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Irradion: Portable Small Animal Imaging and Irradiation Unit

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Abstract : In this paper, we present a multi-robot imaging and irradiation research platform referred to as Irradion, with full capabilities of portable arbitrary path computed tomography (CT). Irradion is an imaging and irradiation unit entirely based on robotic arms for research on cancer treatment with ion beams on small animals (mice or rats). The platform comprises two subsystems that combine several imaging modalities, such as 2D X-ray imaging, CT, and particle tracking, with precise positioning of a small animal for imaging and irradiation. Computed Tomography: The CT subsystem of the Irradion platform is equipped with two 6-joint robotic arms that position a photon counting detector and an X-ray tube independently and freely around the scanned specimen and allow image acquisition utilizing computed tomography. Irradiation measures nearly all conventional 2D and 3D trajectories of X-ray imaging with precisely calibrated and repeatable geometrical accuracy leading to a spatial resolution of up to 50 µm. In addition, the photon counting detectors allow X-ray photon energy discrimination, which can suppress scattered radiation, thus improving image contrast. It can also measure absorption spectra and recognize different materials (tissue) types. X-ray video recording and real-time imaging options can be applied for studies of dynamic processes, including in vivo specimens. Moreover, Irradion opens the door to exploring new 2D and 3D X-ray imaging approaches. We demonstrate in this publication various novel scan trajectories and their benefits. Proton Imaging and Particle Tracking: The Irradion platform allows combining several imaging modules with any required number of robots. The proton tracking module comprises another two robots, each holding particle tracking detectors with position, energy, and time-sensitive sensors Timepix3. Timepix3 detectors can track particles entering and exiting the specimen and allow accurate guiding of photon/ion beams for irradiation. In addition, quantifying the energy losses before and after the specimen brings essential information for precise irradiation planning and verification. Work on the small animal research platform Irradion involved advanced software and hardware development that will offer researchers a novel way to investigate new approaches in (i) radiotherapy, (ii) spectral CT, (iii) arbitrary path CT, (iv) particle tracking. The robotic platform for imaging and radiation research developed for the project is an entirely new product on the market. Preclinical research systems with precision robotic irradiation with photon/ion beams combined with multimodality high-resolution imaging do not exist currently. The researched technology can potentially cause a significant leap forward compared to the current, first-generation primary devices.

Keywords : arbitrary path CT, robotic CT, modular, multi-robot, small animal imaging
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