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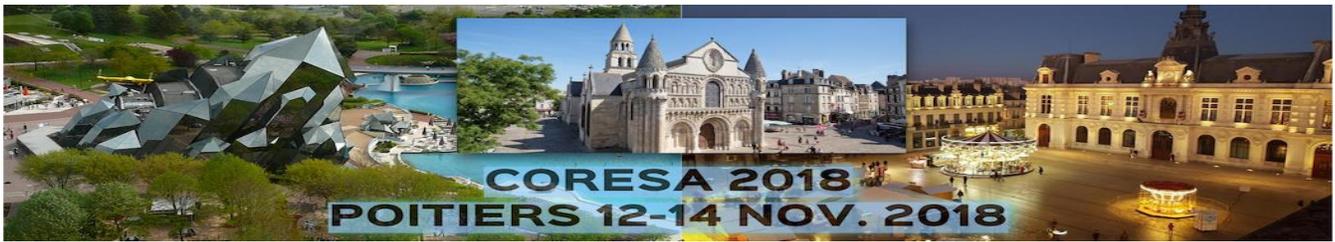
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Titre :

Image Registration for Biomedical Images on Irregular Grids

Auteurs :

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Résumé (100-200 mots) :

Microendoscope with spiral scanning produces images on irregular grids [5]. We propose a novel image registration strategy on irregular grids using Graph Wavelet (GW) constraint under the Log-Demons framework. The GW transformation is flexible to apply to different types of data regardless of the data point densities and how complex the data structure is. We also show how the Log-Demons framework can be adapted to optimize the objective function defined for images on irregular grids. Our results compare the performance of our method on irregular grid with the existing methods on a regular grid. To the best of our knowledge, this research is the first study on image registration on an irregular grid.

Mots-clefs (3 à 5 max.) :

Irregular grid, Graph Wavelets, microendoscopic images, Log-Demons

Contexte et état de l'art :

Our work focuses on registering two images acquired on irregular grids. Such an image has floating point coordinates and different point densities. The images are taken by a multiphoton microendoscopic whose optical fiber scans along a spiral path, starting from the center to the periphery of the area [5]. Such scanning produces a list of raw pixels on an irregular grid with floating coordinates.

Motivated by the fact that the system requires a robust image mosaics, it is important to have a sufficient non-rigid registration between the overlapping regions of two frames to compensate for the non-rigid deformations. These overlapping regions are at different positions of the two images, thus, have different point densities. Apart from the difficulties of the image grid characteristic, such images come up with much noise, illumination changes and non-rigid deformations.

The Log-Demons registration method [1] is known as a popular method for medical image registration, which is simple to implement and fast to compute. However, the optimization with a Gradient based update is easy to fall into local minima and lacks geometric invariance. It was shown in [3] that the graph spectrum is geometric invariant can be successfully embedded in a direct feature matching method under the Log-Demons framework to capture large and complex deformations. However, the registration using graph spectrum is sensitive to noise.

Recent research of Hammond et al [2] proposed a new computation of Spectral Graph Wavelets defined in the graph spectral domain. It is a flexible model constructed on an irregular weighted graph, thus, allows us to utilize the benefits of the graph representation of image on an irregular grid. More importantly, the Spectral Graph Wavelets not only represent images at different frequencies but also are isometric invariant under deformations of shape. Our previous work [4] proves the advantages of registration on regular grid using Spectral Graph Wavelets (SGW) [2] over the benchmark method that uses the graph spectra, especially when noise exists. In this paper, we exploit the previous research on image registration on regular grid that uses SGW under the Log-Demons framework to formalize a novel image registration method for images on irregular grids.

Travail proposé (Décrire l'objectif du travail et indiquer clairement le problème/défi technique étudié) :

Problem: Find transformation s from target image I_T and source image I_S such that $I_T = I_{S \circ s}$ with $I_T \in \mathbb{R}^M, I_S \in \mathbb{R}^N$ with floating point coordinates: $X_T = (V_{xt}, V_{yt}), X_S = (V_{xs}, V_{ys})$, resulting in different graph topologies (Fig. 1).

Background:

Graph definition: A graph $G = (\mathcal{V}, \mathcal{E})$ is composed of a finite set of vertices $\mathcal{V} = \{v_1, v_2, \dots, v_N\}$ and a set of edges \mathcal{E} that represents the connection between edges, e.g. $(i, j) \in \mathcal{E}$ if v_i is connected to v_j . In this research, each sample point is represented by a vertex and edges represent neighboring structure of points. Such graph can be represented on an adjacency matrix A where A_{ij} undirected edge weight between vertices v_i and v_j .

The Laplacian matrix of a graph G is given by $L = D - A$, where D is a diagonal degree matrix and each value D_{ii} on the diagonal is the sum of the weights of all the edges incident to vertex v_i .

Graph Fourier Transform: Given a graph signal $f \in \mathbb{R}^N$ where N is the number of vertices, the eigendecomposition of the Laplacian matrix is written as $v_\ell = \lambda_\ell v_\ell$, where the set of eigenvalues and eigenvectors $\{\lambda_\ell, v_\ell\}_{\ell=1, \dots, N}$ form the eigensystem of the Laplacian matrix. The graph Fourier transform is given by:

$$\hat{f}(\ell) = \sum_{n=1}^N v_\ell^*(n) f(n),$$

Spectral Graph Wavelet Transform: Once the graph Fourier transform is defined, the Spectral Graph Wavelets are modulated by a generating kernel g . The Wavelet coefficients of graph signal f at scale t is given by:

$$W_f(t, n) = \sum_{\ell=1}^N g(t\lambda_\ell) \hat{f}(\ell) v_\ell(n)$$

In order to encode the low frequency of signal f , a second class of waveforms h is defined similarly to the low pass filter in classical wavelet transform, such that: $h(0) > 0$ and $\lim_{n \rightarrow \infty} h(x) = 0$. The scaling function coefficient $S_f(n)$ is given by:

$$S_f(n) = (h(L)f)(n) = \sum_{\ell=1}^N h(\lambda_\ell) \hat{f}(\ell) v_\ell(n)$$

Registration Method: I_S is first interpolated to the grid of I_T with scatter interpolation. Then, compute the SGWs of I_T and I_S on an irregular grid at t scales, resulting $t + 1$ column vectors for each image.

We choose the first k vectors at lower bands for registration, given by $W_T \in \mathbb{R}^{M \times k}$ for the target image and $W_S \in \mathbb{R}^{N \times k}$ for the source image. The registration, thus, can be cast into a feature matching problem that matches $\mathbf{T} = (\alpha_i I_T, \alpha_s X_T, \alpha_g W_T)$ and $\mathbf{S} = (\alpha_i I_S, \alpha_s X_S, \alpha_g W_S)$, where $\alpha_i, \alpha_s, \alpha_g$ account for the intensity, spatial and geometric weights. The objective function is defined as:

$$E(T, S, s) = \alpha_i \|I_T - I_{S \circ s}\|^2 + \alpha_s \|X_T - X_{S \circ s}\|^2 + \alpha_g \|W_T - W_{S \circ s}\|^2$$

The optimization is an iterative approach under the Log-Demons framework [1].

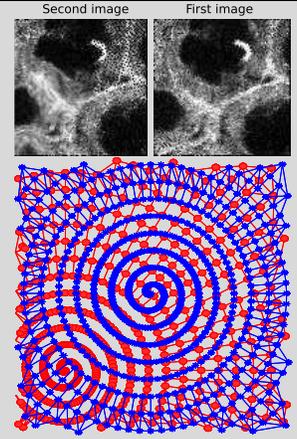


Figure 1: Graph topology of two different images on irregular grid (Blue: first image, Red: second image)

Résultats :

We benchmark our method against the two methods on regular grid (Spectral Demons, SGW Demons) and Spectral Demons on irregular grid.

We experiment two random pairs of frames in the sequence. The target and source images are cropped from the chosen frames. The system allows us to know the global shift between every two frames. For visualization, the images are projected on 100x100 Cartesian grid, and so for the tests on regular grid.

In Fig. 2a, each row represents the registered images of one pair of images with different methods. It can be clearly seen that the registration on a regular grid suffers from the smoothing effect.

Fig. 2b shows the Signal to Noise Ratio (SNR) values w.r.t the number of iterations. In both cases, the registration on regular grid is inconsistent. On irregular grids, the SGW Demons improves approximately 0.6 dB in the first pair and 0.5 dB in the second pair.

Fig. 3 allows us to see more clearly the result of our method applied on the first pair of images on irregular grids. In the representation of the difference, the target image is in the red channel, the source and registered images are in the green channel. The region covered by red line shows that the differences between the registered image and the target image have an improvement compared to the initial difference.

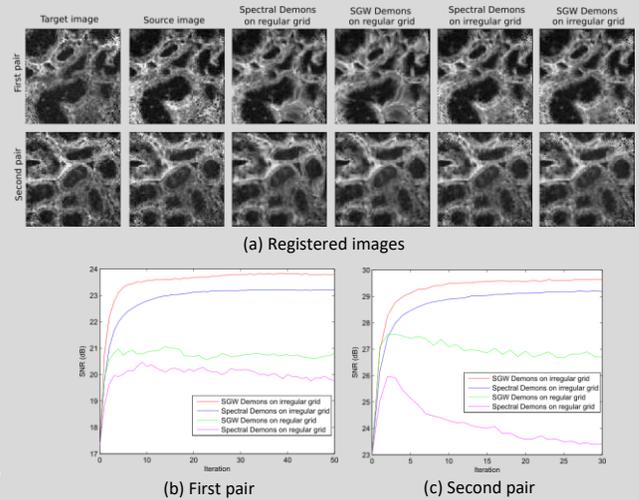


Figure 2: Comparison between the registered images and SNR values of our method and the existing methods for two pairs of images ($\alpha_g = 1$, $\alpha_s = 5$, $\alpha_i = 20$ for registration on irregular grid)

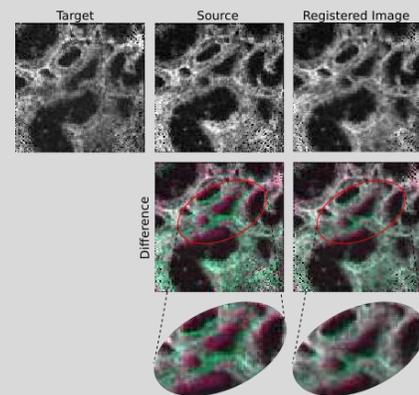


Figure 3: Registration of the first pair on irregular grids (Red channel: target image, Green channel: source image)

Conclusion et perspectives :

Our method shows that the Log-Demons framework can be adapted to the registration of images with floating point coordinates. The experimental results show that this application on the raw coordinates without any projection on Cartesian coordinate system performs better than the classical one on a regular grid. In all tested cases, the registration based on Graph Wavelets is more robust than the Graph Spectral based method. We believe that, our work will motivate other researches on image processing on irregular grids. Our future work will focus on studying the impact of graph construction and to create a complete panorama from the image sequence.

Références (5 max.):

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