French Polytech network form for PhD Research Grants from the China Scholarship Council

This document describes one of the PhD subjects proposed by the French Polytech network. The network is composed of engineering schools/universities. The document also provides information about the supervisor.

Supervisor information	
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PhD information	
Title	Monitoring of cold plasma medical treatments by means of AI analysis of in-situ measurement
Main topics regards to CSC list (3 topics at maximum)	III-7. Ingénierie biomédicale/ Biomedical engineering III-13. Vieillissement : prévention et traitement des maladies des personnes âgées Ageing: prevention and treatment of illnesses of the senior citizen

Required skills in science and engineering	Expertise in coding (i.e. Phyton and Matlab) Expertise in automation Expertise in Artificial Intelligence models (i.e. Physics Informed Neural Networks) Knowledge in plasma physics and biology are appreciated Knowledge in image processing and optical emission spectrometry is appreciated

Subject description (two pages maximum including biblio)

Objective: The objective of this research is the integration of multi-source monitoring data and AI modeling to enhance the real-time analysis and decision-making in cold plasma medical treatments, in order to improve therapeutic precision and efficiency.
Keywords: cold plasma jet, plasma medicine, artificial intelligence.

Background:
Cold atmospheric plasma (CAP) has gained prominence in medical applications due to its unique capacity to generate reactive oxygen and nitrogen species (RONS), charged particles and pulsed electric field at biologically compatible temperatures [1,2]. These active agents play essential roles in key cellular processes, including apoptosis, immune response, and tissue regeneration. CAP demonstrates particular promise in treating age-related pathologies with high prevalence in patients over 60, such as chronic wounds, actinic keratosis, and melanoma. Moreover, its selective cytotoxicity against cancer cells presents exciting opportunities for developing novel plasma-based oncological therapies [3]. Nevertheless, cold plasma itself is also greatly affected by the treated target, making the plasma-target interactions mutual, and the controllability of treatment on complex biological tissues challenging. Thus real-time monitoring becomes essential to optimize therapeutic outcomes, and for advancing plasma medicine and ensuring safe and effective clinical applications.
With the continuous advancement of artificial intelligence technology, its applications in the field of plasma medicine have gradually gained attention. In recent years, researchers have utilized machine learning and deep learning algorithms to investigate the mechanisms of plasma-biomolecule interactions, optimize plasma treatment dose control, and develop adaptive plasma therapy systems [4-6]. These studies have not only enhanced the precision and efficiency of plasma medicine but also provided theoretical foundations and technical support for future clinical applications.
However, most of these studies lack an analysis of multi-source monitoring data. In fact, multi-source monitoring data across multiple scales—such as electrical measurements, ICCD cameras, optical

emission spectroscopy (OES), infrared cameras and also medical imaging equipments sucha as hyperspectral cameras —can provide extensive information on low-temperature plasma jets. In a pioneering study the team of Prof. Mesbah reported on combining infrared cameras and OES to control the thermal dose delivered to an aluminum plate by a plasma jet [7]. Using a similar approach and employing AI modeling to analyze these data, significant insights can be gained for cold plasma medical treatments over biological tissues. More importantly, by establishing relational models among multi-source data, it becomes possible to infer the information obtained from other sensors in real time using only easily monitored data (e.g., ICCD cameras). This approach greatly facilitates real-time decision-making in subsequent treatments.

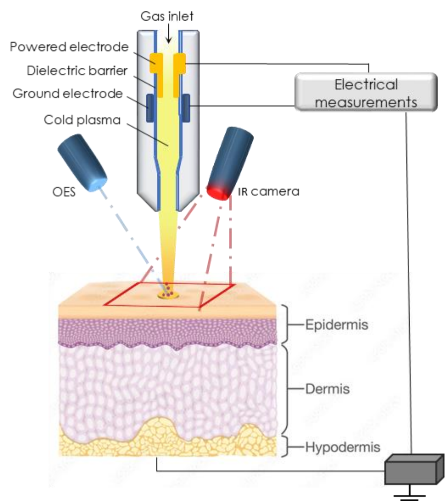

Figure 1 A schematic of the constructed platform including optical emission spectroscopy and infrared camera.

Method

1 - Multi-Source Monitoring Platform

Integrate sensors (electrical measurements, ICCD camera, spectrometer, infrared camera) for synchronized data collection. Calibrate and validate the system for accuracy. (Fig. 1)

2 - AI Modeling

Use Physics-Informed Neural Networks (PINN) and Bayesian optimization to analyze plasma behavior. Apply Principal Component Analysis (PCA) to reduce OES data dimensionality.

3 - Real-Time Monitoring & Decision-Making

Train AI models to infer key parameters (RONS concentrations, temperature) from easily monitored data. Validate predictions against experimental measurements.

4 - Optimization via Active Learning

Use multi-objective Bayesian optimization to refine treatment parameters.

Implement an active learning strategy to iteratively improve the model.

Timetable

Year 1: Literature review, platform design, and initial data collection.

Year 2: AI model development, real-time monitoring validation, and optimization.

Year 3: In-vivo testing, system refinement, and manuscript preparation.
Year 4: Thesis defense and publication submission.

Supervision

This thesis would be co-supervised by Dr. Eric Robert (CNRS Research Director) and/or Dr. Dunpin Hong (Professor at Polytech Orléans).

References

[1] Isbary, G., et al. "A first prospective randomized controlled trial to decrease bacterial load using cold atmospheric argon plasma on chronic wounds in patients." British Journal of Dermatology 163.1 (2010): 78-82.
[2] Maho, Thomas, et al. "Anti-bacterial action of plasma multi-jets in the context of chronic wound healing." Applied Sciences 11.20 (2021): 9598.
[3] Taheri, Donya, et al. "Realtime RONS monitoring of cold plasma-activated aqueous media based on time-resolved phosphorescence spectroscopy." Scientific Reports 14.1 (2024): 22403.
[4] Wu, E., et al. "Determining plasma dose using equivalent total oxidation potential (ETOP): Concept to practical application via machine learning." Applied Physics Letters 125.20 (2024).
[5] Chai, Zhao-Nan, et al. "Unveiling the interaction mechanisms of cold atmospheric plasma and amino acids by machine learning." Plasma Processes and Polymers 21.7 (2024): 2300230.
[6] Hou, Zichao, Taeyoung Lee, and Michael Keidar. "Reinforcement learning with safe exploration for adaptive plasma cancer treatment." IEEE Transactions on Radiation and Plasma Medical Sciences 6.4 (2021): 482-492.
[7] Gidon, Dogan, David B. Graves, and Ali Mesbah. "Predictive control of 2D spatial thermal dose delivery in atmospheric pressure plasma jets." Plasma Sources Science and Technology 28.8 (2019): 085001.