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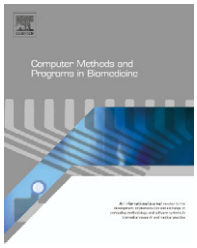

Simultaneous multi-modality ROI delineation in clinical practice

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ABSTRACT

The delineation of tumors and their surrounding organs at risk is a critical step of the treatment planning for radiation therapy. Besides computer tomography (CT), other imaging modalities are used to improve the quality of the delineations, such as magnetic resonance imaging (MRI) and positron emission tomography (PET). A practical framework is presented for using multiple datasets from different modalities during the delineation phase. The system is based on two basic principles. First, all image datasets of all available modalities are displayed in their original form (in their own coordinate system, with their own spatial resolution and voxel aspect ratio), and second, delineations can take place on all orthogonal views of each dataset and changes made to a delineation are visualized in all image sets, giving direct feedback to the delineator. The major difference between the described approach and other existing delineation tools is that instead of resampling the image sets, the delineations are transformed from one dataset to another. The transformation used for transferring the delineations is obtained by rigid normalized mutual information registration. The crucial components and the benefits of the application are presented and discussed.

1. Introduction

Accurate delineation of tumors and surrounding organs at risk is a critical step in treatment planning for modern radiotherapy. Besides the so-called planning CT, which forms the basis for radiotherapy dose calculations and treatment optimization, other imaging modalities are added to improve the quality of the delineations. Due to the superior soft tissue contrast over CT, magnetic resonance imaging (MRI) is one of the most prominent modalities used to enhance the visibility of tumor tissue and surrounding organs at risk [15,4,16]. This technique can be exploited by using multiple scanning sequences in different directions in one imaging session, each depicting specific information on which delineation decisions can be based. Also positron emission tomography (PET) is often used for delineation purposes, especially for identifying positive lymph nodes [12,6,5].

Since these different imaging datasets are becoming more and more available in the clinic, a new infrastructure is needed that provides an efficient and convenient way to work with these sets. In other words, a transition has to be made from a single dataset, CT-based delineation strategy to a multi-modality, multi-dataset-based delineation regime.

We have developed an application which provides a practical framework for using multiple datasets from different modalities during the delineation phase of the treatment planning. We formulated two major objectives:

- Each dataset is displayed in its own coordinate system and with its own spatial resolution. By displaying the sets sepa-

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rately and keeping the image content intact by using its own aspect ratio, delineations are performed on the patient data as it was originally acquired and intended. This property is especially useful when using angulated MRIs or MRIs which are imaged with an high in-plane resolution but a relatively large slice thickness due to scanning time constraints.
- The delineation of structures can be performed in all available datasets and on every orthogonal plane of each dataset. By using different modalities simultaneously and therefore giving direct feedback to the physician, the delineation consistency can improve. We transform the delineations between the different coordinate systems using a transformation which is obtained by image registration.

Furthermore, all contours which are manually delineated by a physician are never changed or adapted by anyone or anything other than the delineator himself. This also means that techniques such as contour smoothing, are only applied on explicit user request. The physician stays in control of the delineation process at all times. This objective increased the acceptance of our tool within our department considerably.

Here, we describe the crucial components of our delineation system, such as the registration phase and the simultaneous construction, transformation and visualization of the delineations on the different modalities. We also show how the framework is used within our department.

2. Materials and methods

2.1. Data definitions

Before we describe our tool in detail, we first define the terms we use regarding the data types needed to explain the principles our ROI delineation strategy.

- *Original image data*: These are usually three-dimensional image datasets as acquired on a imaging modality such as CT, MRI, PET, etc. The datasets have the same resolution and slice orientation as it was captured on the imaging device.
- *Resampled image data*: Image data derived from original image data, usually placed in a different coordinate system having a different resolution and slice orientation than the original image data.
- *Delineation data*: Delineation data is captured in contours (polygons) and triangulated 3D meshes. Note that in this paper delineations are never stored or converted to a voxel models and exist in 3D space without the of use of an underlying (original or resampled) image dataset.
- *Transformation data*: Describes how one coordinate system is associated with another coordinate system. Since we only use rigid transformations (translation and rotation), a transformation is described in a 4×4 transformation matrix when using homogeneous coordinates.

2.2. Clinical setup and work flow

In Fig. 1 the integration of the delineation tool within our department is visualized. It starts with acquiring various medical images from the patient at hand: besides the standard

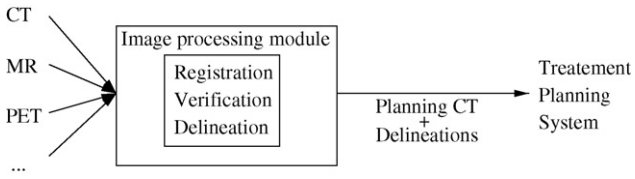

Fig. 1 – The delineation framework as it is currently implemented. The arrows represent a DICOM link. It starts with acquiring the medical images, then the registration and delineation takes place, followed by the export of the planning CT along with the delineations to the planning system.

planning CT, usually several MRI datasets are imaged during an imaging session and stored in a local database (Table 1 shows the number of imaging sessions for each modality in 2007 and 2008). After acquisition, the registration step takes place. The MRIs are registered to the planning CT by using an intensity-based matching algorithm (see Section 2.3). To ensure the quality of the registration, all registrations are visually inspected. Next, the delineation of the tumor and other regions of interest can start based on all available image modalities. Because of the lightweight character of the contouring application combined with a client–server setup (all CPU intensive tasks are performed on the server), this is done on a standard desktop PC of the physician.

After contouring, all delineations are converted to the coordinate system of the planning CT and transferred to the treatment planning system. All in- and outgoing connections of our framework are solely based on DICOM and also all locally stored data is kept in the DICOM file format. We have implemented the specialized radiotherapy subset of DICOM standard (DICOM RT) for transporting and storing the delineation data based on the official standard as described by the National Electrical Manufactures Association (NEMA). But we also used the DICOM conformance statement of our planning system for resolving some minor vendor specific issues. By using the DICOM standard, we are not dependent on vendor specific communication protocols, since DICOM is supported by all major commercially available imaging- and planning systems. Furthermore, this open framework enables us to access all imaging and delineation data easily for research purposes, especially when performing delineation and advanced imaging studies.

2.3. Registration

Before delineation can take place, the available datasets have to be registered to correctly correlate the different coordi-

Table 1 – Number of imaging sessions for each modality in 2007 and 2008 solely used for delineation purposes.

Modality	2007	2008
CT	2635	3129
MRI	868	1208
PET	56	193
Other	9	4