MSc project proposal "Registration of a deformable animal model with multiple 2D photographs"

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Background:

Molecular imaging offers new possibilities for pre-clinical (small animal) research, because it allows *in-vivo* imaging of biochemical (microscopic) processes at a macroscopic level. This means that the onset of pathological processes can be studied at an early stage, long before large-scale anatomical changes occur, and followed over time in the same animal. Nowadays a large range of small animal scanners is available (CT, MRI, PET, SPECT etc.) that enable acquisition of data of the entire animal body and thus to assess disease progression globally. This is of high interest for example in oncology research because it enables monitoring metastatic behavior of different types of cancer.
Other typical molecular imaging modalities are Bioluminescence Imaging (BLI) and Fluorescence Imaging (FLI), which enable in-vivo imaging of gene expression. Both have a very high sensitivity but their spatial resolution is low, which complicates linking the signal to the corresponding anatomy. Therefore, the data is often fused with a modality that provides high anatomical detail, such as MicroCT.

In our section we are working on combining (fusing) bioluminescence imaging (BLI) data (functional modality) with MicroCT data (anatomical modality). The challenges are:

1.) BLI and MicroCT data is acquired in different machines and therefore the datasets have to be brought into geometrical correspondence (registration).
2.) The BLI data is acquired in 2D (Figure 1) whereas MicroCT yields 3D information (Figure 2). To combine the two, a tomographic 3D reconstruction of the BLI light source from the 2D images is required and in order to do this accurately, a heterogeneous soft tissue model of the animal at hand is needed.

In previous work we developed a method to automatically register the BLI and MicroCT datasets, based on the silhouettes of the animal in the 2D photographs and an extracted animal skin from MicroCT [Wildeman et al. 2009] (Figure 3). In addition, we employed an anatomical animal model to segment the entire animal into bones and soft tissues [Baiker et al. 2010]. This heterogeneous tissue map can subsequently be used to perform the reconstruction of the 3D light source by means of Bioluminescence Tomography.

MSc assignment:

Currently, the derivation of the soft tissue map is based on the MicroCT dataset. However, it would be desirable to be able to obtain a heterogeneous tissue map also without having MicroCT data, because a MicroCT machine might not always be available.
The goal of the MSc assignment is to provide a heterogeneous tissue map, based only on the silhouettes from the 2D photographs. To this end, an animal model (Figure 3, bottom right) should be iteratively deformed until it optimally fits the 3D bounding box.

The student should:

- Review the existing work about animation of a model that contains rigid (bones) and soft (skin, organs) elements, within the computer vision literature.
- Extend the articulated skeleton model that we developed [Khmelinskii et al. 2011] by adding realistic soft tissue deformations, especially for the skin.
- Use the animal model for registration with the 2D animal silhouettes (implementation e.g. in Matlab).
- Perform pilot experiments with existing methods for Bioluminescence Tomography, using the heterogeneous tissue model.

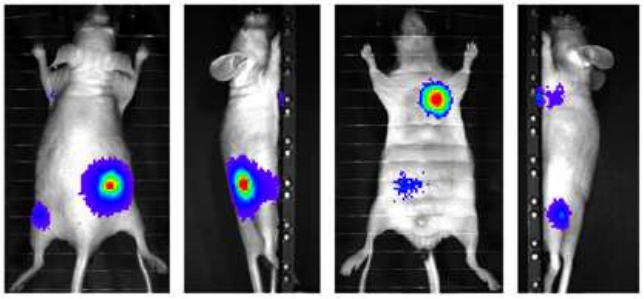

Figure 1 (left): Example of a BLI dataset after acquisition. BLI and light photography images are taken and overlaid (BLI is color coded) to give some indication where the light is emitted. In this case, images are taken from four different angles around the animal.

Figure 2 (right): MicroCT dataset of the animal shown in Figure 1. MicroCT yields a 3D dataset.

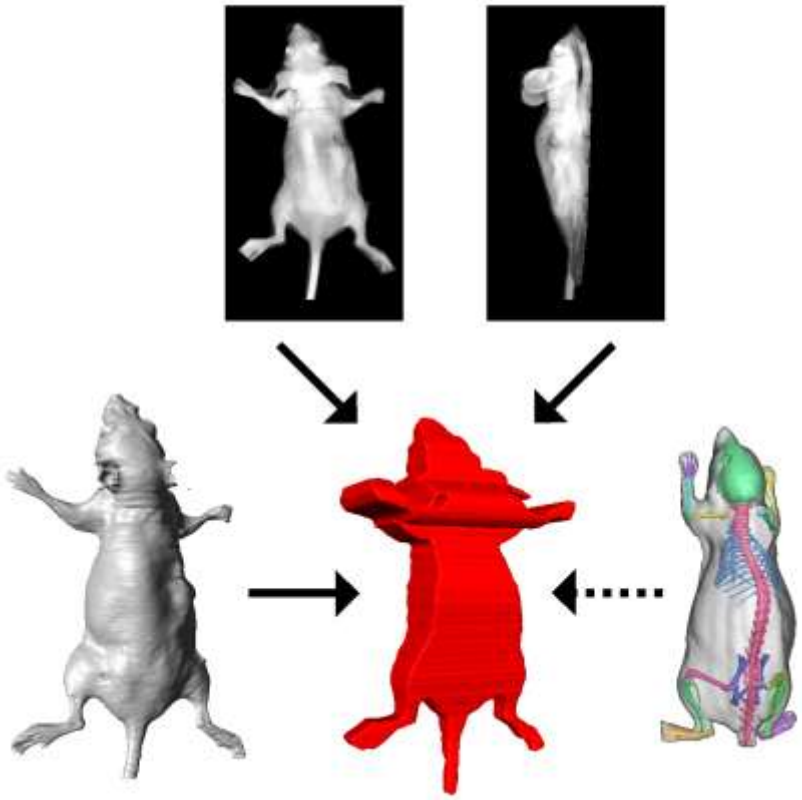

Figure 3: Two animal silhouettes from 2D photographs are used to derive a 3D bounding box (red). This bounding box can subsequently be used to automatically register an animal skin, derived from MicroCT (grey). Alternatively, an articulated animal model (bottom, right) could be deformed such that it fits the anatomy of the animal at hand.

References:

[Wildeman et al. 2009], 2D/3D registration of Micro-CT data to multi-view photographs based on a 3D distance map, ISBI 09, pp 987—990
[Baiker et al. 2010], Atlas-based whole-body segmentation of mice from low-contrast Micro-CT data, Medical Image Analysis, pp 723-737
[Khmelinskii et al. 2010], Articulated Whole-Body Atlases for Small Animal Image Analysis: Construction and Applications, Molecular Imaging and Biology