Tunnel Change Detection by Time Series Images

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Overview

- Images with a resolution of 2592 x 3888 were collected at every 20 minutes by an internal camera from 2013 to 2014 in a pilot tunnel.
- Although the camera was fixed inside the tunnel, tiny deformations together with moisture ingress/egress have been observed due to the changes of loading conditions and construction processes.
- Non-homogeneous illumination and disturbance objects appearing in the images were processed to prevent misjudgments.
- This research focuses on the decoupling of tunnel deformations and moisture ingress/egress, and aims to detect the changes along the timeline by advanced computer vision techniques.

Research Contents

- Unify non-homogeneous illuminations at different images by homomorphic filtering.
- Separate disturbance objects out of the background by low-rank and sparse decomposition.
- Decouple the moisture ingress/egress and tiny tunnel structural deformations by phase-based motion detection.

Methodology

- **Homomorphic filtering**

$$f(x,y) = i(x,y) \times r(x,y)$$

$$\Leftrightarrow F_f[\ln f] = F_i[\ln i] + F_r[\ln r]$$

$$\Rightarrow r(x,y) = \exp(F^{-1}[H(u,v)F_f(u,v)])$$

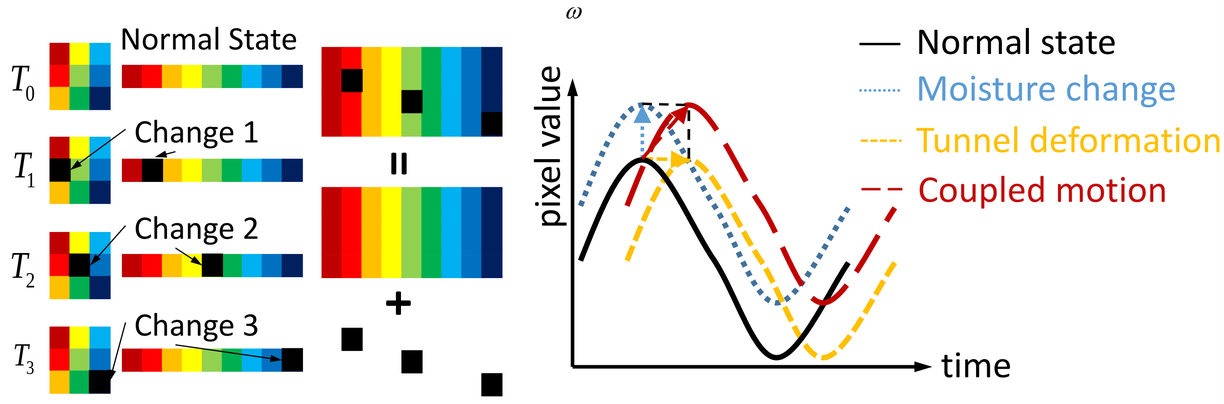
- **Low-rank and sparse decomposition**

$$\min(\|S\|_F), s.t. rank(L) \le r, X = L + S$$

- **Phase-based motion detection**

$$f(x+\delta(t)) = \sum_{\omega} A_{\omega} e^{i\omega(x+\delta(t))} = \sum_{\omega} S_{\omega}(x,t)$$

$$\hat{S}_{\omega}(x,t) = S_{\omega}(x,t) e^{i\alpha\omega\delta(t)}, \sum_{\omega} \hat{S}_{\omega}(x,t) = f(x+(1+\alpha)\delta(t))$$



- **Difference matting**

$$y = \| f_t(x) - f_{t_0}(x) \|_{L_2}$$

Tunnel Images

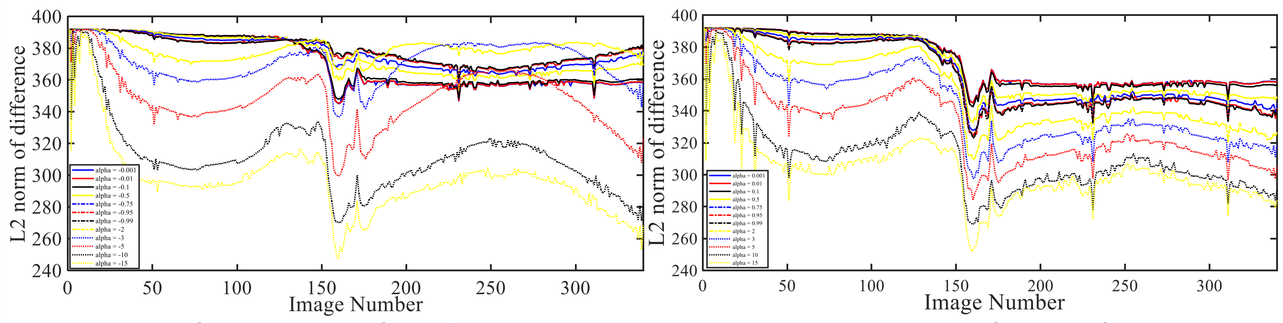
Initial status at 2013.08.01

Water ingress at 2013.09.18

Results

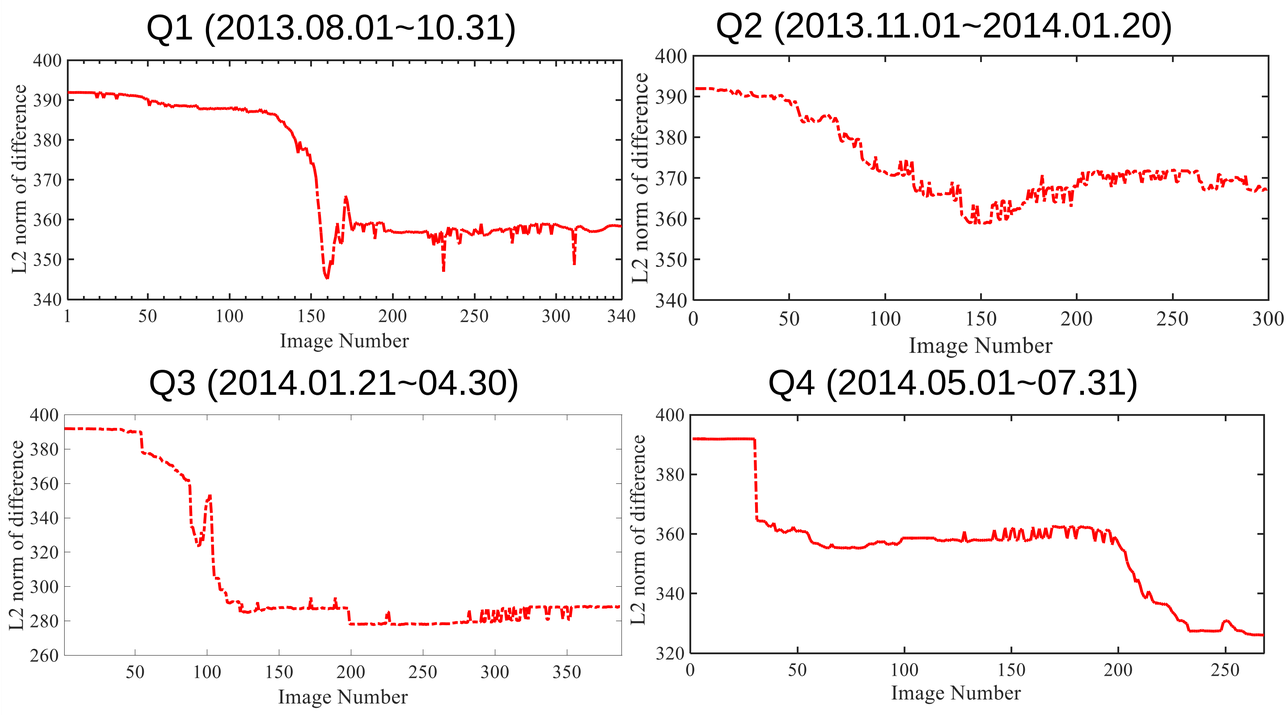
- **Low-rank and Sparse Decomposition**

- **Evaluation index for change detection with different alphas in Q1**



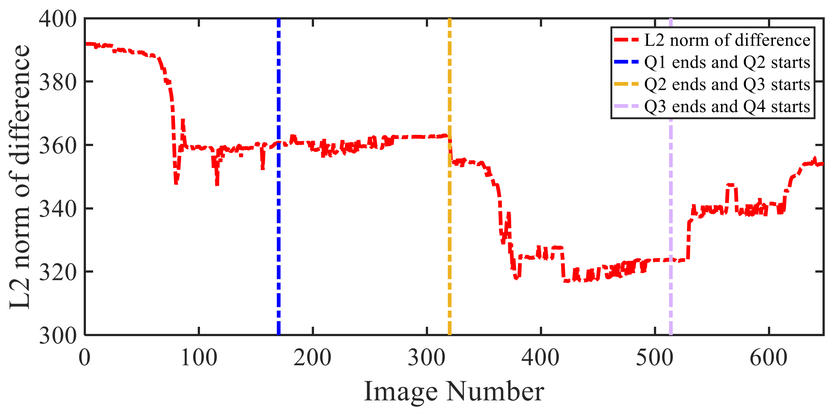
Structural motion in low frequency can be detected with a large alpha. To eliminate the coupled effect of tunnel motion, the value of alpha is set to be -1.

- **Change detection results for individual quarters**



Major changes of water ingress in Q1 and Q3, relative stable progress in Q2, minor changes, e.g. circuit changes and paint fallings, are detected, respectively.

- **Change detection result for the whole year**



Major changes of water ingress and egress and minor changes, e.g. circuit changes and ring paint fallings, are detected during the whole year.

Conclusions

1. Tunnel changes (e.g. water ingress/egress, circuit, internal lights and ring paint falling) can be detected by L2-norm differences of low-rank background.
2. Illumination caused by external lights can be eliminated by homomorphic filtering.
3. Dancing ribbon changes are ignored as sparse component by LS decomposition.

Acknowledgments

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