«LLM-based multimodal planning and decision support for pulmonary tumor ablation»

Location: ICUBE Institute, IMAGeS group, University of Strasbourg (https://icube.unistra.fr)
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Start: Sept 1st, 2026
Duration: 3 years

Context:

The management of lung tumors increasingly relies on a wide range of therapeutic options, including open surgery, non-invasive focused treatments such as radiotherapy, systemic treatments such as chemotherapy or immunotherapy, and a growing number of minimally invasive alternatives such as thermal ablation brought to the tumor through various access routes. Choosing the most appropriate strategy for a given patient is an increasingly complex process that depends on many factors, such as tumor location and size, anatomical constraints, patient comorbidities, and expected therapeutic benefit, but also on the clinician's level of expertise and familiarity with the range of available therapeutic options, highlighting the need for tools that can help synthesize and compare complex, heterogeneous, and rapidly evolving information. This decision-making process is inherently multidisciplinary and requires the integration of heterogeneous sources of information, both patient-specific or general, ranging from medical imaging and clinical data to procedural constraints and treatment outcome simulations and predictions [1].

Among minimally invasive approaches, thermal ablation is an increasingly important minimally invasive option for the treatment of primary and secondary tumors, particularly for patients who are not eligible for surgical resection. Clinical success is strongly influenced by planning, which determines (i) feasibility and access, (ii) safety of the chosen path with respect to critical anatomy, and (iii) expected tumor coverage and margins. While automatic planning assistance tools have been developed for percutaneous thermal ablation [2], they remain focused on isolated aspects of the intervention and do not provide a unified framework for comparing different treatment options, such as surgical resection, or alternative therapies. As a result, clinical decision-making still relies heavily on expert judgment, with limited support for integrating geometric constraints, physical simulation results, and medical knowledge in a coherent and explainable way.

Recent advances in large language models (LLMs), particularly in multimodal and knowledge-augmented settings, offer new opportunities to address these limitations [3]. These approaches make it possible to combine geometric reasoning, physical simulation, medical knowledge, and clinical context within a single decision-support framework, and to provide interpretable assistance to clinicians when evaluating complex therapeutic choices.

In this context, the objective of the proposed PhD is to develop an intelligent planning and decision-support framework for thoracic and abdominal tumor treatment, combining generative modeling, physical simulation, and large language models. The PhD project aims to go beyond isolated planning tools by enabling the comparison of alternative therapeutic strategies and by supporting clinical reasoning in a transparent and explainable manner.

The PhD will be carried out within the IMAGeS team of ICube (UMR 7357, University of Strasbourg), a joint research unit of the University of Strasbourg, CNRS and INSA Strasbourg. The IMAGeS team conducts research at the interface between computer science, artificial intelligence, medical imaging, and computer-assisted interventions. One of its active research interests covers image-guided therapies, surgical planning, and computational modeling for minimally invasive procedures.

The project will be conducted in close collaboration with the IHU Strasbourg, a major European center dedicated to image-guided and minimally invasive therapies, and the University Hospital of Strasbourg. These collaborations provide access to clinical expertise, real-world medical data, and validated clinical workflows, ensuring strong translational potential. The PhD fits naturally within the ongoing research activities of the teams and benefits from a multidisciplinary environment.

This PhD offer is provided by the ENACT AI Cluster and its partners. Find all ENACT PhD offers and actions on https://cluster-ia-enact.ai/.

Description:

The objective of this PhD is to develop an intelligent decision-support framework for thoracic and abdominal tumor treatment based on large language models (LLMs). The project will investigate how multimodal LLM-based approaches can support complex clinical decision-making by integrating heterogeneous sources of information, including geometric and physical constraints, medical knowledge, and patient-specific data.

The candidate will design LLM-based models enriched with retrieval-augmented and knowledge-augmented generation mechanisms. These will enable the integration of both general knowledge—such as clinical guidelines, contraindications, and device-related constraints—and patient-specific information, including medical images, clinical variables, and outputs from planning or simulation tools. In particular, the work will build on automatic planning and simulation methods previously developed within the IMAGeS team [4,5], which provide quantitative assessments of feasibility, safety, and treatment coverage. These existing tools will serve as a key structured and verifiable source of information for the decision-support framework.

The models will be used to produce structured and explainable analyses of possible therapeutic strategies, highlighting their respective advantages, limitations, and trade-offs in terms of feasibility, safety, and expected clinical outcome. The emphasis will be placed on interpretability, transparency of the reasoning process, explicit handling of uncertainty, and meaningful interaction with the clinician, rather than on automated decision-making.

The main scientific challenges addressed in this project concern the ability of large language models to reason over heterogeneous and partially constrained data, to remain consistent with anatomical and physical constraints, and to produce reliable and explainable outputs. Key issues include the integration of multimodal information, the coupling of data-driven reasoning with simulation-based models, the control of hallucinations, and the evaluation of clinical relevance. Addressing these challenges requires advances in multimodal reasoning, knowledge-grounded generation, and human–AI interaction, with a strong emphasis on robustness and interpretability, making this work relevant both for medical applications and for the development of trustworthy AI systems.

To address these challenges, the project will adopt a tool-augmented and evidence-grounded architecture. Geometry checks, constraint validation, and physical or procedural simulations—implemented in existing planning tools—will remain authoritative components of the system,

while the LLM will orchestrate their use and synthesize their outputs into structured and traceable explanations. Retrieval- and knowledge-augmented mechanisms will ground reasoning in curated medical sources, while validation layers (schema constraints, rule checking, inconsistency detection) will limit hallucinations and ensure coherent outputs. The proposed framework will be evaluated using multi-level protocols combining quantitative metrics, expert assessment, and analysis of explanation quality. Interaction workflows will be co-designed with clinicians to ensure usability and integration into realistic clinical settings.

The thesis will build on previous work of the IMAGeS team at ICUBE on surgical planning and interventional modeling, and will be conducted in close collaboration with academic and hospital partners, in particular the University Hospital of Strasbourg and IHU Strasbourg. This environment provides strong methodological foundations and access to clinically relevant tools and data, ensuring both scientific depth and translational impact.

Bibliography

[1] Kowalczyk A, Jassem J (2020). *Multidisciplinary team care in advanced lung cancer*. Transl Lung Cancer Res ;9(4):1690-1698.

[2] Rui Zhang, Shuicai Wu, Weiwei Wu, Hongjian Gao, Zhuhuang Zhou (2019). *Computer-assisted needle trajectory planning and mathematical modeling for liver tumor thermal ablation: A review*. Math. Biosciences and Engineering, 16(5): 4846-4872.

[3] Gargari, O. K., Habibi, G. (2025). *Enhancing medical AI with retrieval-augmented generation: A mini narrative review*. Digital Health, 11, 20552076251337177.

[4] Mehtali, J., Verde, J.M., Essert, C. (2025). *C-NCA: Chained Neural Cellular Automata for Fast and Accurate Thermal Ablation Estimation*. In: MICCAI 2025. Lecture Notes in Computer Science, vol 15963, p. 67-77. Springer.

[5] A. Morin, J.M. Verde, L. Rubbert, A. Garcia, C. Essert (2025). *Planning non-linear trajectories for no-touch thermal ablation using passive steerable needle with controlled stiffness and PSAM*. Healthcare Technology Letters, 12, no. 1: e70033

Qualifications: Master's degree in computer science. A very good level of programming in C++ or Python is required. Knowledge in artificial intelligence, machine learning, or natural language processing is expected. Background in medical imaging, numerical modeling, or computational geometry would be an advantage. Good communication skills and a good level of English are expected.

To apply: Send a CV, cover letter, master internship report, master transcripts with ranking, and the names and contact information of at least 2 people who can recommend you to: essert@unistra.fr and juan.verde@ihu-strasbourg.eu.

NB: Incomplete applications without information about the student's ranking in his/her master's program will not be considered.