Visual Anomaly Detection from Small Samples for Mobile Robots

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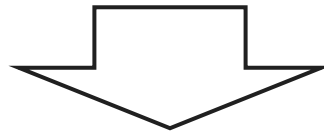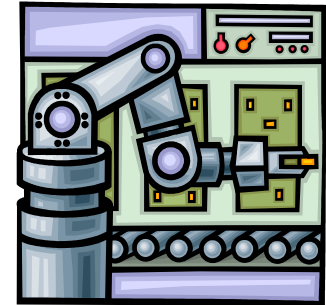**JST PRESTO

Background

Autonomous robots in **real-life settings**


Action planning on the fly
- Unknown and non-stationary environment

Need to comprehend their surroundings

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Background

Need to comprehend their surroundings

- Anomaly Detection
  - Influence for action planning
    - Obstacles
    - Higher-priority task (ex. Fallen person)
  - Anomaly Detection Task
   - Security robot
    - News-gathering robot

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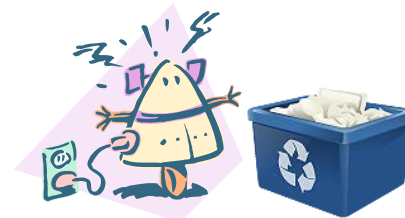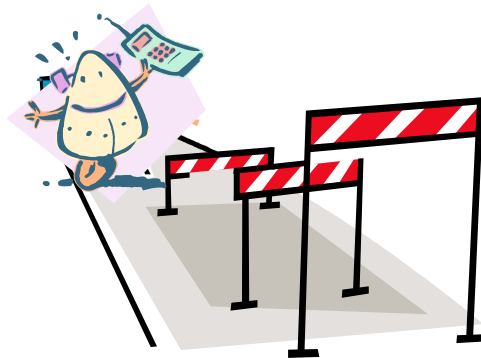
Background

Anomalies for mobile robots
- Salient in vision
  - <u>Apperance or disappearance of objects</u>

Problems for robots ⟷ Fixed Camera
- Amount of samples <u>at same location</u> is small
  - Difficult to apply statistical methods
  - Observation error or noises
- Amount of samples <u>at same situation</u> is small
  - Must filter out ambient changes

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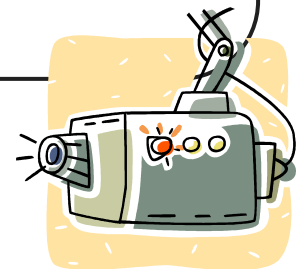
Purpose

◆Small samples at same <u>location</u> and <u>situation</u>
→ Anomaly detection is difficult

Purpose of our work：
To detect anomalies
such as appearance or disappearance of objects
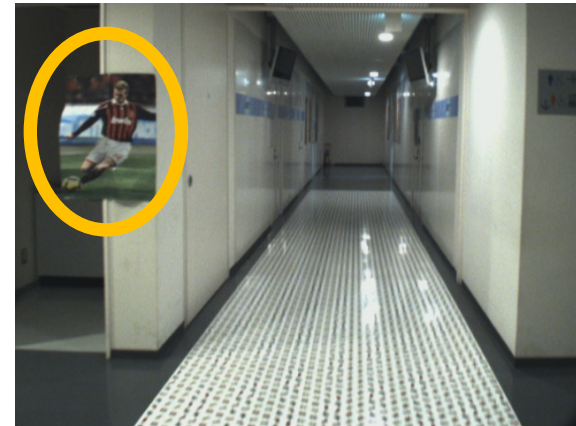Robust Anomaly detection
against ambient changes from small samples

Example of Anomaly

- Appearance of new poster

    in the presence of ambient changes

    – ex. visit at <u>morning</u> -> visit at <u>night</u>

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Related Work

- Anomaly Detection from small samples
  - Image comparison [K. Primdahl et al., 2005] [J. Sato et al., 2006] [Koyama et al., 2010]
    - Susceptible to ambient changes
  - Clustering based method [H. Neto et al., 2007]
    - Unable to use location information

- Non-uniformalized samples
  - Statistical method using large samples [T. Suzuki et al., 2011]

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Requirements

- Non-statistical approach
  - ex. Mixture Gaussian needs thousands of samples

- Utilization of location information

- <u>Utilization of surrounding information</u> for ambient changes

  $\rightarrow$ Anomaly detection method from small samples

   Utilization of surrounding information
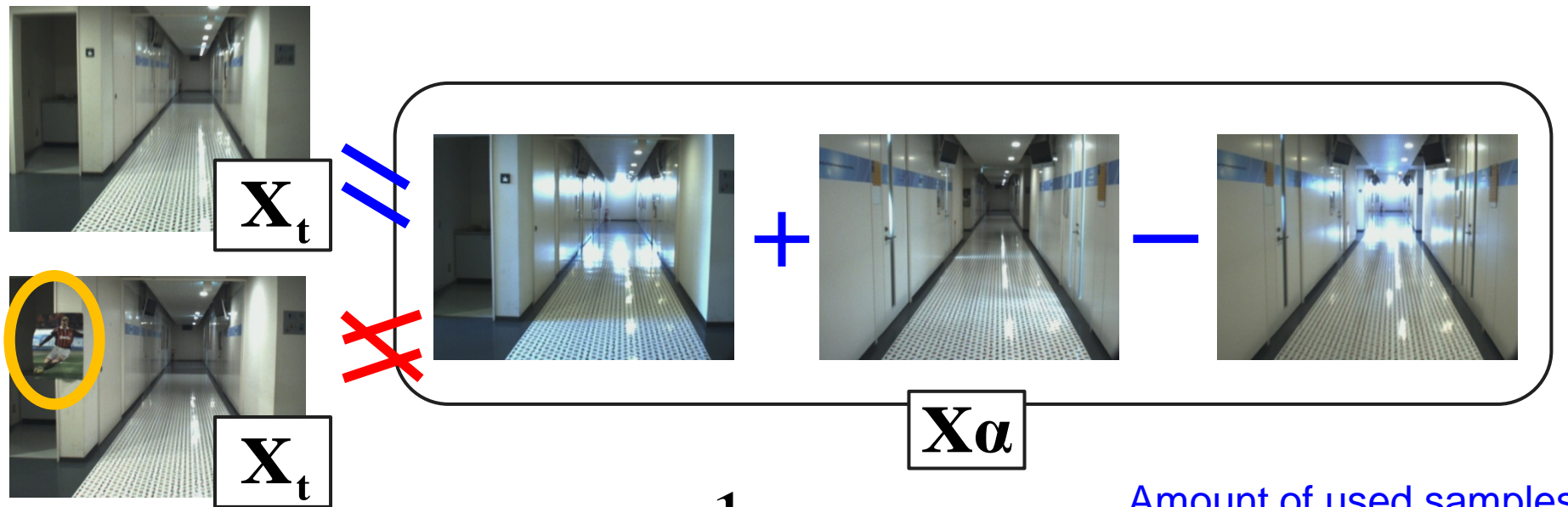
Proposal

1. ## Analysis-By-Synthesis Approach
   - Normal sample must be reconstructed by **combination of past observations**
   - Several works for fixed camera [O. Boiman, 2007] [B. Zhao, 2011]
   - Robust from small samples

2. ## Novel approach for reconstruction
   - "Anomaly of the change between **current observation** and **past observation**"

     → "Anomaly of the **change at the current location** referring changes at other locations"

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Analysis-By-Synthesis Approach

- Anomaly detection based on reconstruction error [B. Zhao et al., 2011]
- Try to reconstruct current sample by **linear combination of small normal samples**, and the reconstruction error is anomaly value

$$Anomaly = \min_{\alpha_t} \frac{1}{2} \left\| \mathbf{X_t} - \mathbf{X\alpha} \right\|_2^2 + \lambda \left\| \boldsymbol{\alpha} \right\|_1$$

Amount of used samples

Reconstruction error

Use GIST feature for X in this work

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Possible Method

Reconstruction from **all samples**

Morning
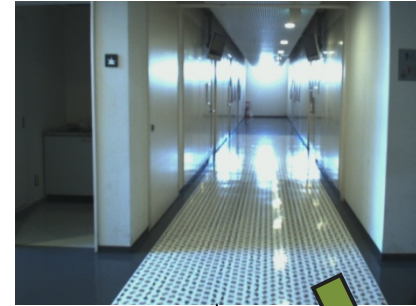
hallway
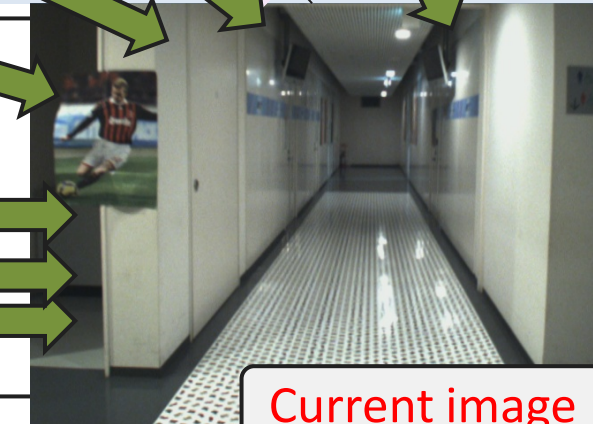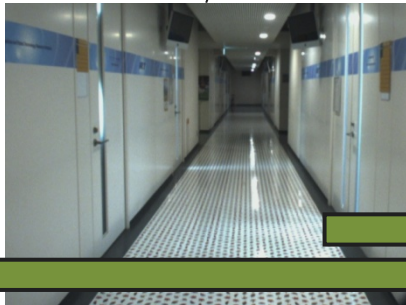
Night

Current image

Too high flexibility

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Proposal Method

Reconstruction from **differences at same location**

Morning
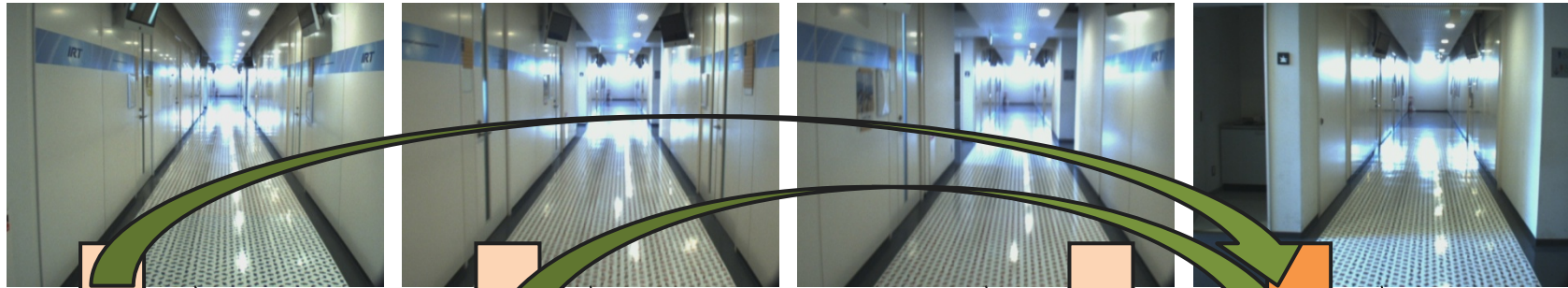
diff

diff

hallway

diff

diff
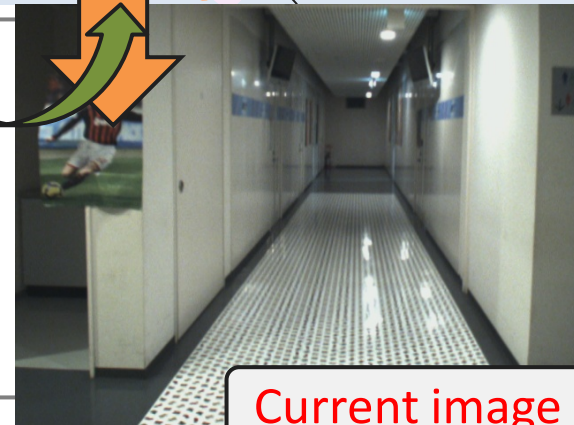
Night

Current image

restriction for reconstruction

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Experimental Settings

- Visit in morning -> Visit in night

    - Compute anomaly value with anomalous poster or not
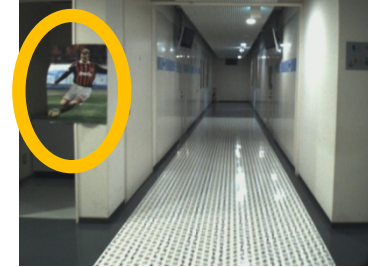
- Compute anomaly value

    at location 1 (start point) to location 100 (goal point)

- Compare three methods

    - Anomaly = max distance of images at the same location [J. Sato et al., 2006]

    - Anomaly = Reconstruction Error (use of all past observances)

    - Anomaly = Reconstruct Error (use of difference at the same location)

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Experimental Result 1

Anomaly = max distance of images at the same location
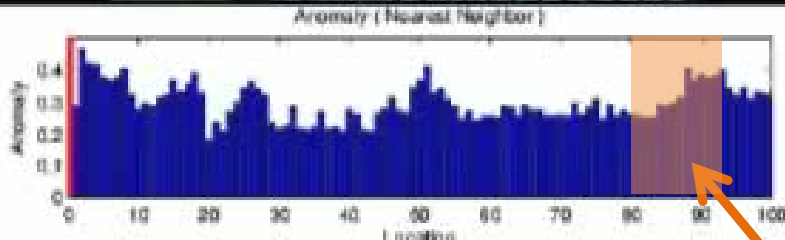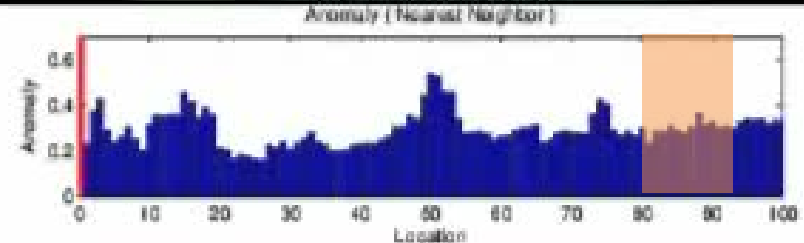
anomaly

normal

Poster is here

Susceptible to ambient changes

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Experimental Result 2

Anomaly = Reconstruction Error (use of all past observances)
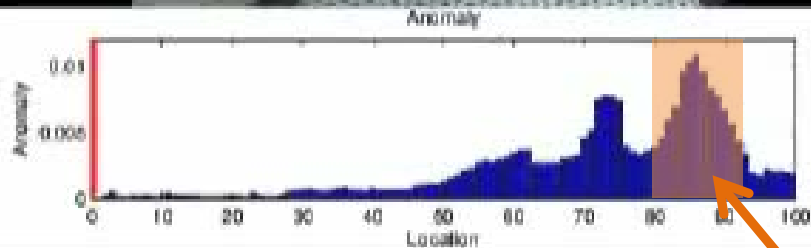
anomaly

normal
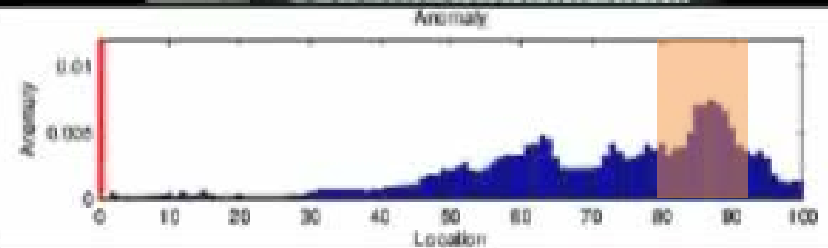
Poster is here

False positive
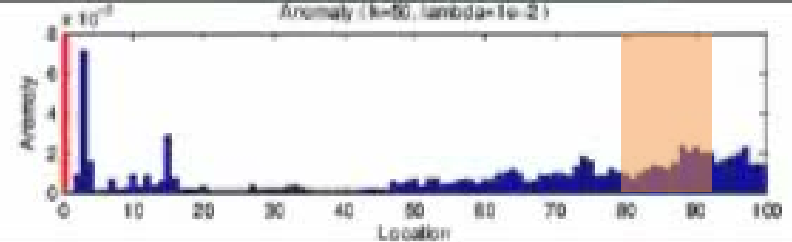
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Experimental Result 3

Anomaly = Reconstruct Error (use of difference at the same location)
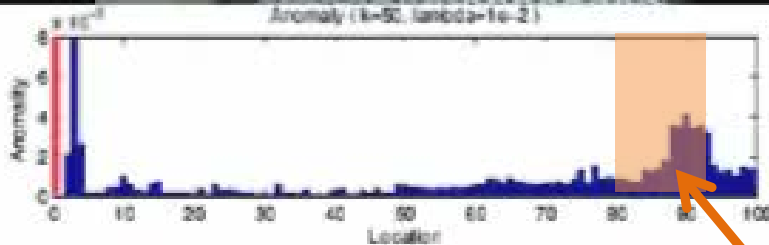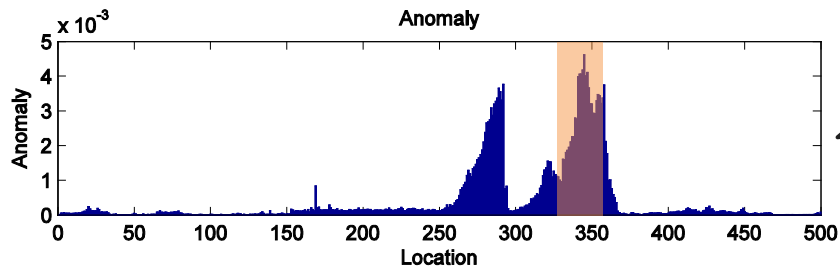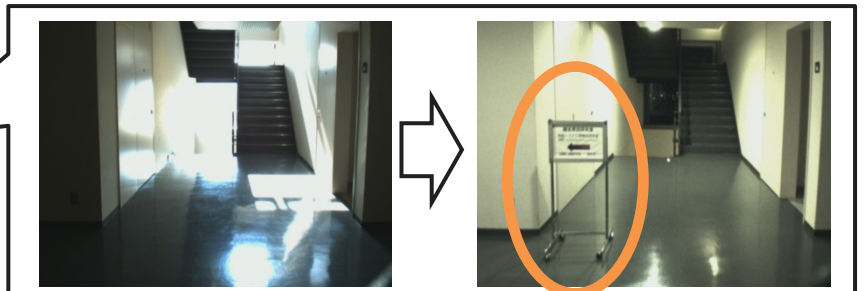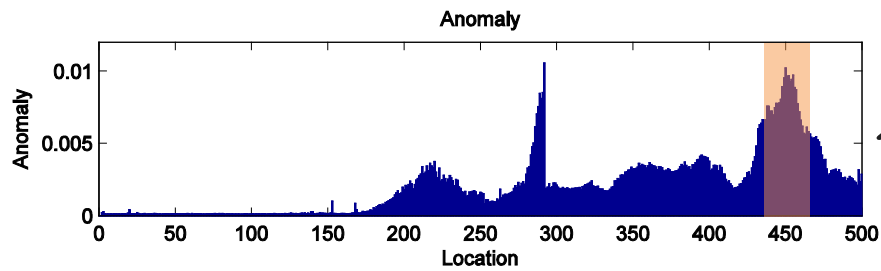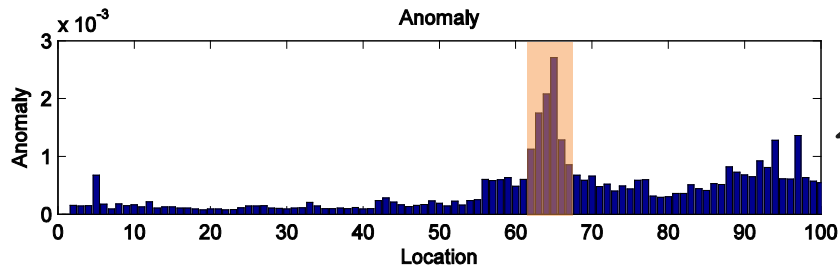

anomaly

normal

Poster is here

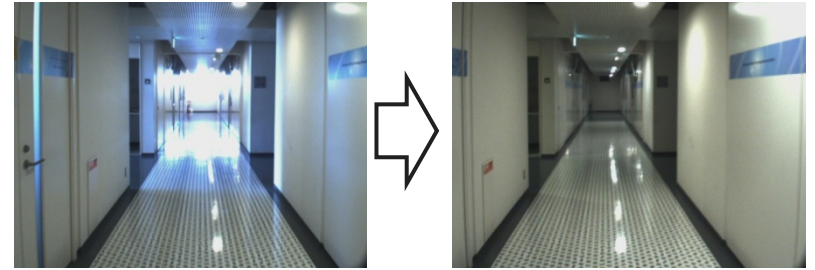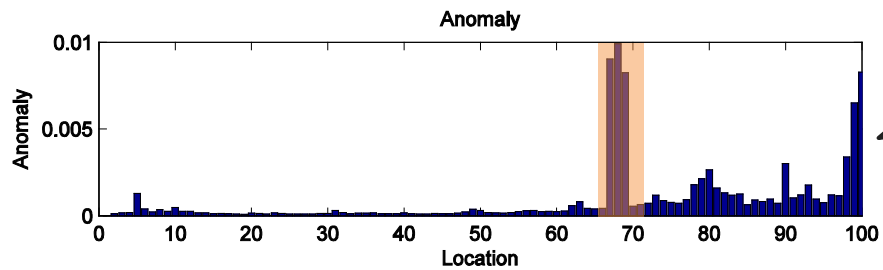Anomaly values are relatively high where a poster is seen.

The system is adjusted to ambient changes in location 0 -> 5.

Other Successful Cases
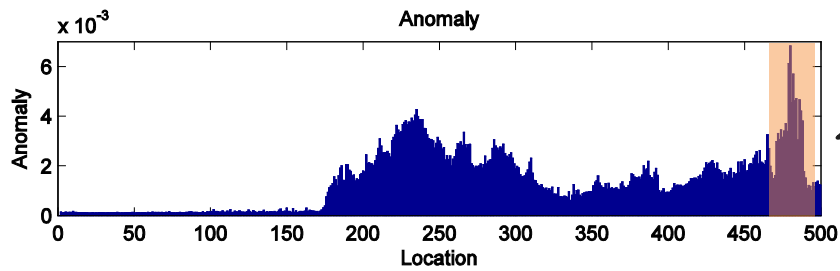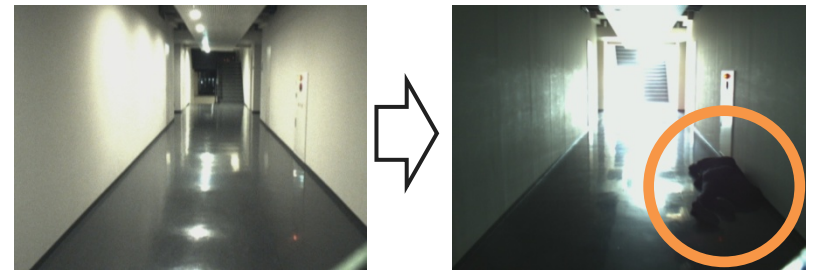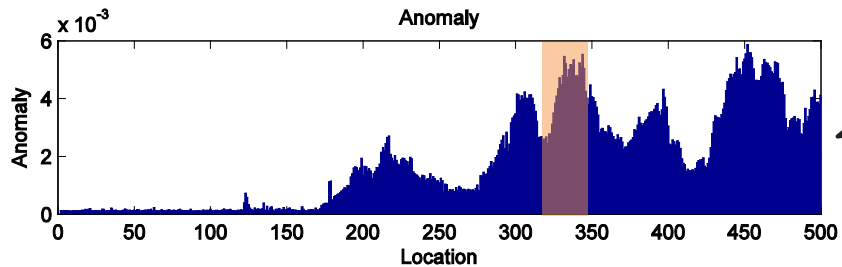
Cases of Failure

Sudden change in direction

Inconspicuous in the 2D image

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Conclusion & Future Work

- ## Conclusion

  - We proposed novel anomaly detection method for mobile robots and demonstrated that it is robust against ambient changes

- ## Future Work

  - Image transform using orientation of robot

  - Use of 3D image

  - Threshold decision method

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