thus reducing reliance on ground truth datasets. Emphasis will be placed on cycle consistency-based generative adversarial networks (CycleGAN) and variational autoencoder (VAE) frameworks, enabling unsupervised training of deep learning (DL) models [4], [5]. The developed methods will be fed by ultrasound radio-frequency data. Constructing a training ULM database poses a significant challenge in DL-based algorithms. Therefore, a crucial task in this postdoctoral endeavor is to build a simulated ULM database comprising human brain microvasculature and tumors injected with UCA bubbles, along with corresponding ground truth maps representing the actual brain microvasculature. Then, the developed methodology will be evaluated and validated using both *in-vitro* and *in-vivo* datasets obtained by iBrain from INSERM (Tours) in collaboration with the neurosurgery department of the CHRU of Tours, specializing in brain tumor surgery. The second objective of this postdoctoral endeavor is to revisit the developed inverse problems to include beamforming process through aberration corrections.

3 Medical context and outcomes

This post-doc is part of a projet related to the therapy of gliomas. Gliomas are the most common primary brain tumors, graded from II to IV based on histological and molecular features, with median survival ranging

from 15 years for grade II to 16 months for grade IV [6]–[8]. Grade II gliomas often progress to higher grades, necessitating awake surgery for resection while preserving function. However, surgery, even in the awake condition, rarely allows complete tumor removal due to deep brain infiltration. Consequently, cure is rarely achievable, necessitating long-term MRI follow-up regardless of glioma grade. Low-grade gliomas undergo MRI every six months, while high-grade gliomas receive adjuvant therapy followed by quarterly MRI surveillance for early detection of progression or malignant transformation. First-pass gadolinium perfusion MRI is standard for assessing neo-angiogenesis [9]. Our project aims to develop a complementary ultrasound (US) imaging tool for brain tumor neo-angiogenesis monitoring and diagnosis, enhancing early lesion detection and treatment adaptation, particularly for anti-angiogenic therapies. *We propose using 3D Ultrasound Localization Microscopy (ULM) for in-vivo brain tumor imaging without skull opening,* ***a novel approach yet to be explored****.*

4 Requirements

We seek a highly motivated postdoctoral fellow to investigate 3D Ultrasound Localization Microscopy (ULM) for *in-vivo* brain tumor imaging without skull opening. The ideal candidate should possess the following qualifications:

- A robust background in signal and image processing, or applied mathematics (inverse problems, optimization, etc.).
- Proficiency in machine learning (ML) techniques, with a specific emphasis on CNN.
- Strong programming abilities in either Matlab or Python.
- Proficiency in the English language.
- An interest in medical US imaging would be advantageous.

5 Application

Prospective candidates are required to submit the following documents in a **SINGLE PDF** file: (1) a one-page cover letter; (2) curriculum vitae including a list of publications; (3) Two reference letters; (4) The position is opened until filled. Please forward all documents to duong-hung.pham@irit.fr and denis.kouame@irit.fr.

6 References

[1] O. Couture *et al.*, "Ultrasound Localization Microscopy and Super-Resolution: A State of the Art," *Ultrafast imaging in biomedical ultrasound*, vol. 65, no. 8, pp. 1304–1320, Aug. 2018. DOI: 10.1109/TUFFC.2018.2850811.

[2] C. Demené *et al.*, "Transcranial ultrafast ultrasound localization microscopy of brain vasculature in patients," *Nat. Biomed. Eng.*, vol. 5, no. 3, pp. 219–228, Mar. 2021. DOI: 10.1038/s41551-021-00697-x.

[3] B. Heiles *et al.*, "Performance benchmarking of microbubble-localization algorithms for ultrasound localization microscopy," en, *Nat. Biomed. Eng*, vol. 6, no. 5, pp. 605–616, May 2022. DOI: 10.1038/s41551-021-00824-8.

[4] B. Sim *et al.*, "Optimal Transport Driven CycleGAN for Unsupervised Learning in Inverse Problems," *SIAM J. Imaging Sci.*, vol. 13, no. 4, pp. 2281–2306, Jan. 2020. DOI: 10.1137/20M1317992.

[5] C. Doersch, *Tutorial on Variational Autoencoders*, 2016. DOI: 10.48550/arXiv.1606.05908.

[6] Q. T. Ostrom *et al.*, "The epidemiology of glioma in adults: A "state of the science" review," en, *Neuro-Oncology*, vol. 16, no. 7, pp. 896–913, Jul. 2014. DOI: 10.1093/neuonc/nou087.

[7] A. Brodbelt *et al.*, "Glioblastoma in England: 2007–2011," *European Journal of Cancer*, vol. 51, no. 4, pp. 533–542, Mar. 2015. DOI: 10.1016/j.ejca.2014.12.014.

[8] C. McKinnon *et al.*, "Glioblastoma: Clinical presentation, diagnosis, and management," *BMJ*, n1560, Jul. 2021. DOI: 10.1136/bmj.n1560.

[9] B. Bobek-Billewicz *et al.*, "Original article Anaplastic transformation of low-grade gliomas (WHO II) on magnetic resonance imaging," *Folia Neuropathologica*, vol. 2, pp. 128–140, 2014. DOI: 10.5114/fn.2014.43784.