CEMMTAUR :

CT synthEsis from Multicentric and Multisquence MRI daTA with qUality assessment for image-guided Radiotherapy

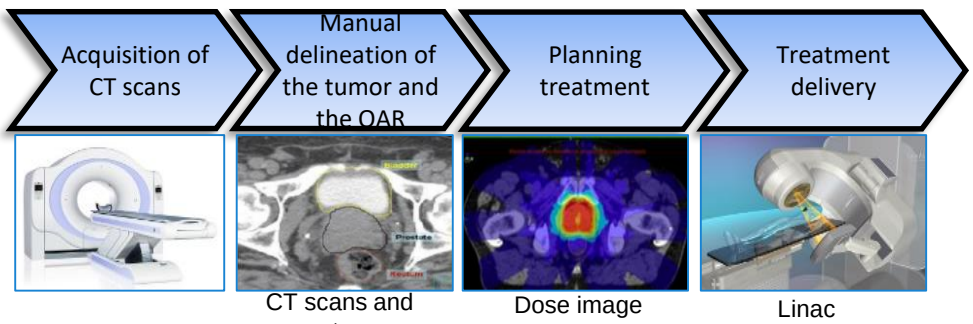
Laboratoire Traitement du Signal et de l'Image, INSERM U1099, Université de Rennes 1
NUNES Jean-Claude

Laboratoire des Sciences du Numérique de Nantes, UMR CNRS 6004, Ecole Centrale de Nantes
MATEUS Diana

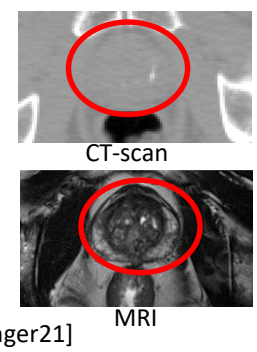
Scientific context

Cancer leading cause of death worldwide (10 million deaths in 2020), radiotherapy is one of the cancer treatment.

Workflow of external radiotherapy (RT):

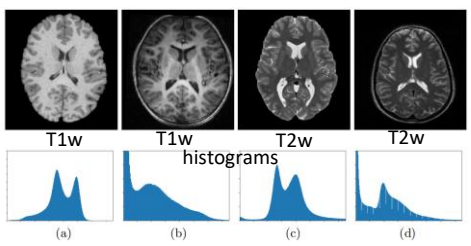


- CT-Scan: reference imaging for dose planning in radiotherapy (RT)
  - poor contrast in soft tissues and ionizing imaging
  - imprecise delineation of the tumor and the organs at risk (OARs)
  - limiting the quality of the daily patient treatment positioning
- MRI: better soft tissue contrast compared to CT
  - but MRI do not provide electronic density information necessary for dose calculation
- State of art MR-to-CT synthesis: deep learning methods (DLM) [Boulanger21]



Limitation of DLM-based MR-to-CT synthesis:

- variety of image acquisition systems (manufacturers, calibration, acquisition parameters, magnetic field, etc.)
  - training data specific to CT/MRI device [Boulanger21]



Goals :

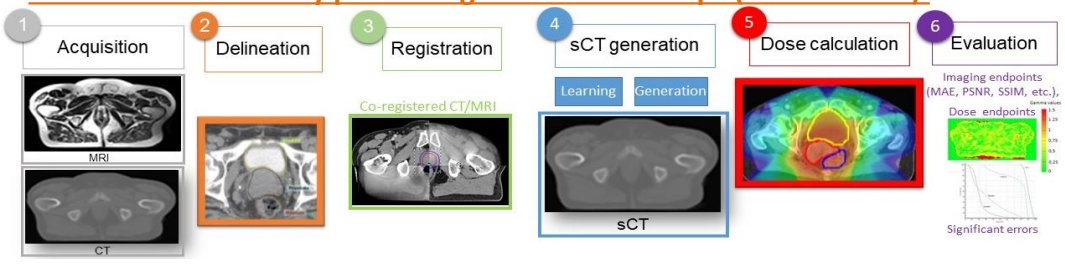
- Generation of synthetic CT (sCT) from MRI, based on DLM
- Development of a a generic approach taking into account the variety of image acquisition systems
- Combine several 3D MR sequences (T1, T2, resolution, LavaFLEX, etc.)
- Develop supervised and unsupervised learning

Data :

- Prostate and brain cancer: 3D CT, 3D MRI (T2, LavaFLEX) from Centre Eugène Marquis (CEM), Centre Régional de Lutte Contre le Cancer (CLCC) de Rennes.

Workflow of the study (Work Packages):

Workflow of the study presenting the different steps (WP1 to WP6):



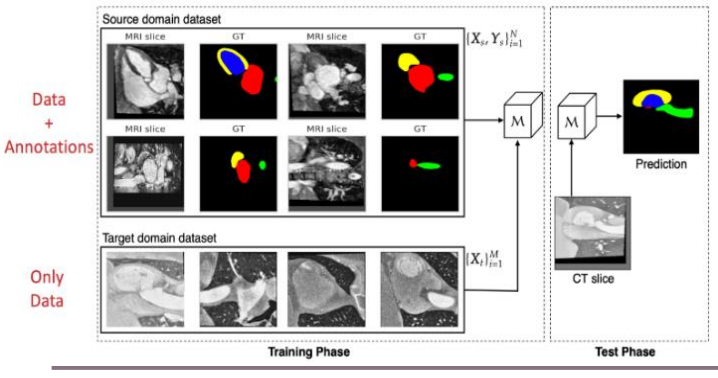
Automatic segmentation and uncertainty WP2

Automatic segmentation (LS2N, Nantes)

- Anatomical regions: **prostate** + OARs (rectum, bladder) and **brain** + OARs (medulla, brainstem, pituitary gland, lens, eyes, retina, chiasm, optic nerve).
- Joint segmentation across different MR sequences (T1 and T2, LavaFLEX): exploit all data available.

Challenges:

- Structures not visible on CT for dose computation: build on unsupervised and weakly supervised domain adaptation [AlChanti21a] to transfer segmentation of soft tissues from MR to CT.
- Associate an uncertainty measurement to the predictions [Jimenez22].



OLVA Optimal Latent Vector Alignment [AlChanti21a] relies on a VAE (Variational Autoencoder) and Optimal Transport to align the latent vector representation of organ shapes from two modalities.

Image registration (MRI/CT and MRI/MRI) WP3

Image registration (LS2N and LTSI):
To match patient anatomy between CT and MRI
Method: a multimodal non-rigid registration approach (MRI/CT) guided by segmentation. Explore hybrid optimization and deep learning based approaches [Fourcade22]

Evaluation of image registration will be based on:

- Iconic measures: Mutual Information (MI), Structural Similarity (SSIM), Modality Independent Neighbourhood Descriptor (MIND)
- Geometric measures based on delineated structures using dice score coefficients (DSCs), Hausdorff distance (HD) and normalized cross-correlation (NCC).

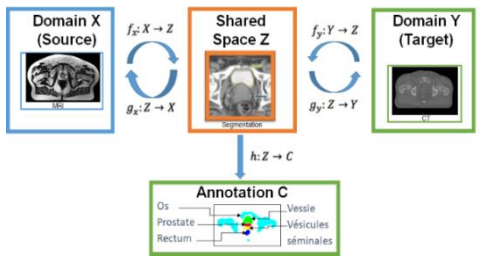
Multicentric MRI-to-CT generation WP4

DL-based sCT generation method (LTSI)

MR-to-CT generation based on DLMs in multi-center context

- from several MR images, multiple inputs (named multi-input single-output (MISO)) [Koike20]
- supervised learning with registered paired MR and CT volumes
- unsupervised (unpaired MR and CT) learning methods [Hoffman17, Hiasa18]
- domain adaptation methods [Wilson20, Guan21, Murez18]

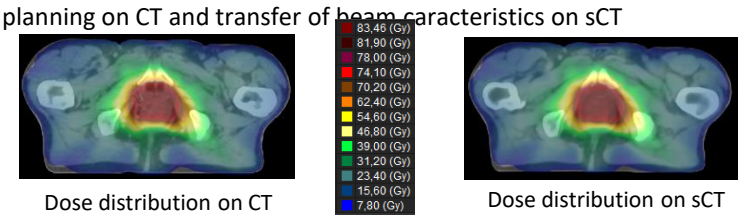
Proposed sCT generation method



Dose calculation WP5

Dose Calculation (LTSI):

- Use of treatment planning system (TPS) Raystation (Raysearch) at Centre Eugène Marquis
- Dose planning on CT and transfer of beam caracteristics on sCT



Dose distribution on CT

Dose distribution on sCT

Evaluation WP6

Standardizing the sCT evaluation (LTSI)

- Imaging endpoints based voxel-wise comparison (sCT vs CT): Mean Absolute Deviation (MAE), Mean error (ME), PSNR, Structural Similarity Metric (SSIM), Visual Information Fidelity (VIF),
- Dosimetric endpoints: voxel-to-voxel dose difference (between dose calculated on CT (reference and on sCT), dose-Volume Histogram (DVH) differences , Gamma-index analyses (comparison of dose distributions)
- Voxel-wise statistical test (Chen permutation test) will be applied on images and on dose distributions [Chourak21].

Expected results and medical potential impact

- Increase the quality of delineation of the target volume and OAR from the MR-image;
- Development of a non-specific center/device, accurate and fast learning of DLM to generate sCT from MRI → accurate dose calculation from MRI (with sCT)
- Avoid the CT acquisition step for patient RT workflow: decrease delineation and registration uncertainties, that could reduce toxicities and increasing local control
- Improve the state of the art in DLMs for sCT generation and joint segmentation-registration;
- Lead to patents and scientific communications/publications.

References

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