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PET-CT Registration: Comparative Affine and Deformable Methods

Registro PET-CT: Comparación de Métodos Afín y Deformable

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Resumen— Este trabajo presenta un análisis comparativo entre los métodos de registro afín y deformable para la alineación de imágenes médicas PET-CT.

Palabras clave

PET-CTEliminar PET-CTMedical ImagingEliminar Medical ImagingAffine RegistrationEliminar Affine RegistrationDeformable RegistrationEliminar Deformable RegistrationDICOM

Abstract— This work presents a comparative analysis between affine and deformable B-spline registration methods for PET-CT medical images alignment.

I. INTRODUCTION

PET-CT image registration is crucial for accurate tumor localization but remains challenging due to respiratory motion and anatomical variations [1]. Positron Emission Tomography (PET) captures metabolic activity, while Computed Tomography (CT) provides high-resolution structural images [2]. Previous methods focused on whole-body registration but lacked precision in localizing specific features [3]. Deep learning methods offer improvements but require large datasets and extensive training, limiting clinical feasibility [4]. For overcome these limitations, our study introduces a two-stage registration process: first, an affine transformation ensures a global alignment, followed by a deformable B-spline model for local adjustments.

II. MATERIAL & METHODS

The registration process was developed in Python using SimpleITK for image processing. The dataset consisted of PET and CT DICOM images from 12 patients, obtained in collaboration with Centro de Imagenología Nuclear, Guadalajara PET. Each patient case included 263 PET images and 343 CT images. The workflow begins by loading the CT and PET images in DICOM format, PET image is resampled to match the CT's spatial resolution using trilinear interpolation. The registration process employs a two-stage approach. First, an affine transformation is computed using gradient descent optimization and Mutual Information (MI) as the similarity metric. A subsequent deformable registration step applies a B-spline transform to account for local anatomical variations, optimized with the Limited-memory Broyden-Fletcher-Goldfarb-Shanno algorithm (L-BFGS). The final registered PET image is generated by resampling the original PET data using the computed transformation. Visualization includes 2D multiplanar reconstructions (axial, coronal and sagittal) with CT in a grayscale and PET custom semi-transparent colormap. PET intensities are normalized to the 99.99th percentile for consistent display.

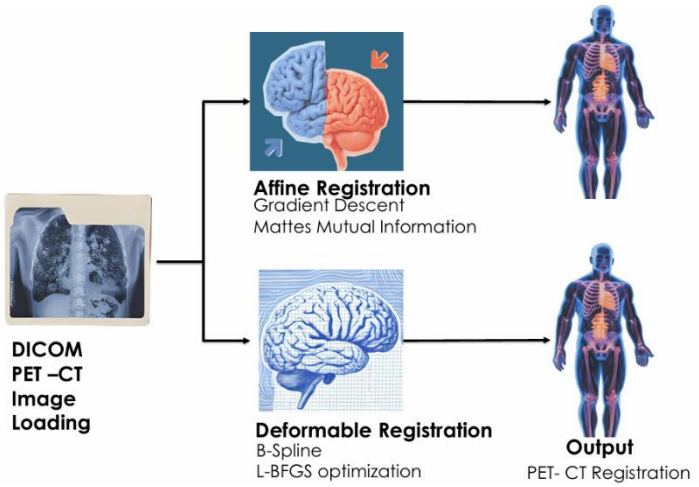
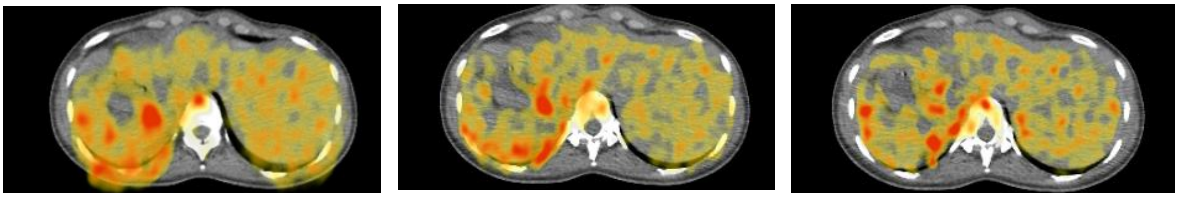


Figure 1. Workflow of PET–CT registration using Affine and Deformable B-Spline method

III. **RESULTS**

The registration pipeline successfully aligned PET and CT images using both affine (7~10 minutes) and deformable B- spline (15~20 minutes) transformations withs L-BFGS optimization.



Without Registration *Affine Registration* *Deformable Registration*

Figure 2. Comparative results: Without Registration, Affine Registration and Deformable Registration

The quantitative metrics MI and MSE (Mean Squared Error) were used to objectively measure image alignment. Higher MI indicates better alignment, reflecting more shared information, while lower MSE shows reduces pixel intensity differences.

Table 1. Quantitative comparison metrics

Metric	***Affine***	***Deformable***
MI	0.0749	**0.1048**
MSE	0.1130	**0.1116**

The deformable registration method achieved superior alignment with higher MI (0.1048) and marginally better MSE (0.1116). As shown in Fig. 2 the qualitative results visually support this improvement, with better correspondence especially in the posterior right region of the images, highlighting the advantages of deformable registration for capturing fine structural differences.

IV. **CONCLUSION**

Deformable registration outperforms affine registration in quality and accuracy. Affine registration handles only global transformations, deformable registration accounts for complex local variations, optimizing a loss function that integrates spatial and frequency domain similarities for more precise alignment.

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