

**MATLAB EXPO 2021**

# **Snow Hazard Index**

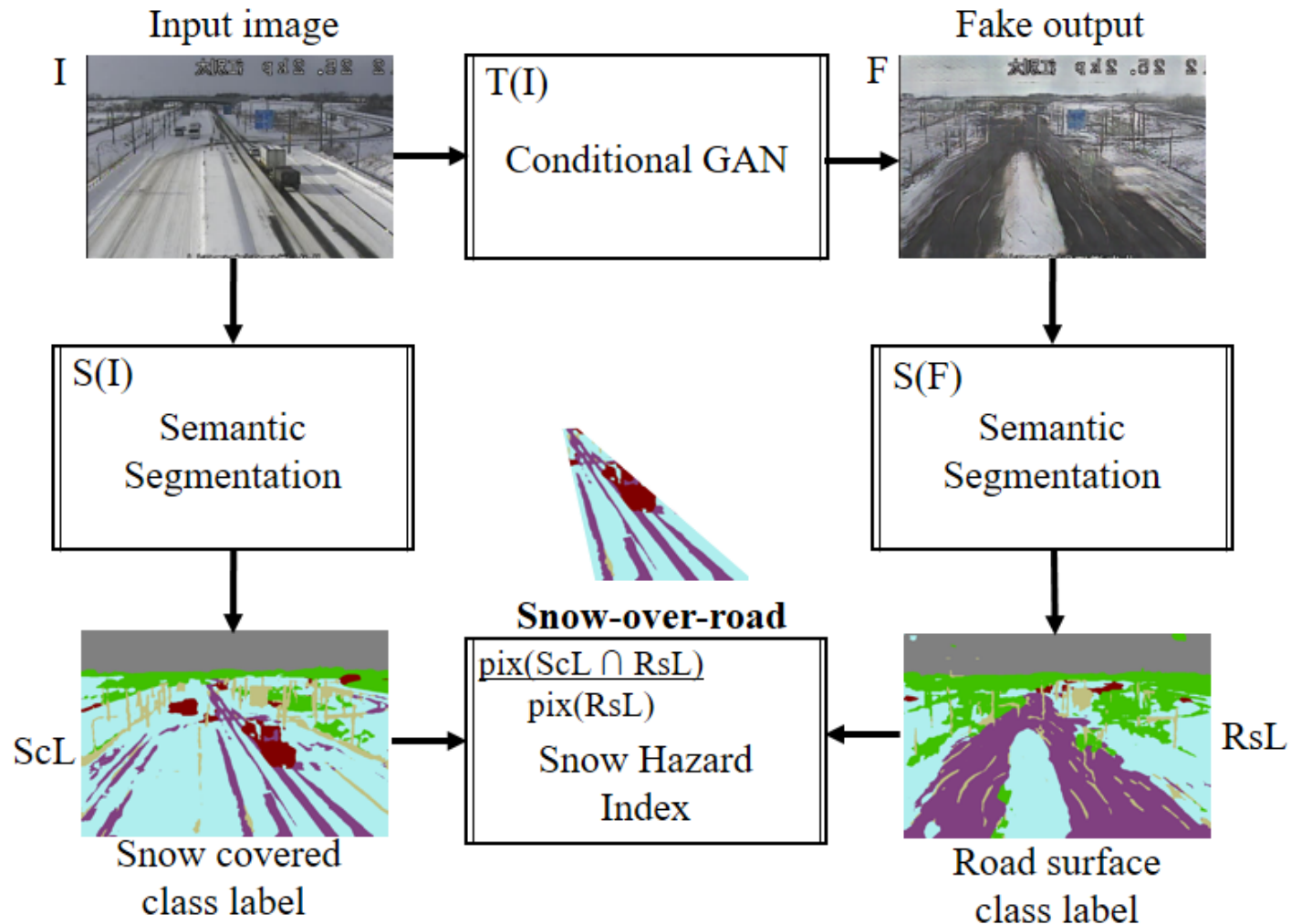
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Using Conditional GAN and  
Semantic Segmentation

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# Today's talk : Snow Hazard Indicator Pipeline



# Outline

- 1. Introduction**
- 2. Deep Learning Application**
- 3. Snow Hazard Indicator Results**
- 4. Snowy Night-to-Day Results**
- 5. Concluding Remarks**

# 1. Introduction

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# 1.1 Background

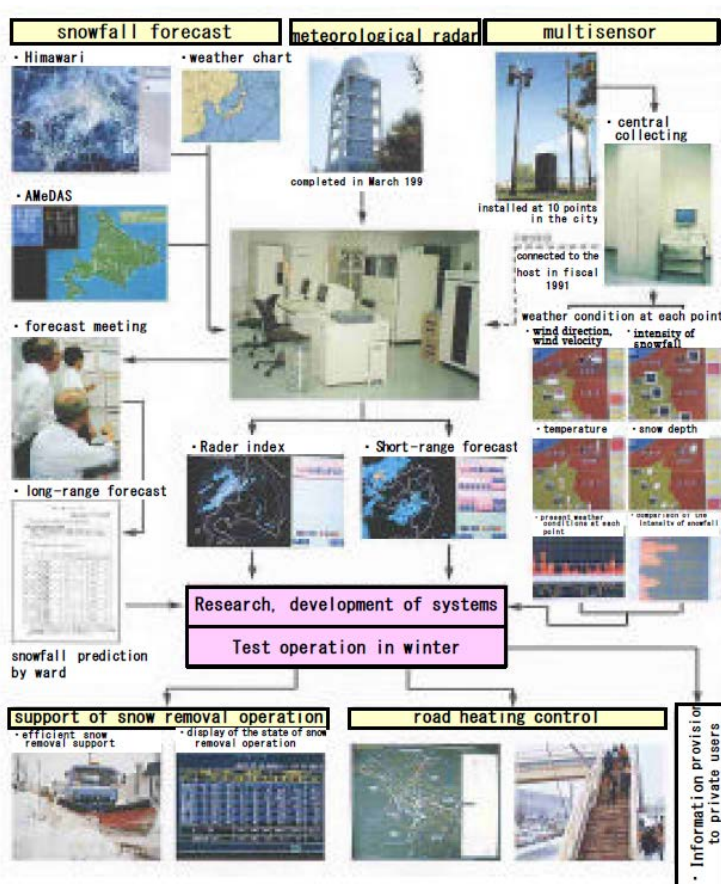
- January 10, 2021, owing to **heavy snowfall** on the Hokuriku Expressway, approximately **1,000 cars were stuck**.
- This congestion was caused by a **slippery accident**.
- **Road surface monitoring** is critical for **winter road safety**.



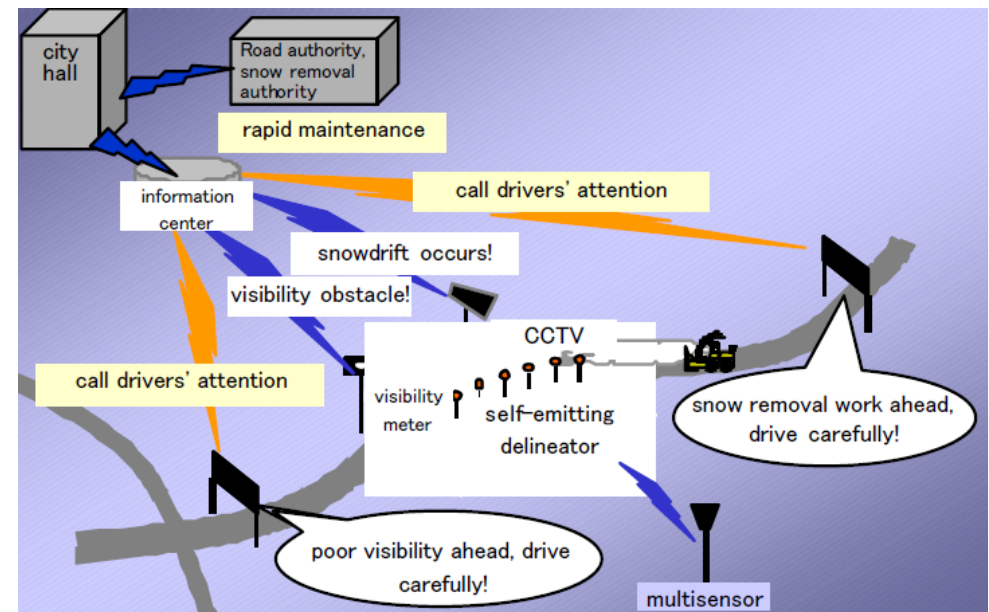
[www3.nhk.or.jp/tohoku-news/20210119/6000013183.html](http://www3.nhk.or.jp/tohoku-news/20210119/6000013183.html)

# 1.2 Intelligent Monitoring Winter Road

- Snowfall forecast / sensing system for road status, comprehensive network



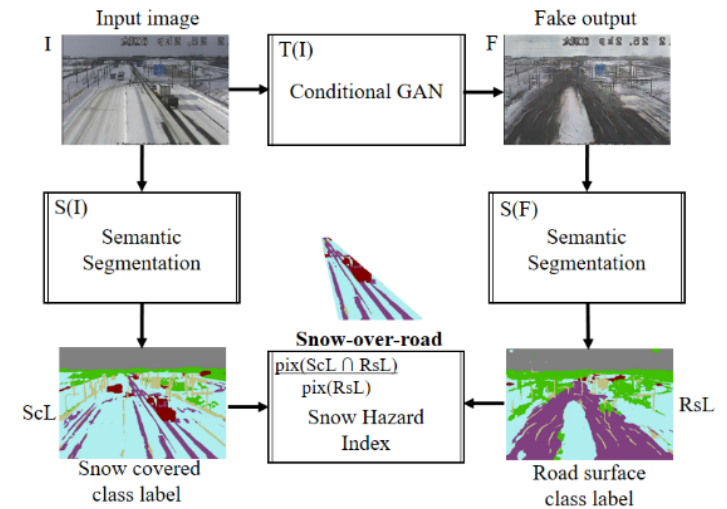
- Required multi-mode observed weather / image data, so costly



Kido et al., Sapporo City (1999) : "Management of Roads in Winter using CCTV camera".

# 1.3 Practical Indicator for Winter Road Safety

- Challenges
  - **Vision based** practical indicator
  - **Fewer data**, only image input, less cost
  - Provide **hazardous measure** for road managers/users
- Our proposal
  - Before-snow image translation
  - Snow / road segmentation
  - Live image post-processing
  - Compute a snow hazard indicator.



## 1.4 Trial steps and Validation

- Trial steps
  - 1) Image translation of the road surface region hidden under snow using a **conditional GAN**
  - 2) Snow-covered /Road surface, per-pixel classification using **semantic segmentation**.
  - 3) Indicate the **amount of snow covered on the road**
- Apply our pipeline
  - Field study of **snow and cold regions** in Japan.





## 2. Deep Learning Application

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## 2.1 Image-to-image Translation for Conditional GAN

- pix2pix framework
- One-to-one Image Translation

 real image

 generated fake image

- Objective “one-to-one” consistency

  $x_r^a$     $x_r^b$  Aligned training sample

$\|G(x_r^a) - x_r^b\|_p$ : target consistency

## 2.2 MATLAB enabler for Conditional GAN

### Custom Loop for Deep Learning

- 1) **dlarray** & **dlnetwork**: handle data and networks flexibly
- 2) **dlfeval** : evaluate custom loss & gradient function
- 3) **PairedImageDatastore**: easy to access paired dataset

### MATLAB® (primary tools)

- Deep Learning Toolbox™, Parallel Computing Toolbox™
- Computer Vision Toolbox™, Image Processing Toolbox™

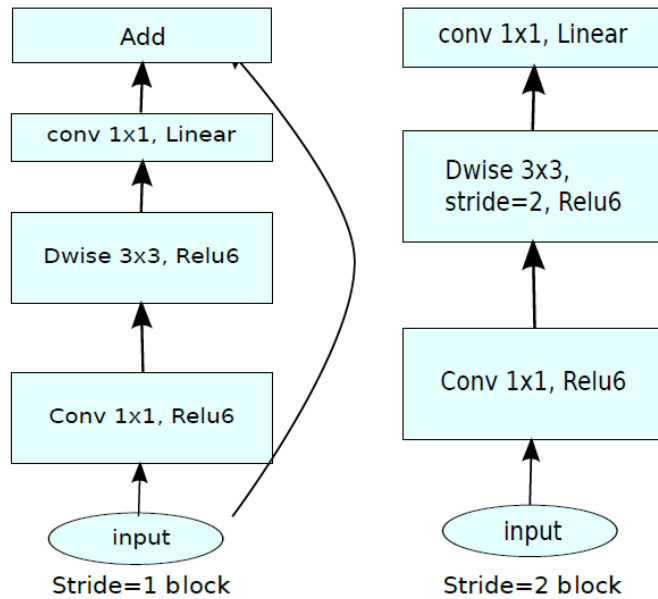
### **New Released R2021a:**

- **pix2pixHD** generator : high-resolution label-to-image translation.

# 2.3 Semantic Segmentation for Snow and Road

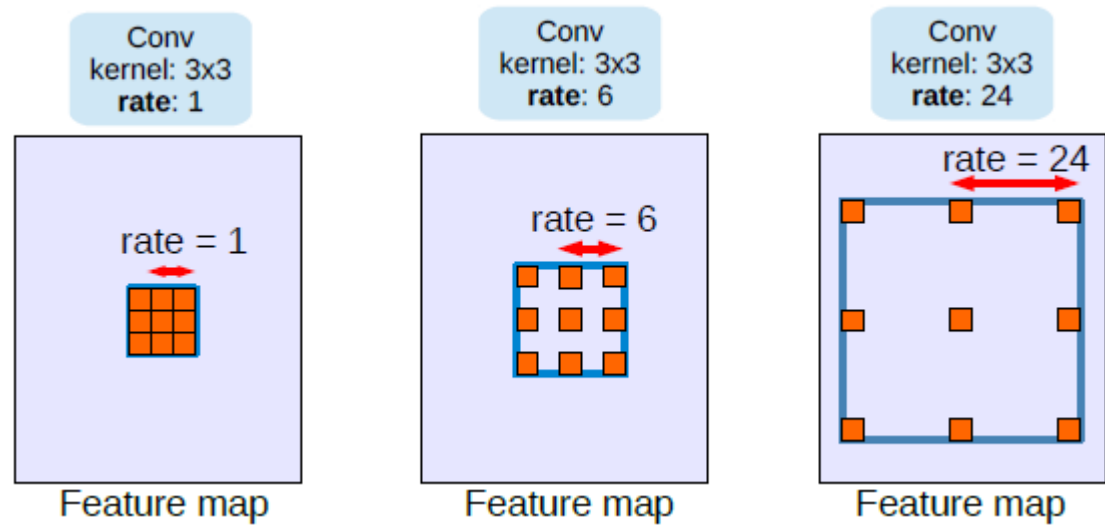
## MobileNetv2

- Bottleneck Residual block
- Reduce memory : max. 400K



## DeepLabv3+

- Atrous Pyramid Pooling
- Dense convolution



See) Chen et al. : "Rethinking Atrous Convolution for Semantic Image Segmentation"(2018)

See) Sandler et al. : "MobileNetV2: Inverted Residuals and Linear Bottlenecks"(2018)

## 2.4 MATLAB set the pace for Semantic Segmentation

### Standard Deep Learning Enablers

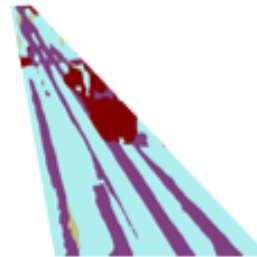
- 1) `pixelLabelImageDatastore`: handle image and label paired set
- 2) `deeplabv3plusLayers` : easy to build e.g. MobileNetv2, Xception
- 3) `trainNetwork`: training dataset, layers, and options
- 4) `semanticseg`: easy to predict test image by trained network
- 5) `evaluateSemanticSegmentation`: easy to evaluate accuracy

### MATLAB® (primary tools)

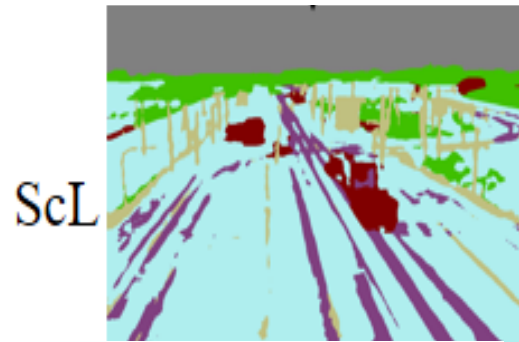
- Deep Learning Toolbox™, Computer Vision Toolbox™
- Parallel Computing Toolbox™

# 2.5 Image Processing for Snow Hazard Index

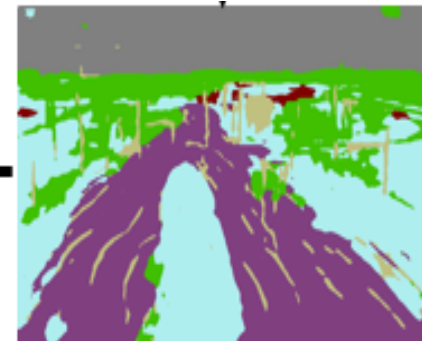
## 3) Intersection of both labels



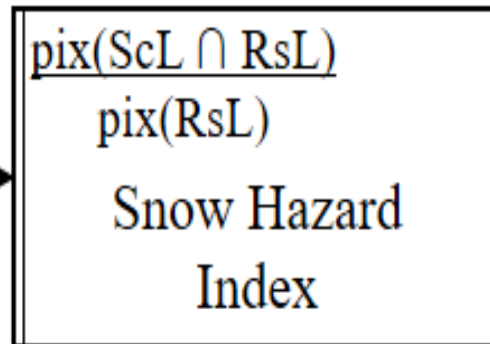
1) *Snow covered class label*



2) *Road surface class label*



Snow-over-road



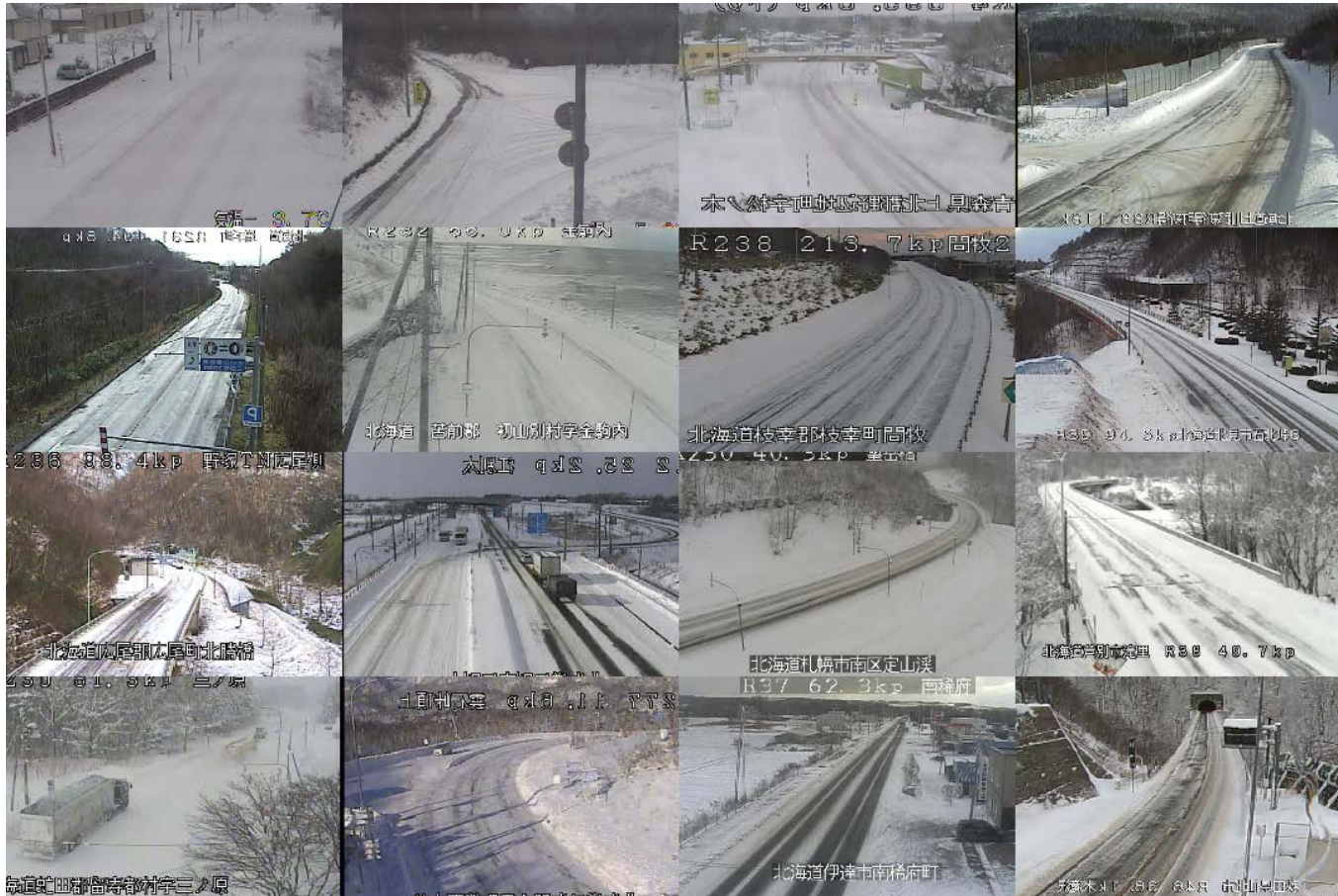
- Automatically compute **the snow hazard ratio index**, without the ground-truth of the road surface image.

# 3. Snow Hazard Indicator Results

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# 3.1 Input Raw Image Examples

- Snowy road surface test image, hazardous condition
- Note: background snow is **NOT** dependent on traffic accident





# 3.2 Ground truth Road Surface Examples

- “before snow” real situation,
- Target ROI road surface have been shown clearly





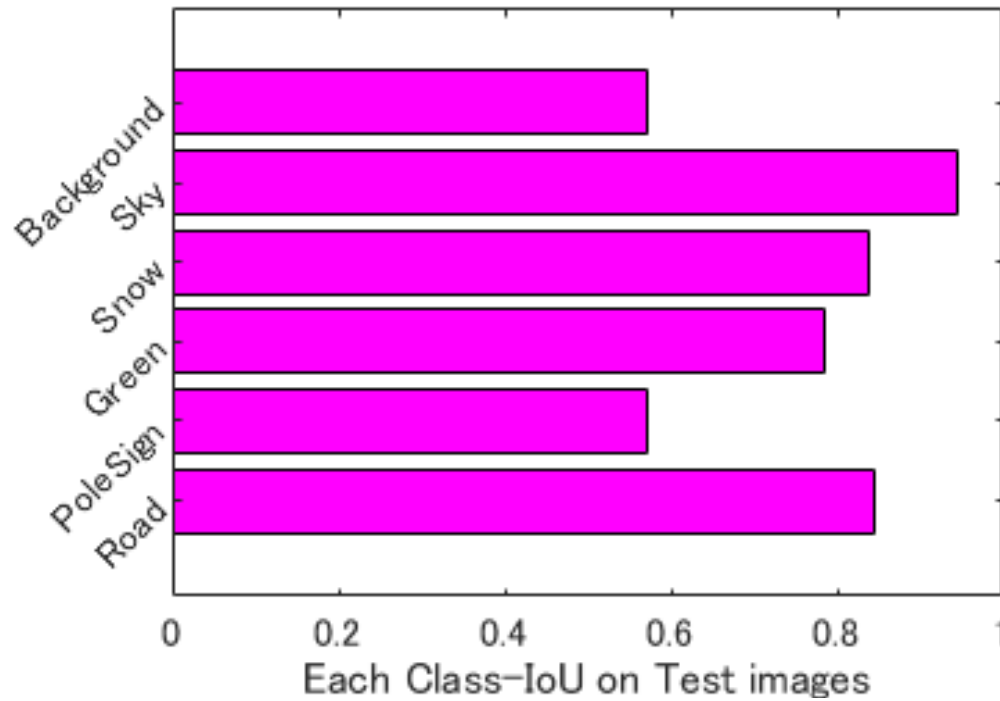
# 3.3 Fake output Road Surface Examples

- Test **snowy raw input** is translated to **“before snow” fake** situation using the trained pix2pix



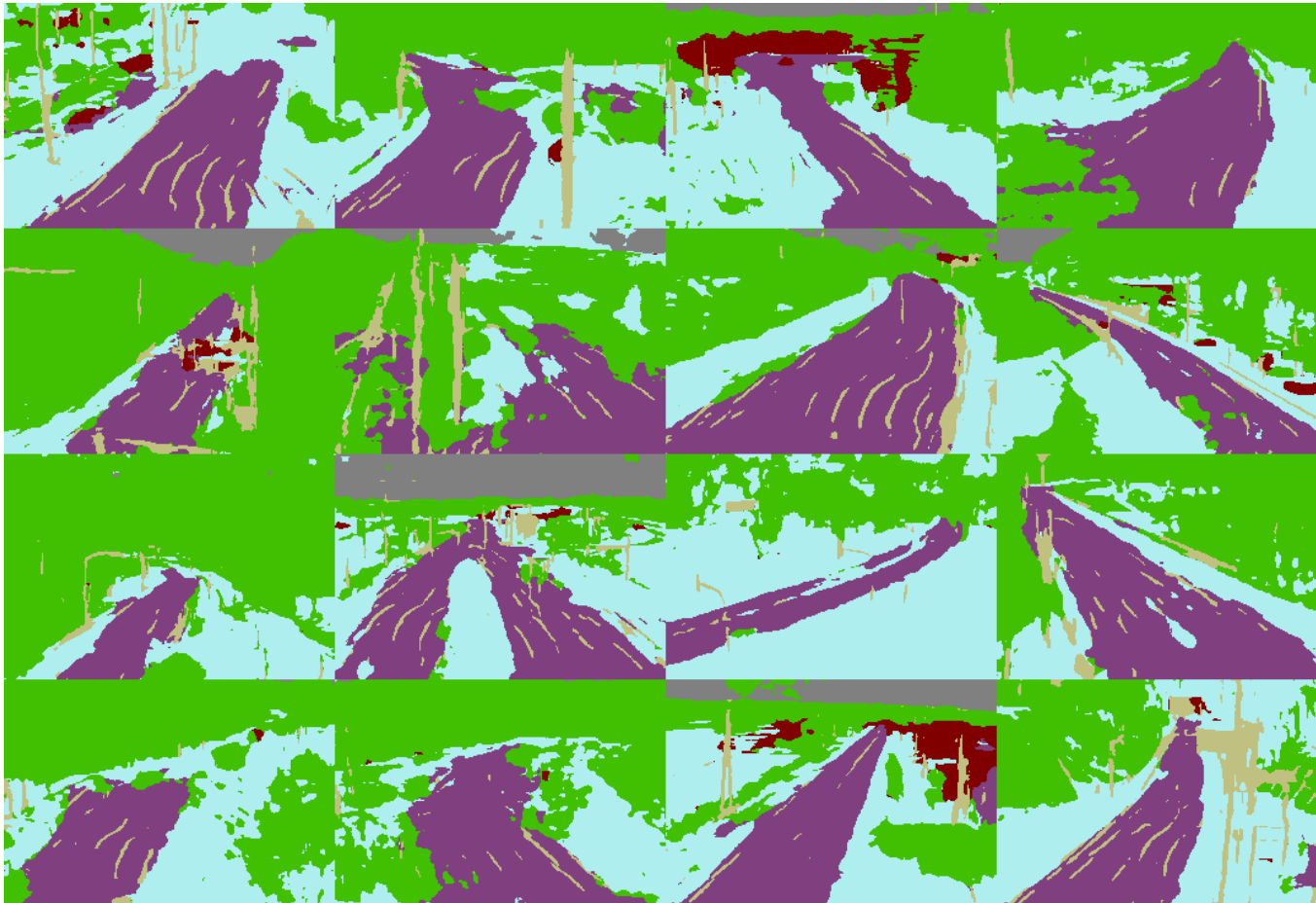
## 3.4 Trained Segmentation for Snow and Road Surface

- Train a DeepLabv3+ with a backbone MobileNetv2
- Each class Intersection of Union(IoU) is more than 0.6.
- The road and snow class IoU is 0.8, so useful



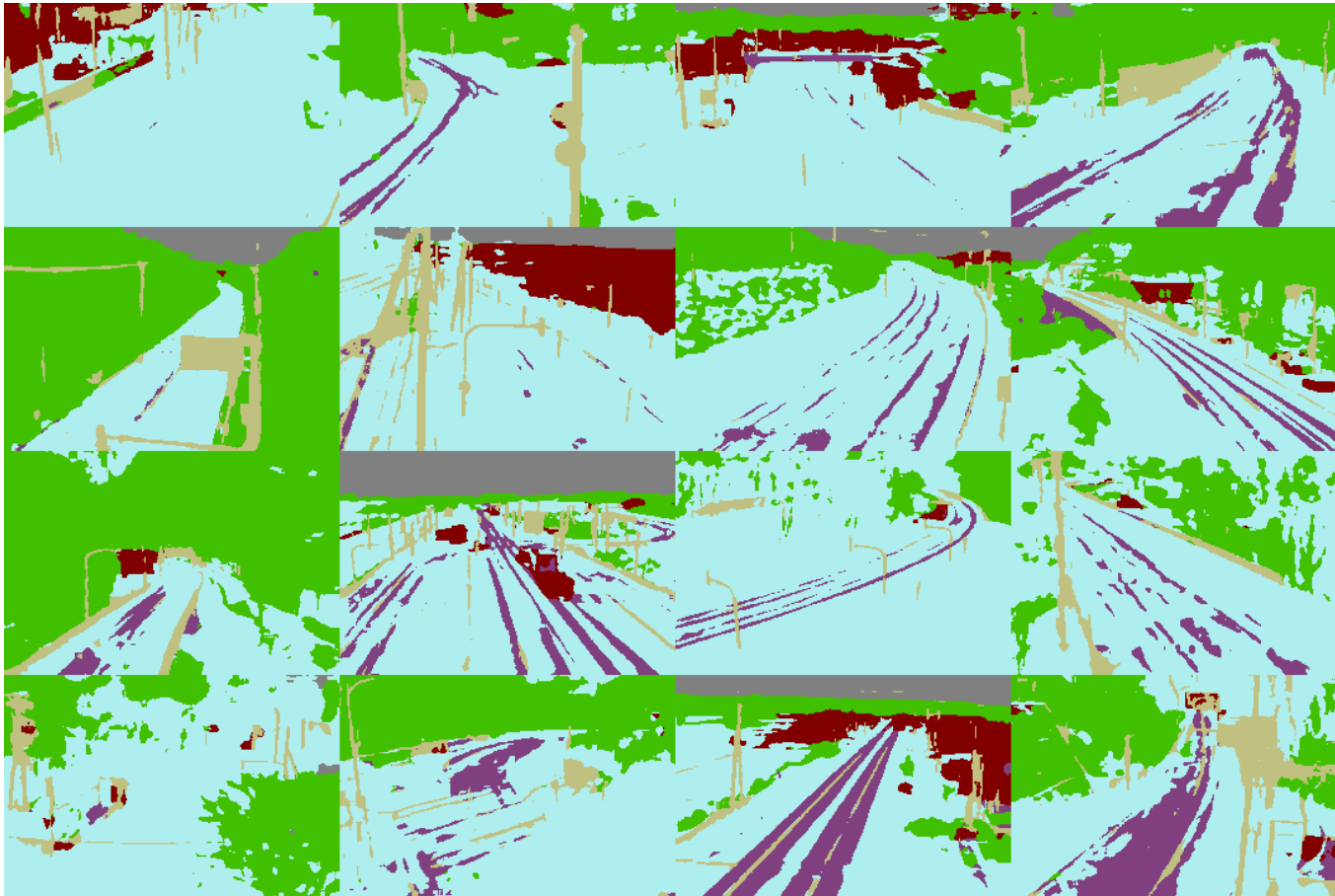
## 3.5 Road Surface Label Prediction from fake output

- Predict the **fake output** of “before snow” using the trained semantic segmentation network



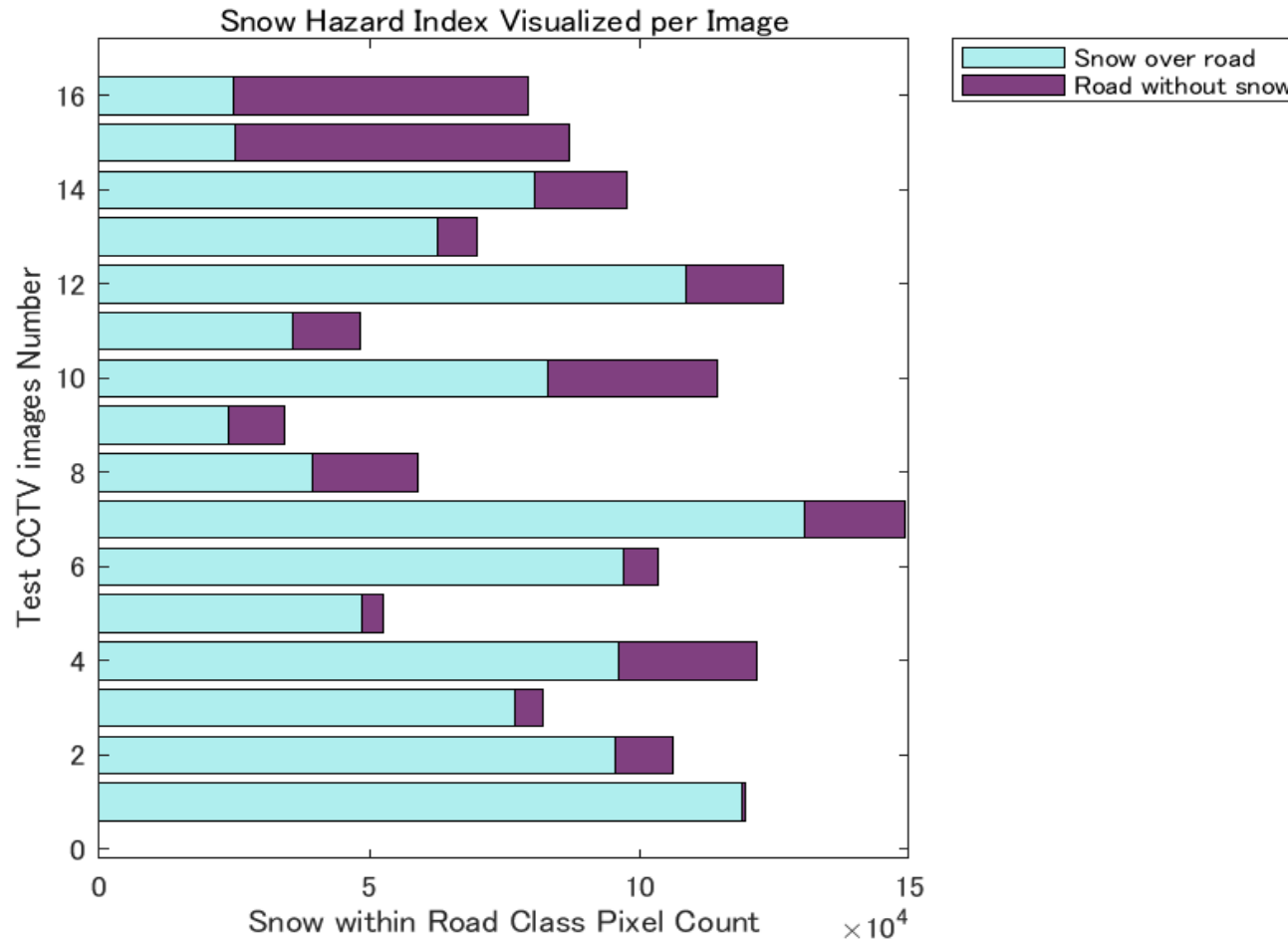
## 3.6 Snow Region Label Prediction from raw input

- Predict the **real region** of “snowy road” using the trained semantic segmentation network



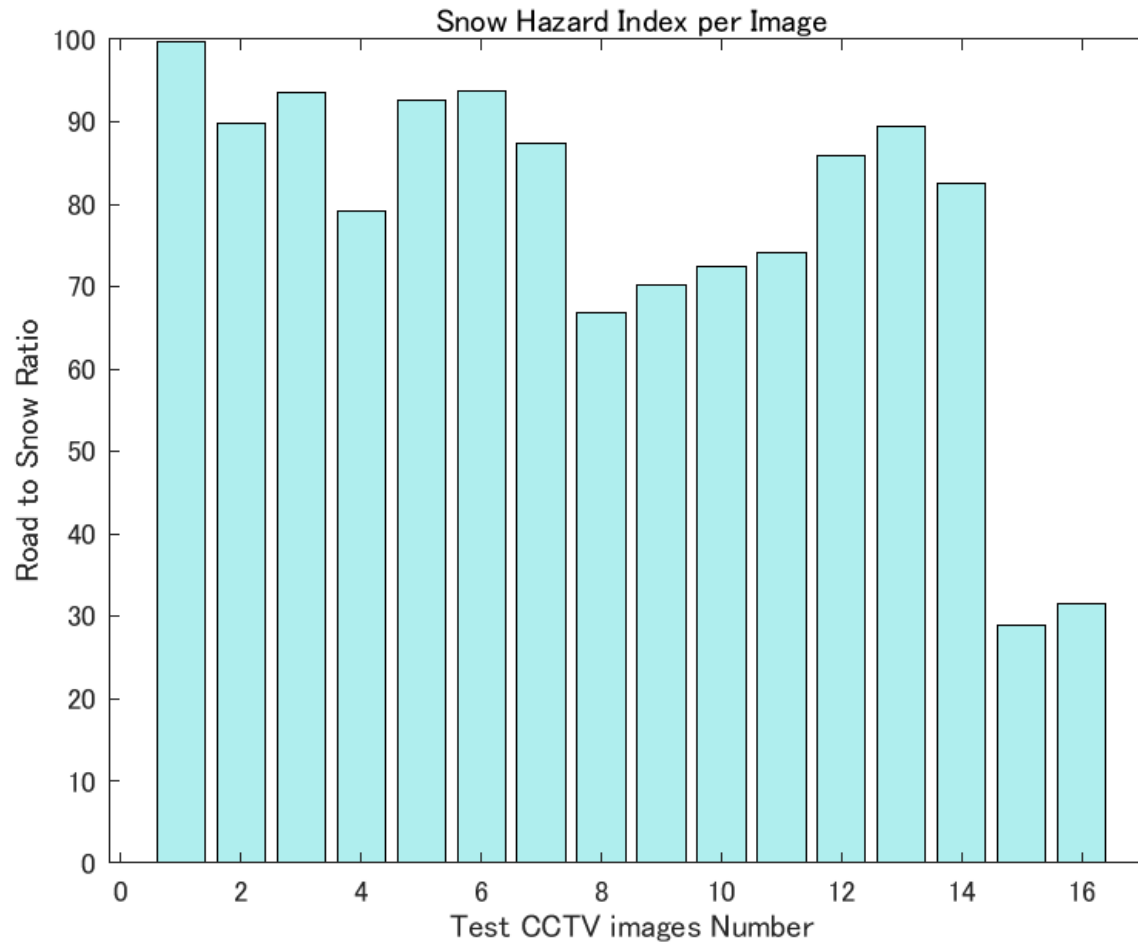
# 3.7 Snow-over-road and Road Surface without Snow

- Bar plots of the pixel count for the monitoring target ROI
- **Snow-over-road**, and **Road surface without snow**



## 3.8 Snow Hazard Ratio Index

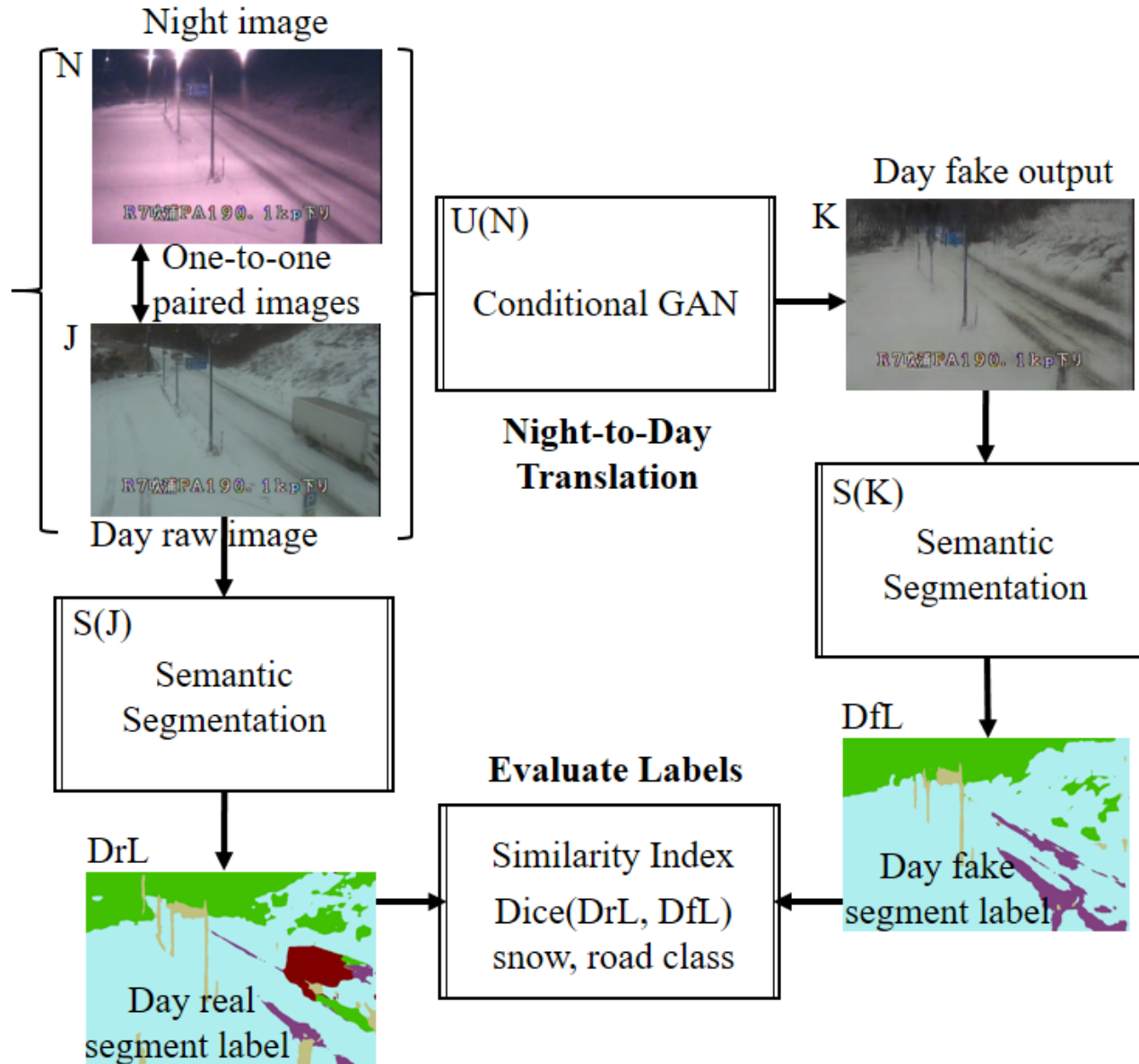
- Bar plots of the *snow hazard ratio* index; indicates the *snow ratio within the road surface ROI* of each image.



## 4. Snowy Night-to-Day Results

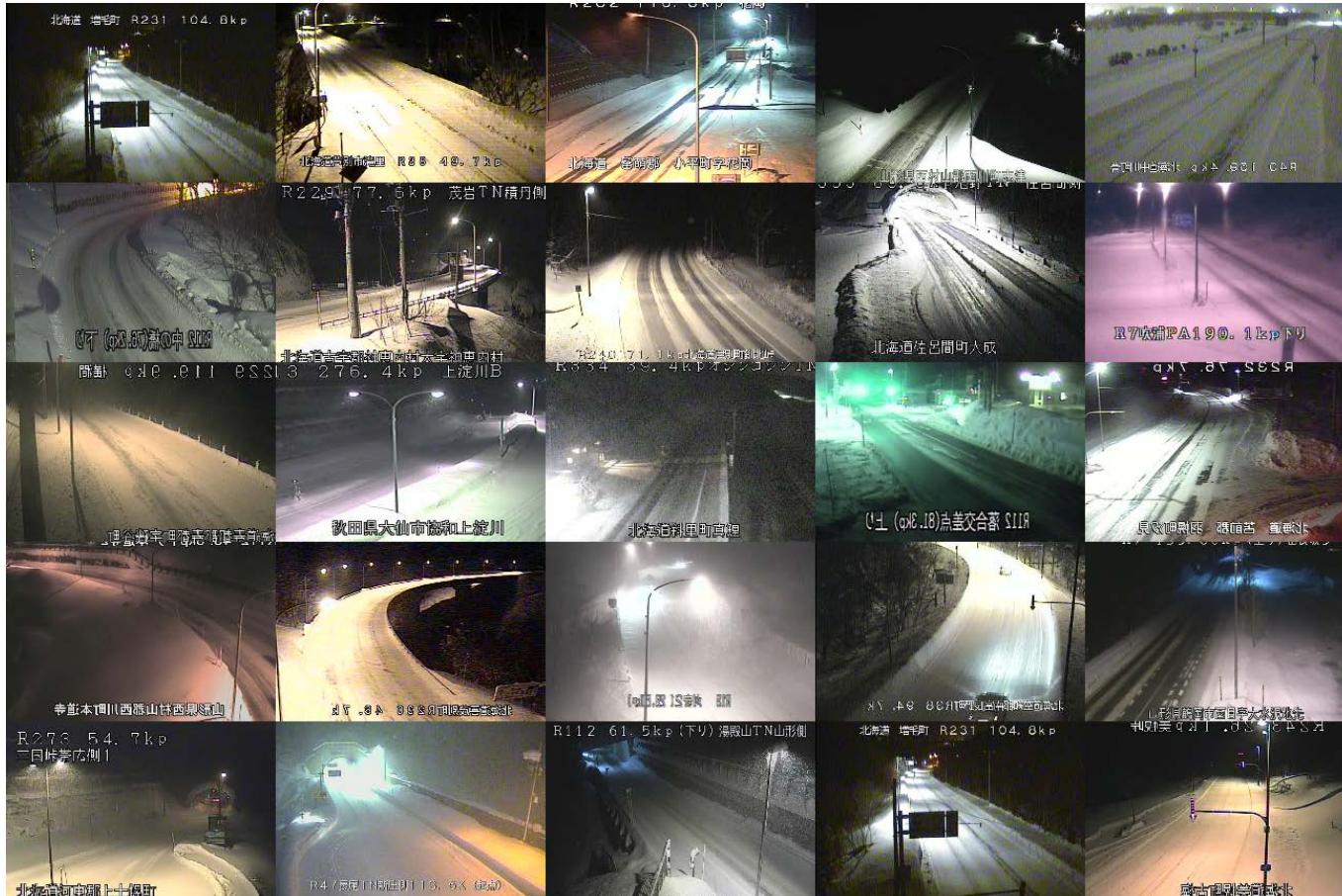


# Talk+ : Snowy Night-to-Day Translator Pipeline



# 4.1 Input Night Image Examples

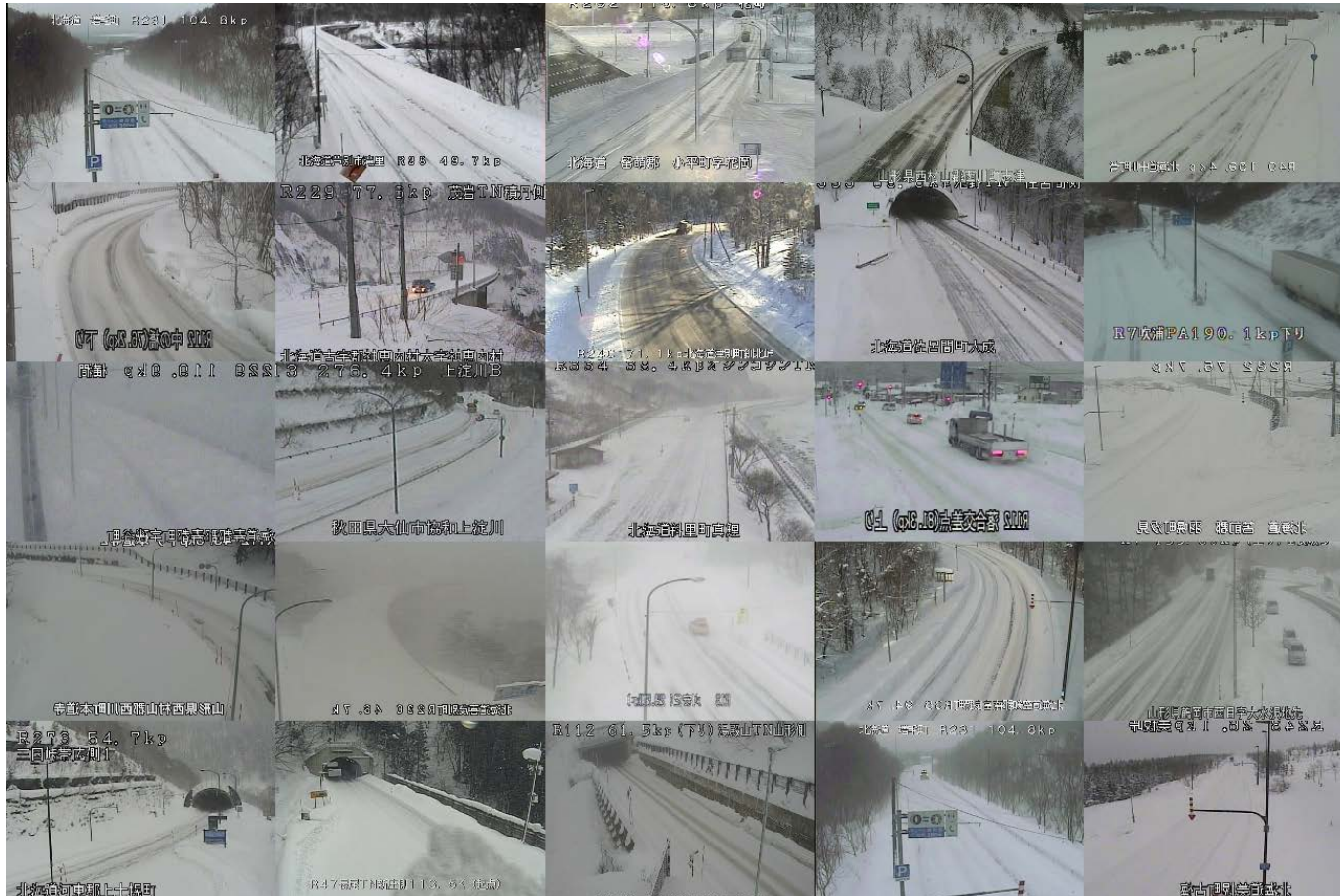
- Snowy night road surface : test images are selected
- Under lighting points, roads are moderately lighted up





# 4.2 Ground truth Day image Examples

- “day time” real situation,
- Snowy road surface have been shown clearly



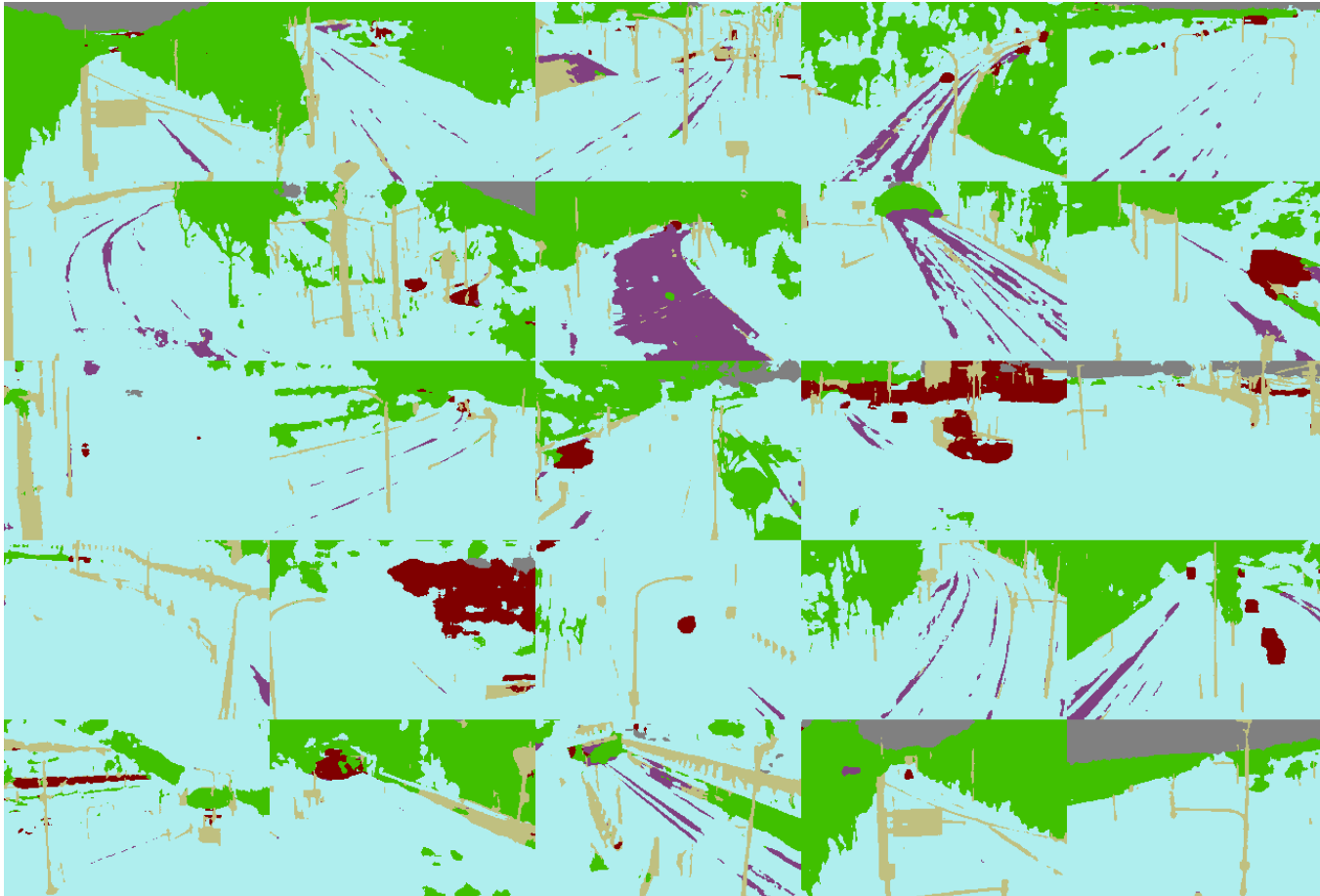
# 4.3 Fake Day output Examples

- Test night raw input is translated to “day time” fake situation using the trained the “night-to-day” pix2pix



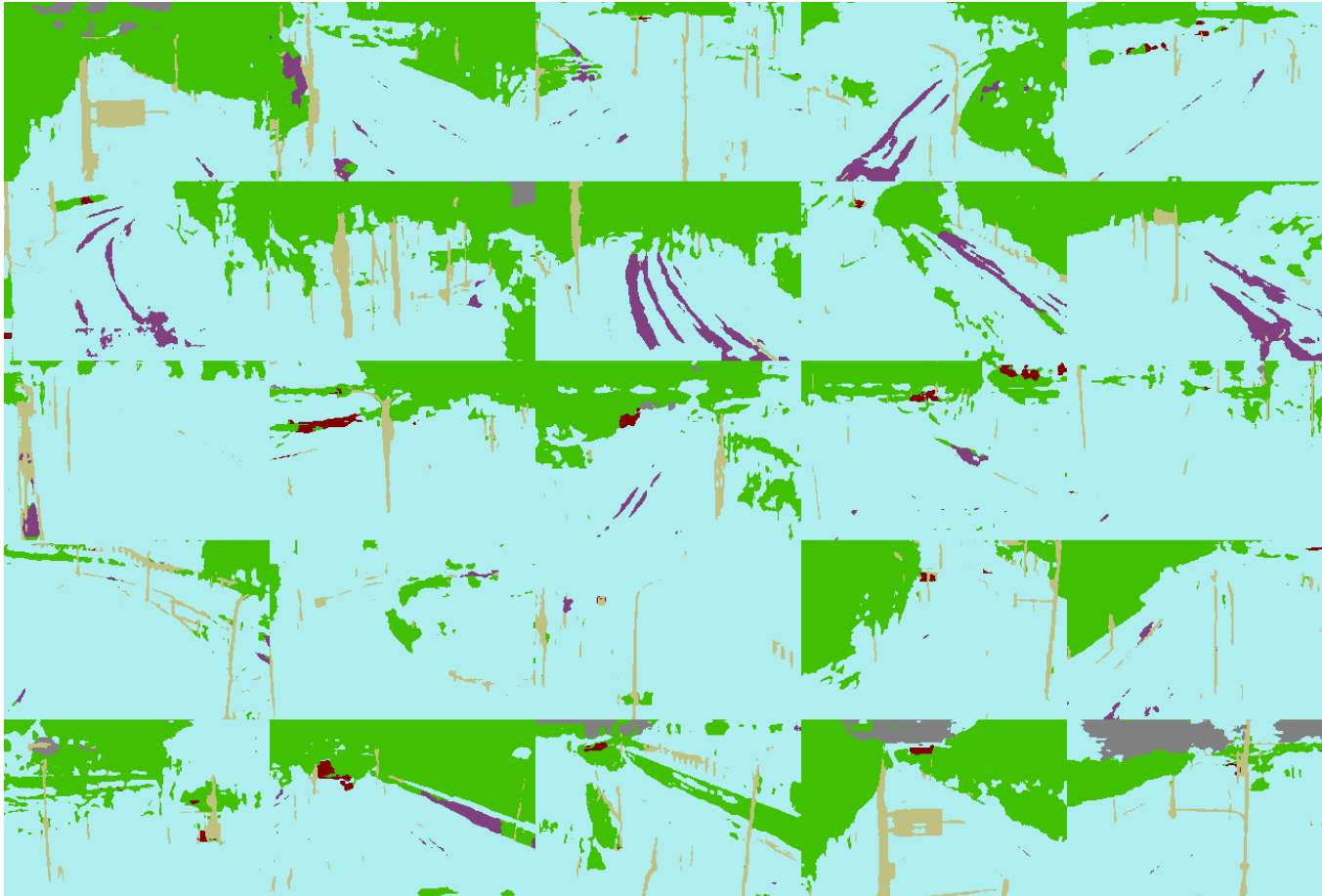
## 4.4 Day Label Prediction from Real input

- Predict the **fake snow label** of “day time” using the trained semantic segmentation network



## 4.5 Fake Day Label Prediction from fake output

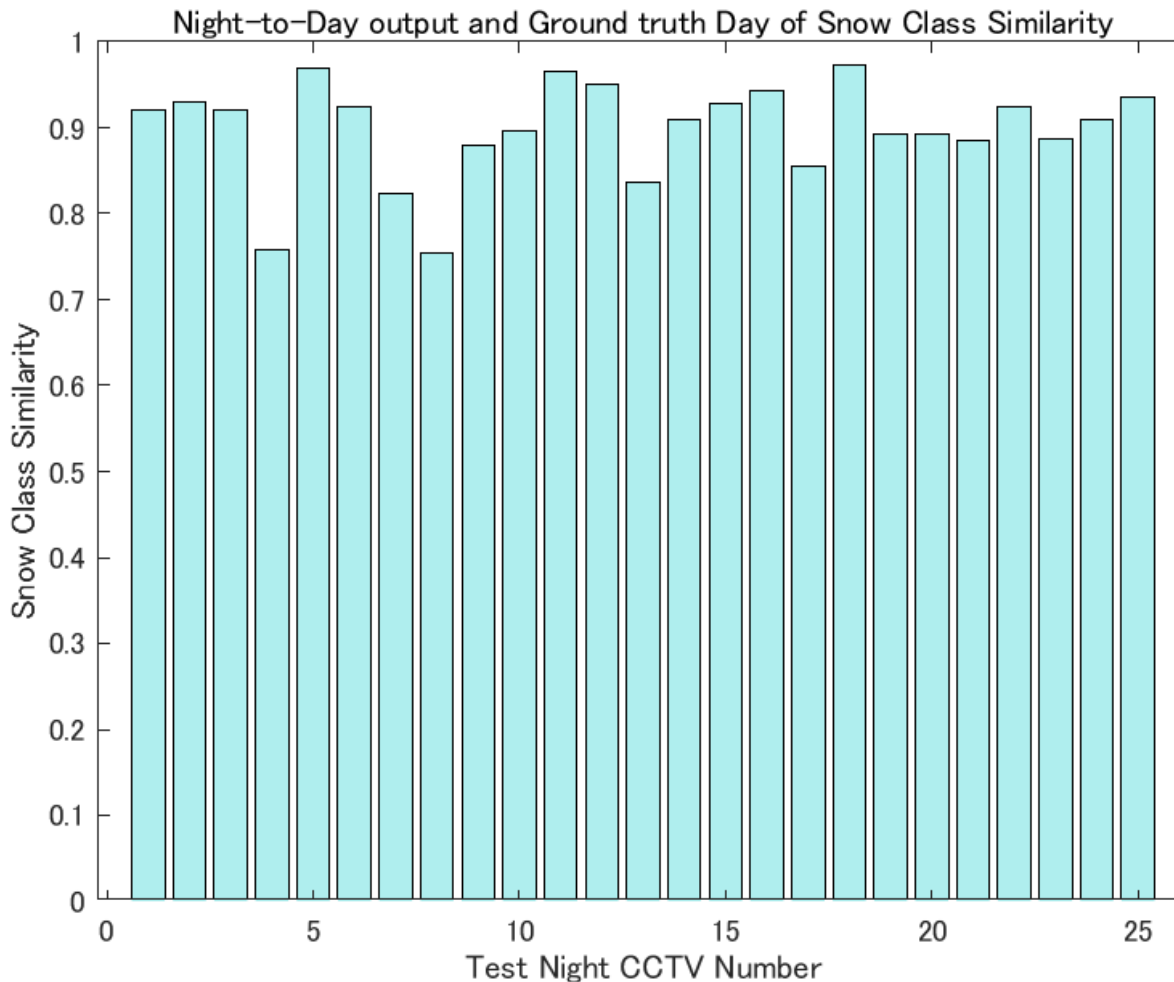
- Predict the **real snow region of “day time”** using the trained semantic segmentation network





## 4.6 Similarity between Real Snowy day and Fake

- Intersection of fake day snow region, and real day snow region
- These similarity scores are high more than 0.75



# 5. Concluding Remarks



## 5. Concluding Remarks

- Fake day label output from snowy night image have been **well approximated** to the Real snowy day label.
- Combine two pipelines for snowy night road status to make decisions of operations : “road closures” / “snow removal”, **even at night**.
- Extend to **edge computing** for automatic real-time provision for drivers about hazardous road status.

# Deep Learning for Pattern Recognition

- RIIPS (Research Institute for Infrastructure Paradigm shift).
- DLPR project: Natural Disaster, Traffic Detection.

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