Adding navigation to radio-guided surgery: new possibilities, new problems, new solutions

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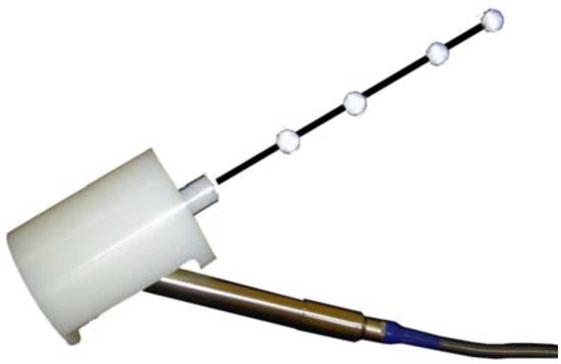
Handheld nuclear probes have been used since the late eighties for functional guidance during surgical procedures [Hoffman1999]. The motivation is to guide the surgeon based on the read-out of the handheld detector to regions of the body where high concentrations of a radio-labelled tracer can be found. If the tracer has been designed to specifically target molecular or physical processes, these nuclear probes enable to detect and spatially localize these processes and thus assist the surgeon by providing him/her with functional information in space, otherwise invisible or difficult to acquire intra-operatively.
Here we present a way to improve these procedures further by means of combining nuclear probes with tracking system and explore the possibilities that arise from that combination.

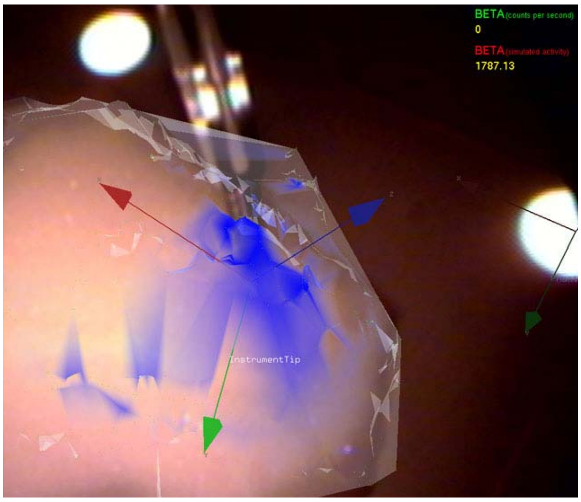
Tracked beta probe



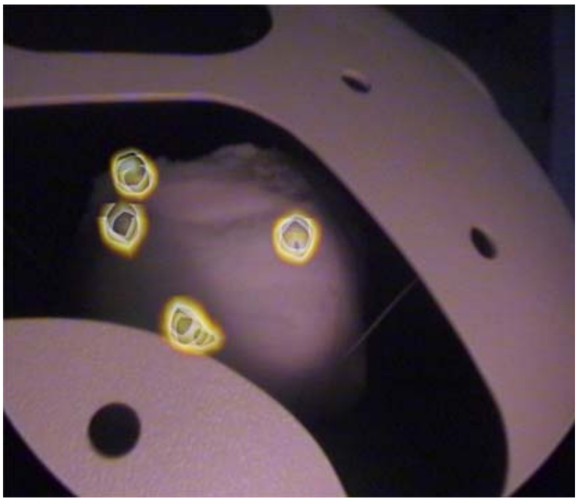
Tracked gamma probe

First we introduce the use of tracked gamma-probes for 3D tomographic reconstruction of radioactivity distributions as an extension of our previous work [Wendler2007]. By these means we show that intra-operative 3D nuclear imaging and thus in situ precise localization of labelled tissue is possible.
Second we describe the use of tracked beta probes for surface nuclear imaging. These images we show not only allow an intuitive visualization for control of tumour resection borders, but further enables accurate guidance of therapeutic areas to the sources of radiation. In particular in this application we use two visualization

approaches: augmented reality visualization and our novel concept of a simulated nuclear probe in the tip of any surgical instrument [Wendler2006].
In both presented applications we designed a system that synchronizes the readings of the nuclear probe with its position and orientation as provided by an optical spatial localization device. Moreover the position and orientation of the respective phantom and the one of a calibrated camera are acquired.
In the case of the tracked gamma probe, using the acquired positions and orientations of the probe, and ad-hoc developed models of the detection process we generated a system matrix as it is done in SPECT and calculated the source distribution using standard reconstruction techniques.
For the beta probe application we use the acquired points on the surface of the tumour bed and use them to generate a 3D surface by means of Delaunay triangulation. Moreover, this surface is visualized and the information of the probe read-out is colour-encoded in the same surface.
Further possibilities, current problems and ideas for solutions of these systems are finally discussed in the frame of the first implementations and experimental results of our group.



Beta probe reconstructed surface


Gamma probe reconstructed volume

References

- **[Hoffman1999]** Hoffman, E.J., et al.: Intraoperative probes and imaging probes. Eur J Nucl Med Mol Imaging 26(8) (1999) 913–935.
- **[Wendler2006]** Wendler, T., et al.: Navigated three-dimensional beta probe for optimal tumor resection. MICCAI 2006, LNCS 4190, pp. 561–569, 2006.
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