Résumé du projet de recherche (Langue 1)

In many applications, image segmentation is required at some point of the analysis, eg when assessing the texture of a tumor (either in PET or in MRI), when defining the gross tumor volume or the biological tumor volume for treatment planning in radiotherapy, or when computing kinetic parameters in brain studies. In PET, segmentation is always challenging due to the limited spatial resolution in PET images (from 2 to 8 mm depending on the PET system – from scanner dedicated to brain research to whole-body clinical scanners). Guiding PET image segmentation by integrating higher resolution MR images (~1 mm for anatomical MRI) is thus appealing. Methods have already been developed to take advantage of high-resolution images in PET segmentation tasks (eg. Shidahara et al 2009, Bousse et al 2012). A possible strategy consists in using an initial tumor localization derived from PET data, which is then used to constrain a deformable model for accurately segmenting the tumor in high-resolution images (Rouchdy et al 2011, Wojak 2010, Wojak et al. 2010). The latter scheme allows for many refinements such as performing tumor segmentation into parts by combining deformable models and fuzzy sets (Khotanlou et al, 2009), or jointly exploiting the information contained in multi-protocol MRI scans using multi-phase and multi-channel level set techniques (IsraelJost et al 2008). The current limitations of these methods are currently twofold: first, most of them are relatively sensitive to the accuracy of image spatial registration between the images; second managing possible mismatches between modality-specific information provided by the two imaging modalities remains an issue. Several aspects will be investigated to move forward in that research. Since 2006, IMT-Télécom ParisTech has performed seminal work on structural knowledge modeling (such as fuzzy spatial relations embedded in a graph (Bloch 2006) or ontological representation (Hudelot et al. 2008)) with the aim of guiding segmentation and recognition of structures in images, based on the fact that in both normal and pathological contexts, spatial relations are much more stable than shape information that is highly prone to individual variability. Sequential (Colliot et al. 2006, Fouquier et al. 2012) and global (Nempont 2009) constraint satisfaction schemes have been elaborated, yielding promising results on tumoral MR data. Building on these works, we will investigate the use of structural knowledge and spatial reasoning for modeling and understanding the structure and evolution of tumors within their anatomical context from PET-MRI data. Research will be carried out along two directions: (1) performing tumor segmentation using novel deformable tumoral organ models incorporating weak constraints on tumor location; (2) assessing the impact of a tumor on adjacent structures thanks to a description of image content jointly in qualitative and quantitative terms. To comply with the foreseeable variety of PET-MRI protocols, which will likely include multiple MR acquisitions delivering data with potentially different dimensions (eg T2+functional MRI) and statistics (eg T2+DCE-MRI), a unified and versatile framework for measuring similarity/discrepancy in multimodal multi-channel contexts is required. IMT-Télécom SudParis has previously developed region-based segmentation schemes using information-theoretic similarity measures in the level set framework (Rougon et al 2006). Recently, novel high-dimensional geometric entropic estimators have been identified (Hamrouni-Chtourou 2012), paving the way for multi-feature multi-channel statistical segmentation schemes that will be developed in this project. For specific anatomical territories investigated via multi-protocol MRI (eg abdominal and thoracic regions undergoing cardio-respiratory motion), technological constraints are likely to limit the applicability of motion correction within reconstruction (§ 5.1.1) to a subset of MR data. Hence, MR-based retrospective registration will be needed for aligning the remaining MR images. In addition, multimodal nonrigid registration will remain a need in longitudinal PET-MRI studies and radiotherapy planning. Depending on the PET-MRI protocol, various alignment strategies will be investigated based on IMT previous experience: (1) landmark-based: developments will rely on a nonlinear registration method developed by IMT-Télécom ParisTech, combining a breathing model with constraints on structure interfaces and tumors, which was shown to yield physiologically consistent results for PET-CT (Chambon et al. 2011, Moreno et al. 2008); (2) voxel-based: relying on a versatile multimodal high-dimensional statistical registration model developed by IMT-Télécom SudParis (Hamrouni et al 2011).

Résumé du projet de recherche (Langue 2)

The thesis results will include the development, implementation and validation of PET-MRI segmentation approaches, with handling of possible mismatch between PET and MRI information, and the demonstration of the quantitative impact of using MRI-guided PET segmentation in PET image quantification and radiation therapy planning.