Field of View Alignment on a Multimodal PET/CT Scanner for Small Animals

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Abstract **This work describes a procedure for the alignment of the fields of view of a multimodal system. Combined PET/CT systems for small-animal imaging usually have two axially displaced fields of view (FOV) that are mechanically aligned only to a certain degree; the remaining errors can impair sub-millimeter registrations. The correction of these residual uncertainties in the geometry is calculated using a software tool that automatically computes the misalignment between FOVs and compensates for them during image reconstruction. The procedure only requires the use of a simple phantom for calibration.**

I. Introduction

MOLECULAR imaging of rats and mice requires precise registration of anatomical and functional imaging data [1]. Combined PET and CT imaging not only provides anatomical landmarks, but can also be used to calculate attenuation coefficients of the sample tissue, useful for corrections during the PET image reconstruction process. Instead of using two different instruments, combined PET and CT systems are axially integrated and aligned in such a way that the sample can be transferred from one system gantry to the other automatically, reducing the risk of misalignments.

However, the two axially displaced fields of view (FOV) can be mechanically aligned only to a certain degree; the remaining errors can impair sub-millimeter registrations. This difficulty stems from the fact that to achieve CT image resolutions of 50 micrometers and less, the X-ray source and the detector have to be carefully aligned. This alignment cannot only rely on the mechanical external landmarks of the device housing, because the X-ray beam direction at the tube exit window may vary from unit to unit. Therefore, the correction of these intrinsic uncertainties in X-ray beam and detector orientations with respect to their housings needs a post-acquisition calibration that includes the imaging reconstruction process.

Once the corrected X-ray CT geometry is calculated, the displacements with respect to the mechanical alignment cannot be easily transferred to the PET detectors. Unlike previous methods that rely on complex phantoms or intensive user intervention, our software tool automatically calculates the misalignment between FOVs, compensates for them during image reconstruction and requires the use of a simple phantom for calibration.

II. Methods

Two different imaging systems have been used in this evaluation: a small animal PET/CT in which both modalities are axially aligned (eXplore VISTA/CT, GEHC) [2], and a rotating PET/CT in which both FOV are intrinsically overlapped due to its co-planar geometry (VrPET/CT, SUINSA Medical Systems) [3].

In order to co-register the different modalities FOV, some previous works reported have made use of a special phantom that is located in the place of the animal holder; the fixture is prepared in such a way that it is easily transported between imaging devices; from those measurements a three-dimensional registration method for automated fusion of micro PET-CT-SPECT whole-body images was developed [4]. An alternative method based on lines visible in both modalities is also described in [5].

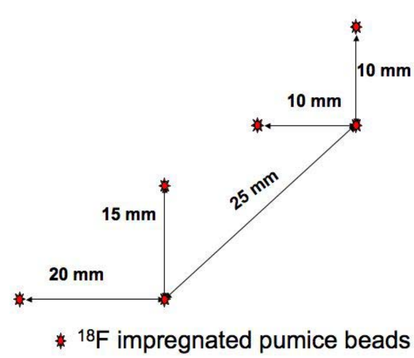

Fig. 1. Pumice beads arrangement in a 7 points configuration.

Our goal was to develop a simple method that will require minimal or no user interaction, and without the complexity of a dedicated device. For this purpose, a phantom with five to seven point landmarks visible in both modalities has been devised. Pumice stone was ground and fragments smaller than one millimeter were selected and dipped in an FDG solution. These hot beads were glued to a low-density, geometrically

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calibrated foam structure (Fig. 1). This phantom was fixed to the animal bed, and it was scanned on the PET, automatically transferred to the CT FOV on the double ring machine, and CT scanned. This axial translation was not necessary for the rotating scanner since both modalities share the same FOV given its co-planar design.

PET and CT FOV residual registration error was calculated identifying the pumice beads in each modality a following a point registration procedure [6]; this process can be followed, if necessary, by a Mutual Information registration procedure in order to improve the alignment accuracy [7,8]. The resulting coordinates were used to calculate the rigid transformation between the devices. The result is a six parameters (three translations and three rotations) matrix and provides an estimated registration error at each landmark.

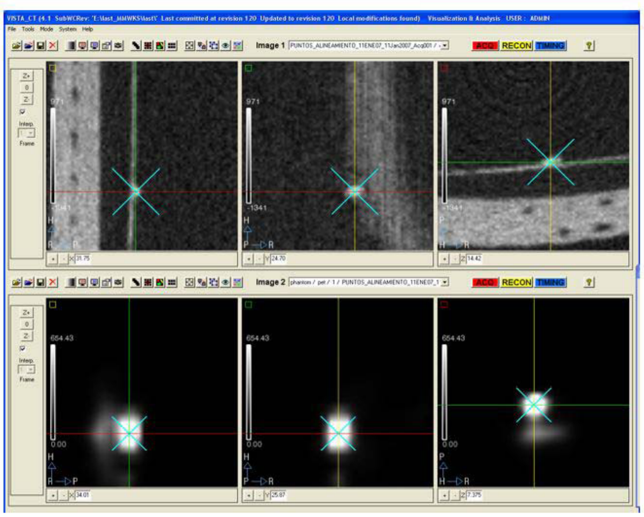

Fig. 2. CT (upper panel) and PET (lower panel) magnified images of a landmark. The blob center of gravity is used as the reference in the PET image.

III. Results

Pumice beads are easy to identify in CT. Image resolution is lower for the PET device compared to the CT; in this case the center of gravity of every blob has proven to be a very precise estimator of the landmark position. Fig. 2 depicts a triplanar view showing the landmarks as they are visualized in the two modalities.

An example of the alignment evaluation is shown in Fig. 3. Since major rotations and translations can be almost eliminated by correct hardware reorientation, only resulting matrices containing less than one degree of rotation around any axis are accepted and software corrected during the registration procedure. (Tx, Ty, Tz) (Rx, Ry, Rz) indicate the FOV translations and rotations respectively.

Results show that the PET/CT device is correctly aligned in terms of rotations, so this component is discarded from the intrinsic registration procedure. However, translations have to be applied in order to correctly fuse the datasets. Validation of the results, that was done using manual registrations, demonstrates that this is a reliable procedure easy-to-reproduce. Residual errors were due to the use of a model restricted to 6 parameters; it has been suggested that cone-beam geometries may require perspective trans-formations (15 parameters) to compensate for pixel size variations [9].

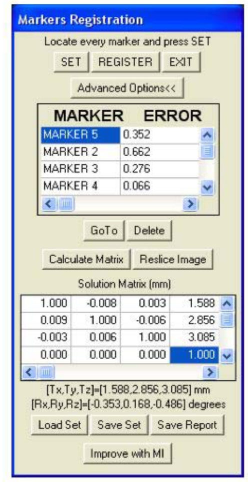

Fig. 3. Results for a 5 landmarks phantom. Error in mm is shown for each marker, together with the transformation matrix.

IV. Conclusions

Our results demonstrate that the proposed method can calculate the FOV misalignment with enough accuracy to achieve image registrations with sub-millimeter resolution in an easy and reliable way, with very little intervention from the user. To further improve the usefulness of the procedure would require the use of a 15 parameters transformation model and an increase of the number of landmarks.

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