Overview

- Images with a resolution of 2592 × 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
  \[ f(x, y) = i(x, y) \times r(x, y) \]
  \[ \Leftrightarrow F[f \cdot \ln f] = F[i \cdot \ln i] + F[r \cdot \ln r] \]
  \[ r(x, y) = \exp(F^{-1}[H(u, v)F_f(u, v)]) \]
- Low-rank and sparse decomposition
  \[ \min\|S\|_1, s.t. rank(L) \leq r, X = L + S \]
- Phase-based motion detection
  \[ f(x + \delta(t)) = \sum a_x e^{i\omega(x + \delta(t))} = \sum a_y S_y(x, t) \]
  \[ \hat{S}_y(x, t) = S_y(x, t) e^{i\omega(x)} \]
- Difference matting
  \[ y = \|f_i(x) - f_{new}(x)\|_2 \]

Tunnel Images

Initial status at 2013.08.01
Water ingress at 2013.09.18

Results

- Low-rank and Sparse Decomposition
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- 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 -1.
- Change detection results for individual quarters
  Q1 (2013.08.01~2013.11.30) Q2 (2013.11.01~2014.01.20)
  Q3 (2014.01.21~2014.04.30) Q4 (2014.05.01~2014.07.31)
- Change detection result for the whole year
  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.

Conclusions

1. Tunnel changes (e.g. water ingress/egress, circuit, internal lights and ring paint fallings) 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.

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