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Accurate Registration of Multitemperal UAV Images Based on Detection of Major Changes

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OUTLINE

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Introduction

Why multitemporal UAV image registration ?

Registration of multitemperal images refers to the process of mapping the set of multitemporal images to the same coordinate system.

- Image fusion
- Change detection
- ……

Unmanned Aerial Vehicles (UAVs)-based imaging systems have been rapidly developed among **low altitude** remote sensing.

- high flexibility、low cost、stronger survivability……

Introduction

The problems of multitemperal UAV image registration

- Large rotation and scale changes
- Complicated non-rigid changes
- Scene changes between the times the images are acquired

Accurate registration of multitemporal UAV images is challengeable!

Introduction

Image registration

Mathematical definition：

$$I_R(x, y) = I_I(T(x, y))$$

T： geometric transformation

$$\begin{cases} \text{Parametric: Rigid、Affine、Projective······} \\ \\ \text{Non-parametric: Thin plate Spline、 Elastic 、} \\ \qquad\qquad\qquad\qquad\quad \text{Optical flow field······} \end{cases}$$

Introduction

Optical flow field

Optical flow field： every pixel has its own displacement vector

⇨ Complicated non-rigid changes

The problem of solving the optical flow field is usually converted to the energy functional minimization problem.

Optical flow：

$$E(w) = \sum_{p} \psi(|I_1(p) - I_2(p + w_p)|^2) + \lambda \sum_{p} \phi(|\nabla u_p|^2 + |\nabla v_p|^2)$$

Introduction

SIFT flow

Objective function:

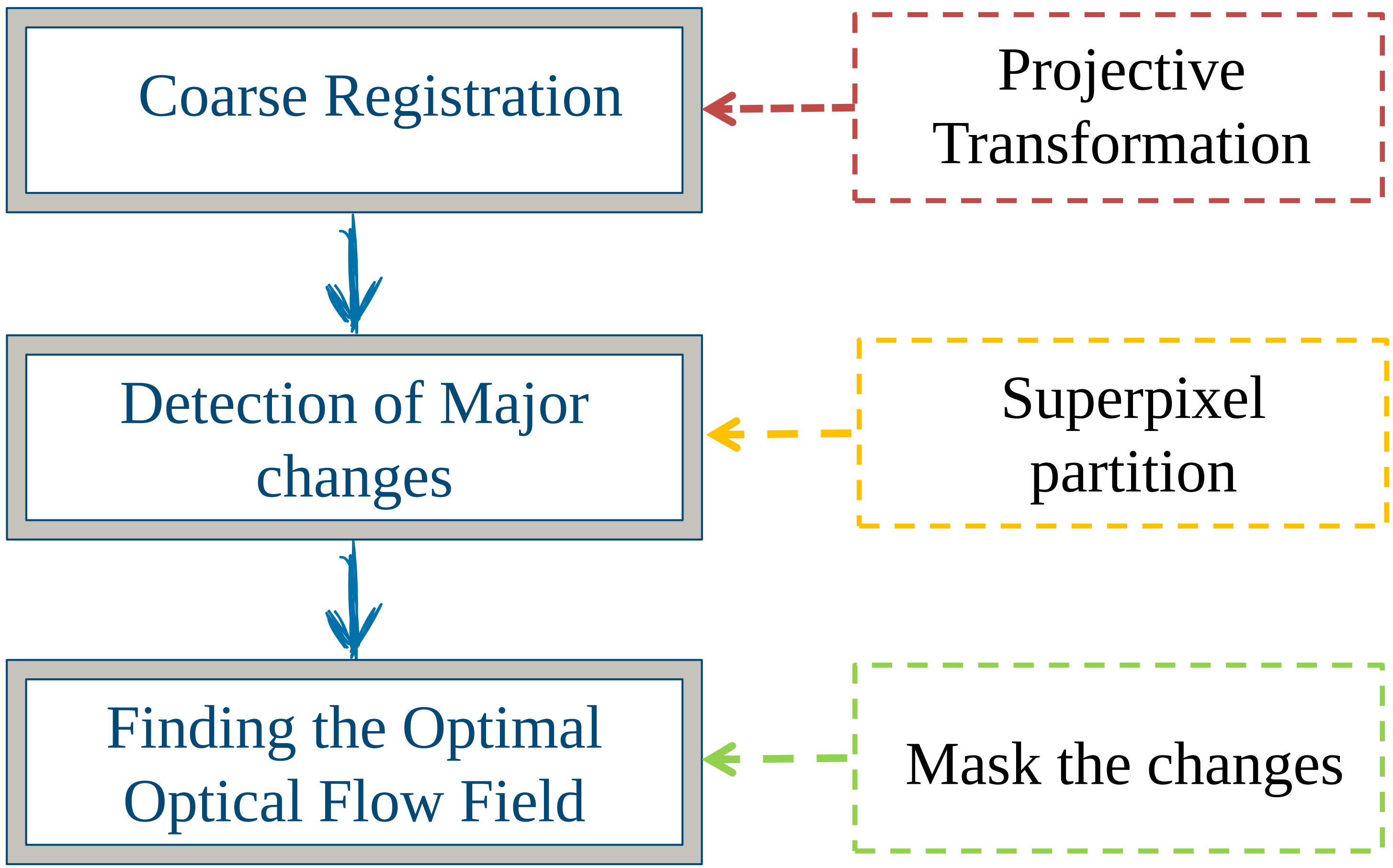
$$
\begin{aligned}
E(\mathbf{w}) = {} & \sum_{\mathbf{p}} \min\left(\| \boxed{s_1(\mathbf{p})} - \boxed{s_2(\mathbf{p}+\mathbf{w}(\mathbf{p}))} \|_1, t\right) \\
& + \sum_{\mathbf{p}} \eta\left(|u(\mathbf{p})| + |v(\mathbf{p})|\right) \\
& + \sum_{(\mathbf{p},\mathbf{q})\in\varepsilon} \min\left(\alpha |u(\mathbf{p}) - u(\mathbf{q})|, d\right) \\
& \qquad + \min\left(\alpha |v(\mathbf{p}) - v(\mathbf{q})|, d\right)
\end{aligned}
$$

Match SIFT descriptors instead of raw pixels.

- The dense SIFT descriptor is computed at a fixed orientation and scale.
- There should not be pixel-wise correspondence in changes while the SIFT flow algorithm wrongly match the pixels.

Proposed Method

Flowchart



Proposed Method

Coarse registration

Projective transformation：

A point $\mathbf{p} = (x, y)$ is represented in homogeneous coordinates by $[x_h, y_h, w_h]^T$, both coordinates are related by $x = x_h / w_h$ and $y = y_h / w_h$.

$$[x_h, y_h, w_h]^T = H[i, j, 1]^T$$

$$H = \begin{bmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & 1 \end{bmatrix}$$

Handle global affine transformation
and change of perspective.

Proposed Method

Detection of major changes

Superpixel Partition

Structure Information

Color Information

Change Detection

$$c(\boldsymbol{p}) = \begin{cases} 0, & \boldsymbol{p} \in \text{changes} \\ 1, & \text{others} \end{cases}$$

Proposed Method

Finding the Optimal Optical Flow Field

Modify the data term of SIFT flow:

Ignore the correspondence in changed areas

$$E(\mathbf{w}) = \boxed{\sum_{\mathbf{p}} \min(\| s_1(\mathbf{p}) - s_2(\mathbf{p}+\mathbf{w}(\mathbf{p})) \|_1, t)} \Rightarrow \sum_{\mathbf{p}} c(\mathbf{p}) \min(\| s_1(\mathbf{p}) - s_2(\mathbf{p}+\mathbf{w}(\mathbf{p})) \|_1, t)$$

$$+ \sum_{\mathbf{p}} \eta(|u(\mathbf{p})| + |v(\mathbf{p})|)$$

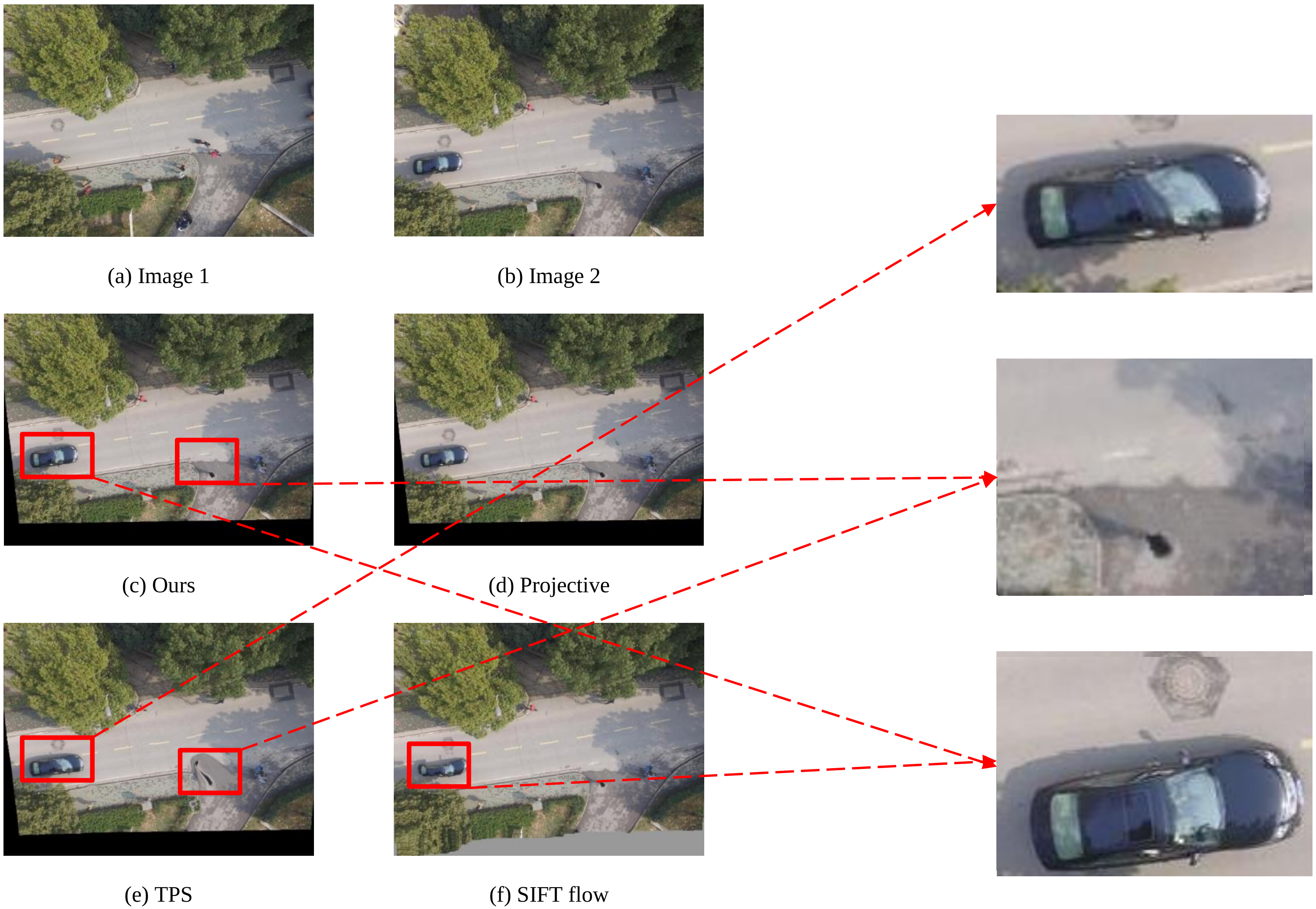
small displacement term

$$+ \sum_{(\mathbf{p},\mathbf{q})\in\varepsilon} \min(\alpha |u(\mathbf{p}) - u(\mathbf{q})|, d) + \min(\alpha |v(\mathbf{p}) - v(\mathbf{q})|, d)$$

smoothness term

Experimental Results

Image Set 1



Experimental Results

Image Set 2

(a) Image 1

(b) Image 2

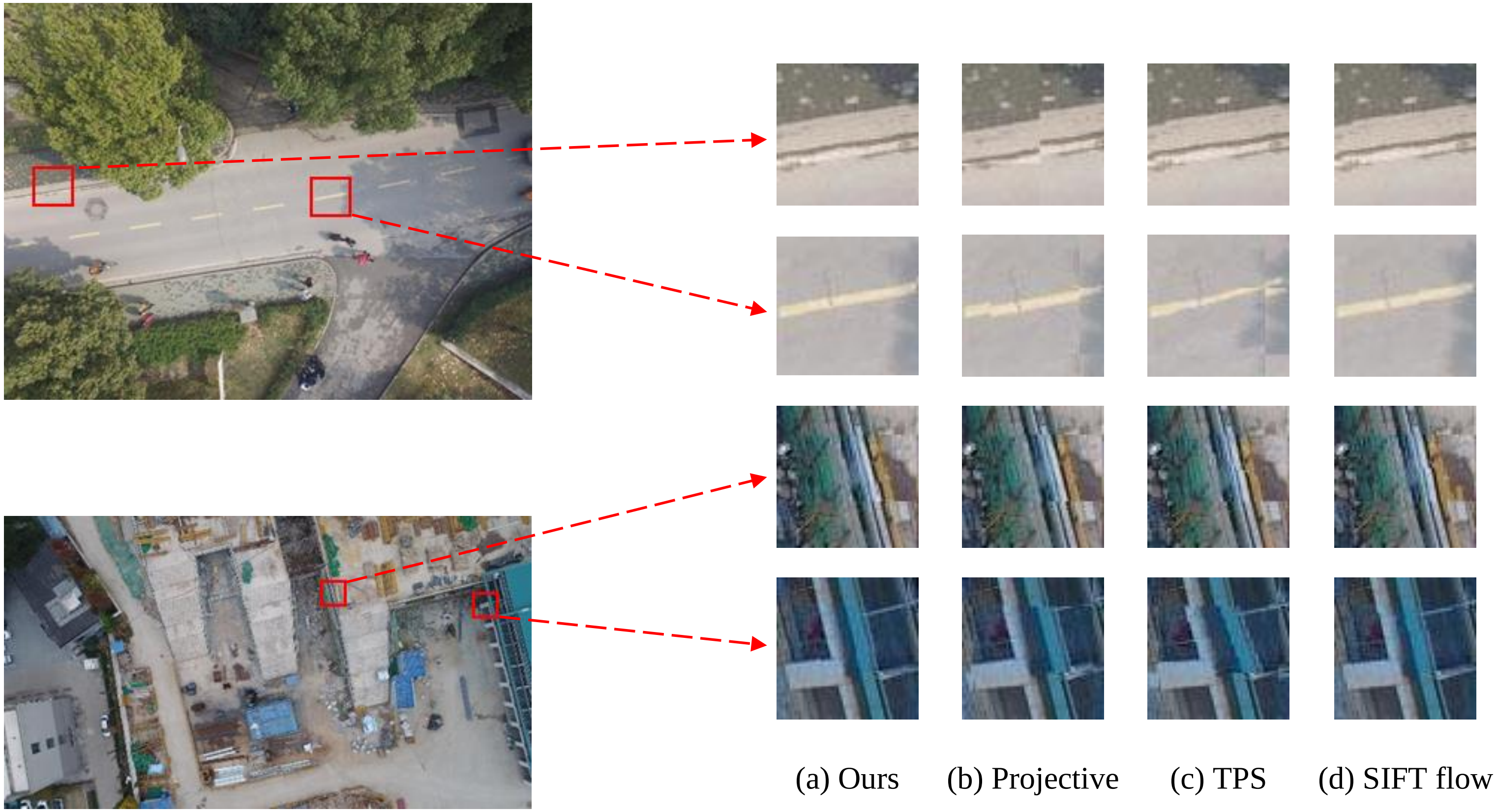
(c) Ours

(d) Projective

(e) TPS

(f) SIFT flow

Experimental Results



(a) Ours (b) Projective (c) TPS (d) SIFT flow

Experimental Results

Compare the registration accuracies quantitatively by root mean square error (RMSE)

$$\mathrm{RMSE} = \sqrt{\frac{1}{m}\sum_{i=1}^{m}(x_i - x_i^{'})^2 + (y_i - y_i^{'})^2}$$

Quantitative comparison（RMSE, Unit: pixel）

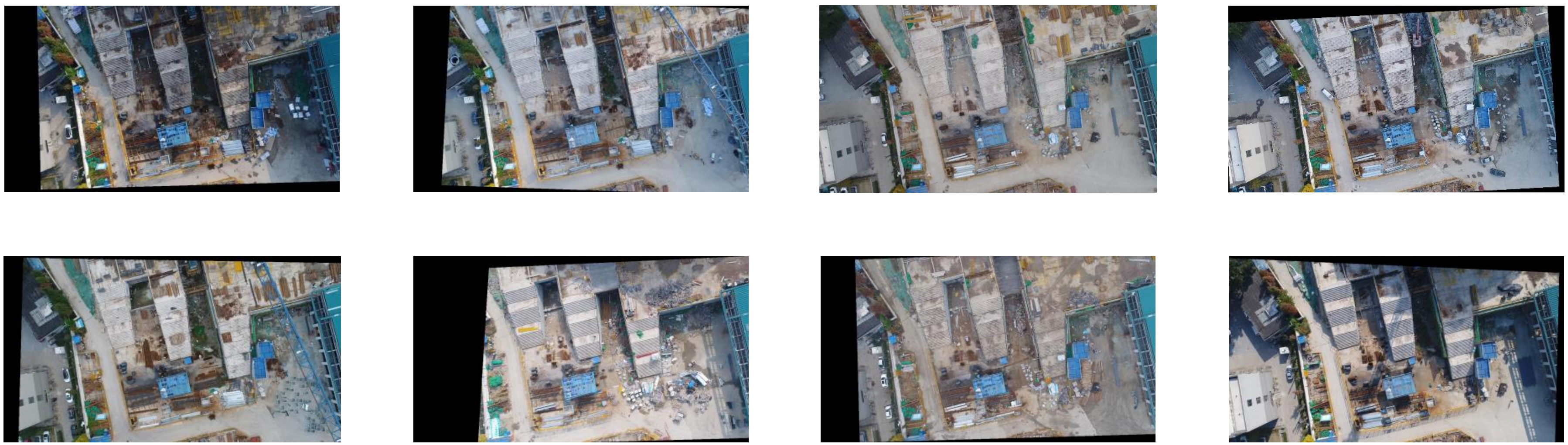
	Ours	Projective-based	TPS-based	SIFT flow
Image pair 1	0.4395	2.9002	1.6170	0.8738
Image pair 2	0.5722	2.4093	4.6936	1.0210

Experimental Results

The results of registration of UAV image sequences

Experimental Results

The results of registration of UAV image sequences



Conclusion

Summary

- Coarse-to-fine image registration method to align multitemporal UAV images
- Modification of SIFT flow algorithm based on masking the pixel-wise matches in major changes.

Outlook

- Deep learning based matching to increase the efficiency.
- Exploring accurate registration of time series UAV images with abundant changes.

Comments
and
Questions?