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Contour Point Signature in Registration Tomography and Magnetic Resonance Images

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Medical image registration plays a crucial role in several clinical applications, where the alignment of image modalities is essential for accurate diagnosis and effective treatment[1, 4]. To address this registration challenge, we explore an innovative feature-based approach using the Contour Point Signature (CPS) proposed in [2]. Given a contour A, whose reference points are $\mathcal{P} = \{p_1, p_2, \ldots, p_N\}, p_i \in \mathbb{R}^2$, the Contour Point Signature relative to point p_i:

$$f_{p_i}(j) := \frac{1}{\|A\|}|p_i - p_{r(j)}|, \quad \begin{cases} r(j) & = i, i+1, \ldots, N, 1, 2, \ldots, i \\ j & = 1, 2, \ldots, N+1. \end{cases} \tag{1}$$

This function represents the relative distance distribution of contour points, which is a unique signature for each shape. Taking the signatures of all points in $\mathcal{P}$ using equation (1), we obtain a matrix whose ij-entry is given by $f_{p_i}(j)$ (descriptor feature matrix of the shape). The Matrix stores the signatures of contour points, providing a structured representation of the shape based on its contour, capturing the object's form.

To register two images ("fixed" and "moving"), we use a cost matrix H that quantifies contour similarity and determines the optimal "rotation" for alignment. It is computed using the CPS of both contours and the Euclidean distance d in $\mathbb{R}^N$. It is defined by:

$$H(j) = \sum_{i=1}^{N} d(f_i, g_{\pi(i,j)}), \quad j = 1, 2, \ldots, N, \tag{2}$$

where the rotation function is given by $\pi(i,j) = (i + j - 2) \mod (N) + 1$. The optimal rotation index value of $\hat{j}$ is obtained by $H(\hat{j}) = \min_{j=1,\ldots,N}\{H(j)\}$.

CPS does not require processing the entire image, which is suitable for large-scale medical imaging applications. It is invariant to translation, rotation, and scale, and robust to noise [2]. Despite these advantages, the overall registration process remains sensitive to noise due to its dependence on preprocessing for contour extraction. We employ a marching squares method to extract iso-valued contours based on a given intensity threshold. Hence, the quality of the extracted points is crucial for reliable registration. Nevertheless, despite this sensitivity, the obtained contour points can still be used to simulate landmark-based registration, enabling the evaluation of CPS in different scenarios.

Figure 1 illustrates the CPS-based registration process. (a) Fixed image (512×512 pixels), with extracted CPS points as reference landmarks. (b) Moving image (256×256 pixels) before transformation, with CPS points misaligned due to positional and scale differences. (c) Aligned

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CPS points after transformation. Moving points have been adjusted to align CPS points with those of the fixed image. This means a successful registration.

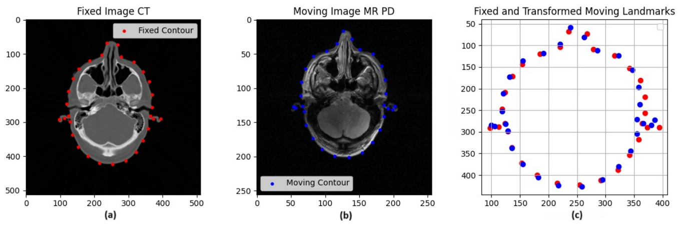

Figure 1: Medical image registration using CPS. (a) Fixed image with extracted CPS points. (b) Moving image before transformation. (c) CPS points aligned after transformation. Source: Own work.

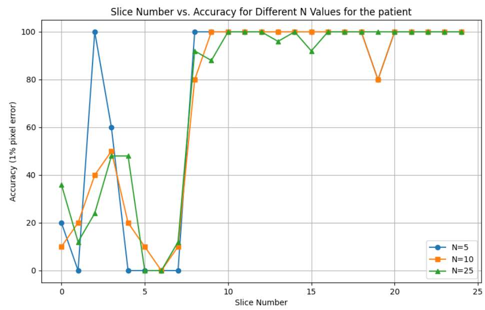

Figure 2: Accuracy results. Image dimensions 512×512 pixels, error threshold of 1% (approx. 5.12 pixels). Source: Own work.

The accuracy is evaluated using the Euclidean distance between corresponding fixed and moving points in the patient's slices after transformation (Figure 2) [3]. Figure 2 shows an accuracy 72.80% for $N = 10$. Findings indicate that CPS is an appropriate registration method, and accuracy relies on the quality of contour extraction. A more appropriate preprocessing step could improve landmark correspondence and overall registration accuracy.

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