PhD Offer

Mask-free brain radiotherapy guided by surface: towards real-time adaptative treatment

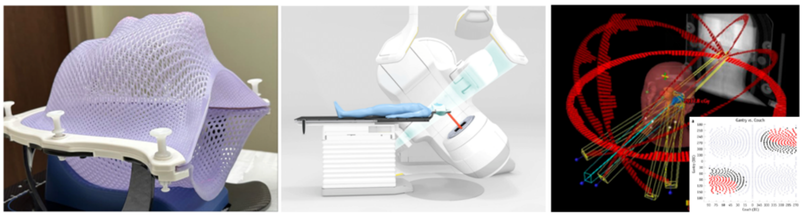

Figure 1: left, thermoformed masks used for immobilization in head radiotherapy; middle, treatment using surface tracking with camera and x-ray imaging; and right, beam trajectory optimization.

Scientific Context

Cranial radiotherapy, used in 10 to 15% of treatments, relies on the rigorous immobilization of the head using thermoformed masks (figure 1-left). Although precise, these devices are uncomfortable, anxiety-inducing, costly, and not environmentally friendly. This project proposes an innovative alternative based on surface-guided radiotherapy (SGRT), using cameras and x-ray imaging to track the patient's movements in real-time (figure 1-middle). The goal is to improve comfort by eliminating masks and to develop adaptive strategies that compensate for involuntary movements through dynamic adjustments of the beam or table positioning (figure 1-right). This approach promises to enhance the safety, precision, and comfort of treatments while influencing industrial practices towards devices better suited for dynamic and adaptive radiotherapy.

Hypotheses and questions raised

Surface-guided radiotherapy (SGRT), using cameras, is a recent technique aimed at improving the precision of patient positioning before each session. Our hypothesis is to determine whether SGRT can be used to reposition, verify, and monitor head movements, thereby replacing the treatment mask with a simple customized headrest. This would simplify the process while enhancing patient comfort. However, this approach raises a major clinical question: how can the safety and effectiveness of the treatment be ensured under these conditions? Our second hypothesis is whether adapting the irradiation (planning, dynamic adjustment) would ensure precise and robust treatment without requiring the beam to be stopped in case of small involuntary head movements.

Job Description and Missions

The first step will be to estimate the precision of positioning and movement tracking using the existing ExacTrac Dynamic® system through a clinical study involving 40 patients at Brest University Hospital. Following this, algorithms will be developed to extract critical internal structures from fluoroscopy images (x-rays) in real-time. The aim is to correlate external movements with those of internal structures by proposing a model. Dynamic adaptation strategies, including beam trajectory optimization, table repositioning, and hybrid beam-table compensation, will be implemented to maintain precision despite movements. The feasibility and dosimetric impact of these strategies will be evaluated through numerical simulations. To summarize, the thesis will be divided into the following steps:

1. **Platform Setup**: Establish an SGRT platform for the head using ExacTrac Dynamic® to position and track head movements during treatment. Develop algorithms and methods to align surfaces and anatomy in real-time.
2. **Clinical Evaluation**: Assess SGRT's capability in a clinical setting with 40 volunteers. Analyze movement measurements, anatomical realignment, and the impact of intra-fraction movements on dosimetry.
3. **Innovative Strategies**: Develop strategies to adapt the treatment beam before and during irradiation based on SGRT data, including optimizing ballistics, table movement, and dynamic beam adjustment.
4. **Simulation and Experimentation**: Evaluate movement compensation strategies through numerical simulations (Monte Carlo) and experimental irradiation of phantoms where feasible.

Profile

- **Education**: Master's research in computer science, signal & image processing, computer vision, medical physics, applied mathematics, or a related field.
- **Skills**: Proficiency in image processing, optimization, automation, and programming, particularly in Python.
- **Qualities**: Autonomy, open-mindedness, motivation, and English communication skills.

Position Context

The thesis will be conducted at LaTIM UMR 1101 / ACTION team, under the supervision of Julien Bert (research scientist) and Vincent Bourbonne (radiation oncologist). The project involves collaborations with the University of Brest, Brest University Hospital, INSERM, and international partners. Access to advanced research facilities and clinical data will be provided.
The thesis is expected to start in the fall of 2025, with a duration of three years.

Contact: For applications, please send your CV to: Julien Bert (Julien.bert@univ-brest.fr)