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Software for the Use of Multi-Modality images in External Radiotherapy

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1 Preface

This report is based on the technical Annex 1 of the SUMMER project. The document is meant to provide a workflow description for multi-modal image fusion for registration of pre-, per- and post-treatment images for follow-up treatment in radiotherapy (RT). Quantitative integration of anatomical and functional magnetic resonance (MR), positron emission tomography (PET) and computed tomography (CT) imaging datasets can incorporate unique diagnostic information into CT-based treatment planning for RT.

2 Pre-, per, -post treatment images for follow-up in RT

Radiotherapy (RT) is one of the main therapeutic branches of cancer treatment next to surgery and chemotherapy. RT applies ionizing radiation to kill malignant cells and control cell growth. To spare the surrounding normal tissues (which radiation beam has to pass through to treat the tumor) shaped radiation beams are aimed from several angles of exposure to intersect into the tumor delivering the highest dose to the tumor.
For a reliable tumor delineation fusion of different (e.g. functional and anatomical) image modalities has clinical significance. To obtain a more exact tumor targeting during the RT treatment our aim was to develop a methodology optimizing a 3D-3D registration algorithm for fusing anatomical and functional (e.g. PET/CT and MR) images [1].
Our goal was to find an optimal geometric transformation between PET/CT or fMRI and MR images ready for clinical application. As PET and CT images are taken simultaneously with the same machine they already have a common representation, but a poor anatomical soft tissue contrast. However, MRI is well suited for imaging of soft tissues. Therefore we aligned CT from PET/CT and T1-weighted MR images having a common frame of reference into one coordinate system containing complementary information in the same image [2].
The acquired results provide information of the metabolic activity of the tumor cells obtained from PET and a good soft tissue contrast of T1-weighted MR in the same fused image. Assigning a lookup table for different activity sequences of the PET image it is possible to get an even more intuitive help for delineation of the tumor and possible cancer metastasis.

2.1 Image fusion

Image fusion is a process of combining different image information from a set of similar images into a single image which preserve all the relevant information of the input images. Input images are multi-modal functional and anatomical images acquired by different scanners.
The pre-processing step of the image fusion is the image registration, transforming all images into the same coordinate system (in our case in CT space).

3 Material and methods

3.1 Datasets

One head and neck patient consisting PET-CT and MR-T1 image modalities from Institute Claudius Regaud.
Fondazione Santa Lucia provided one head and neck patient consisting PET-CT and MR-T1, T2 weighted images and tree more patients of fMRI, MR-T1, MR-T2 and CT images from finger tapping study.

3.2 Workflow

Before the registration all the images were resampled to 1 mm voxel size. The CT and T1 weighted MR images were registered using commercial software, Analyze 11.0, AnalyzeDirect Inc. based on normalized mutual information (NMI) metric.
The CT is considered fixed image, the MR-T1 is aligned into the CT coordinate system. By applying the inverse transformation matrix to PET we can display the functional image of the PET with the MR-T1 obtaining functional and anatomical complementary information simultaneously.

4 Results

Registering CT and MR T1-weighted images commercial software called Analyze 11.5 was used. The transformation matrix of CT-MR registration was applied to the PET and MR T1-weighted images. On the registered PET-MR images consecutive distinction of the metastatic region was not satisfactory (Fig. 1). Applying a lookup table (LUT) to PET metabolic activity. (Fig.2) the tumor distinctness is more.

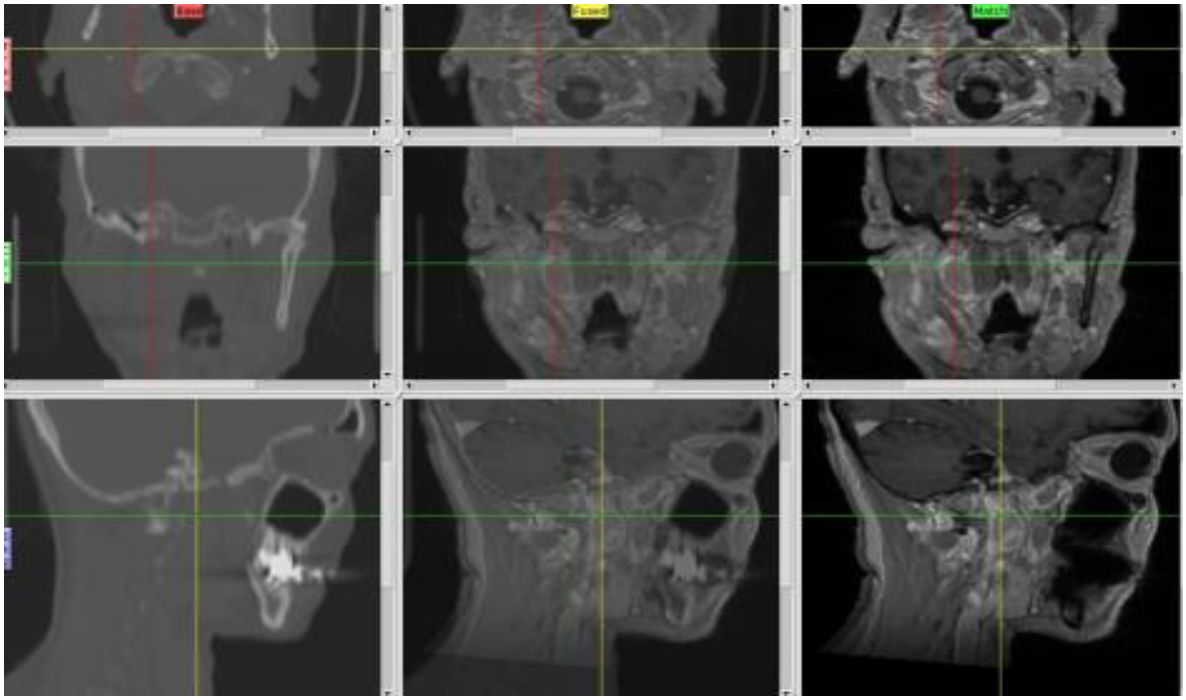

Figure 1: Head & neck patient. Courtesy to Institute Claudius Regaud, Toulouse.
a.) PET-CT b.) fused PET-CT and MR-T1 images c.) MR-T1

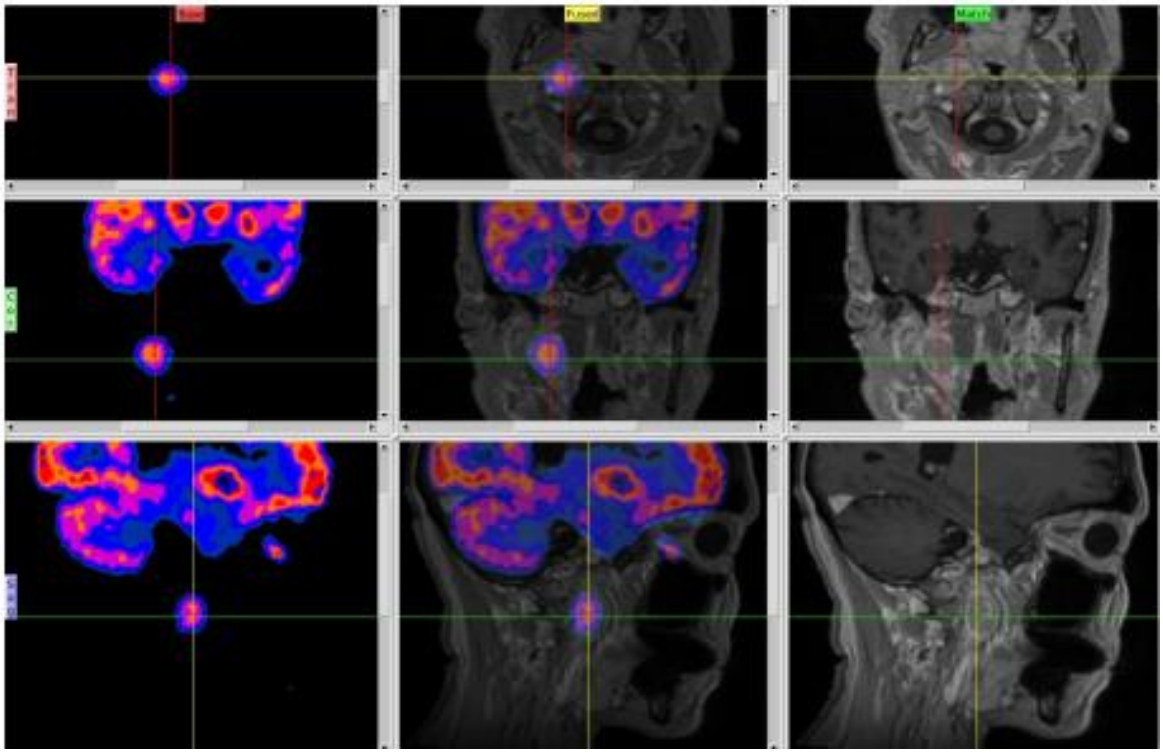

Figure 2: Head & neck patient.
col 1.) PET-CT associated with LUT col 2.) fused PET-CT, LUT with MR-T1 col 3.) MR-T1

One of the challenges is to associate an accurate lookup table to the activity maps. Depending of the chosen look-up table we can define different tumor margins (Fig. 1,2) or different activity maps e.g. in case of finger taping functional MRI (Fig.2, 3).

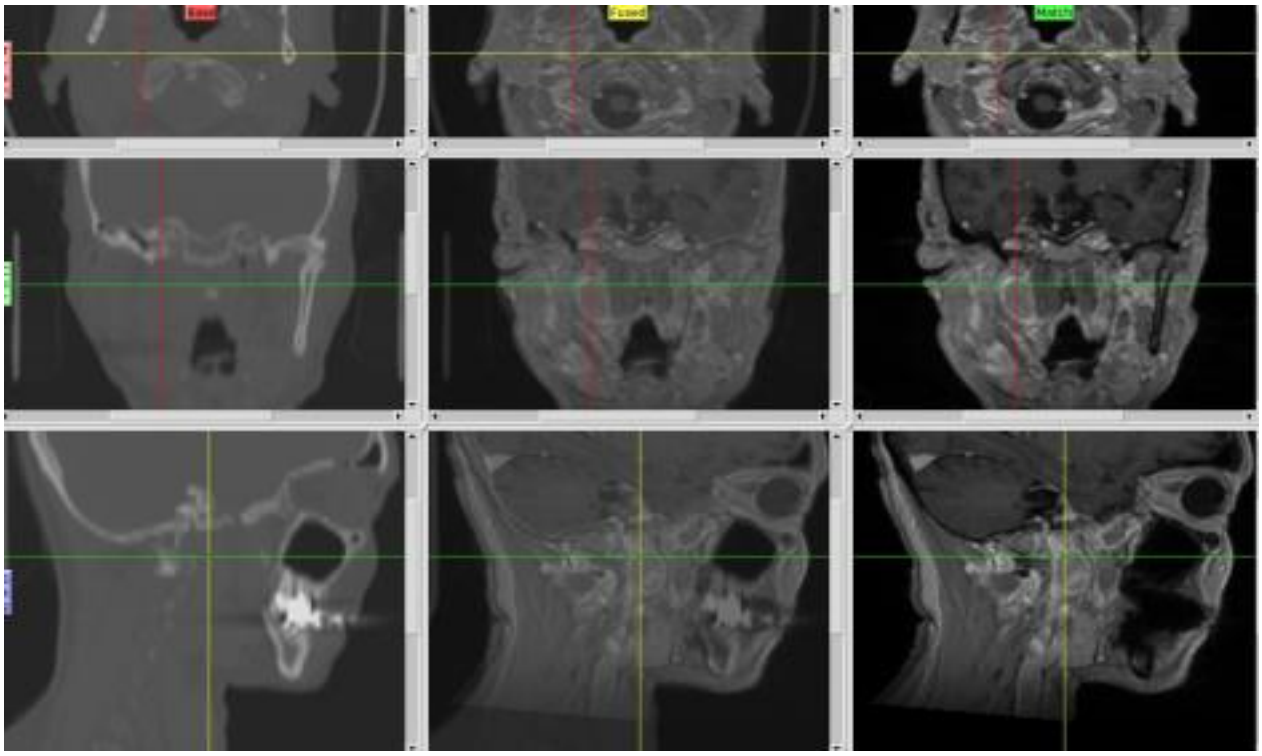

Figure 3: Glioma patient. Courtesy to Institute Claudius Regaud;
a.) MR-T1 b.) fused MR-T1 with fMRI c.) fMRI

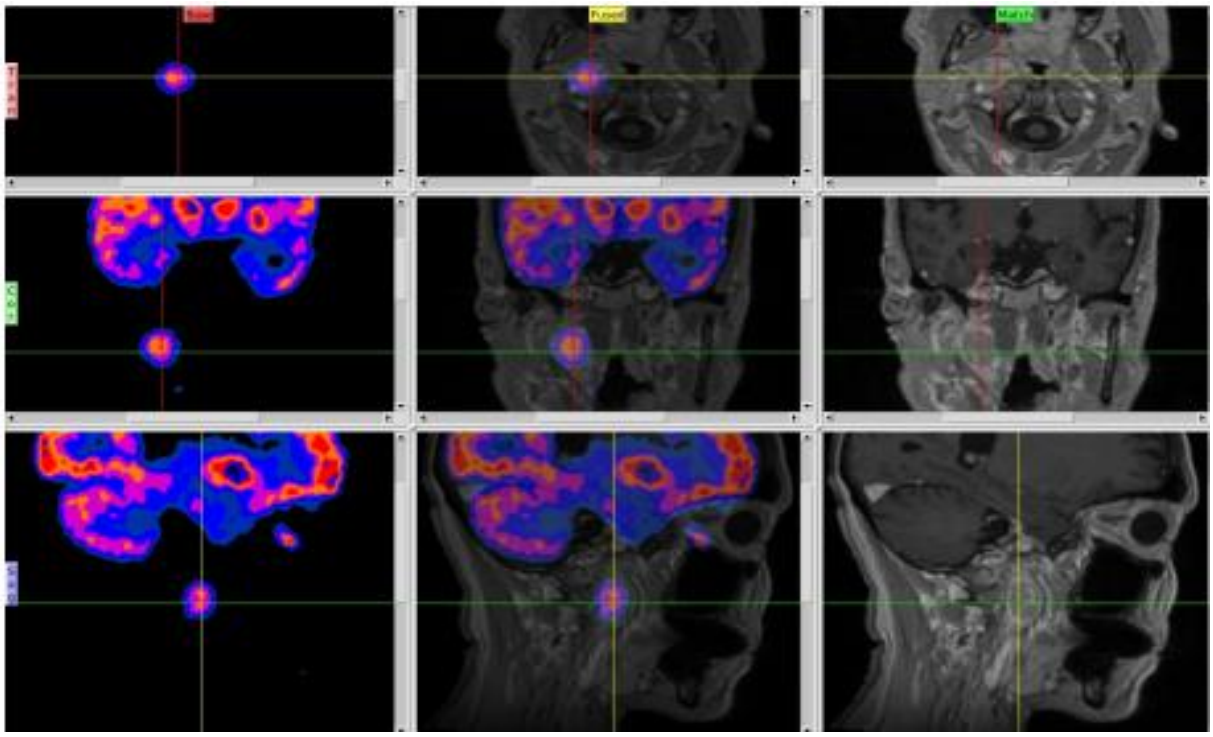

Figure 4: Glioma patient.
a.)MR-T1, b.) fused MR-T1-fMRI with assigned LUTc.) fMRI with associated LUT

5 Challenges

- Determining automatically the accuracy of registration[6-7]
- Assigning a standard look-up table to the metabolic or activity maps.

6 References

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