The 11th REAAA BUSINESS FORUM

SEPTEMBER 4th, 2024 (WED) / BITEC, BANGKOK

# Application of Machine Vision-Based Road Surface Maintenance Technology for Coping with Climate Change in Korea

**Dr. KIM, In-bae**

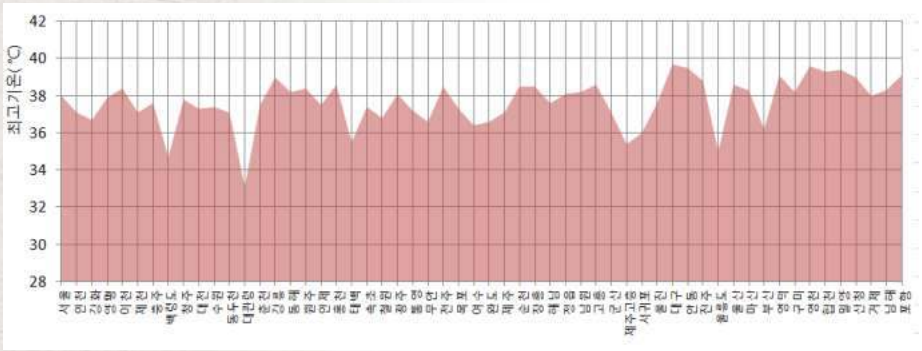
Principal Researcher / Korea Expressway Corporation Research Institute

Korea Expressway Corporation

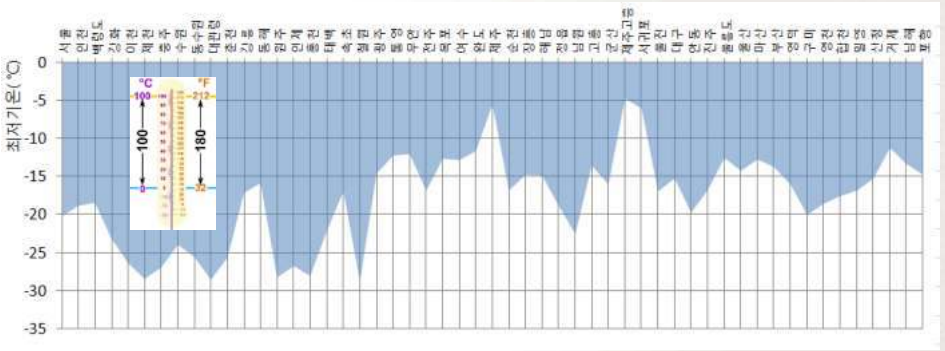
# Road Damages due to Abnormal Temperatures in Korea

## ▪ Climate and Temperature Characteristics of Korea

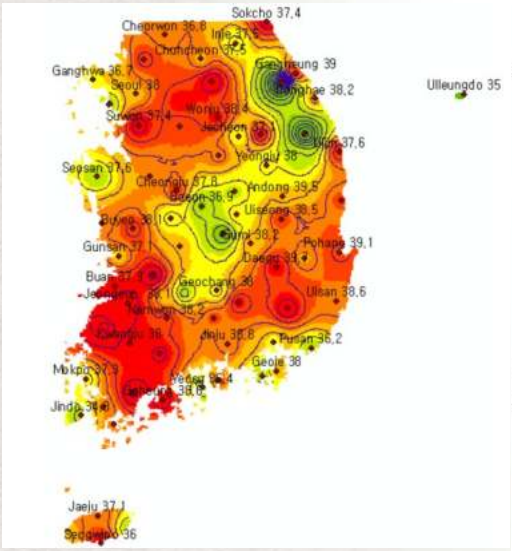
- 50 year Frequency Maximum Atmospheric Temperature Range by Region (33.1℃ ~ 39.7℃ ; 92℉ ~ 103 ℉)



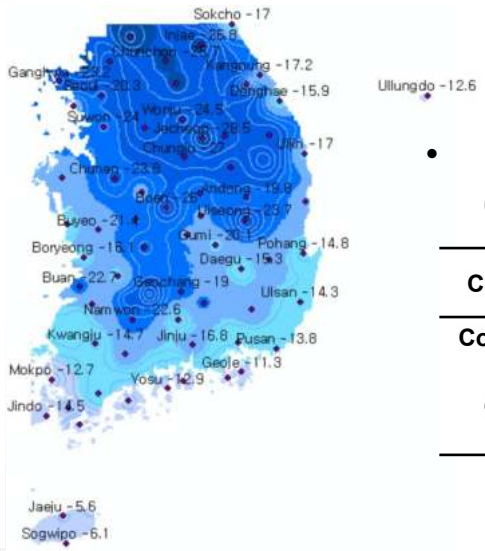

- 50 year Frequency Minimum Atmospheric Temperature Range by Region (-28.8℃ ~ -4.8℃ ; -20℉ ~ 23 ℉)




[Highest Temperature Contour Map]




[Lowest Temperature Contour Map]

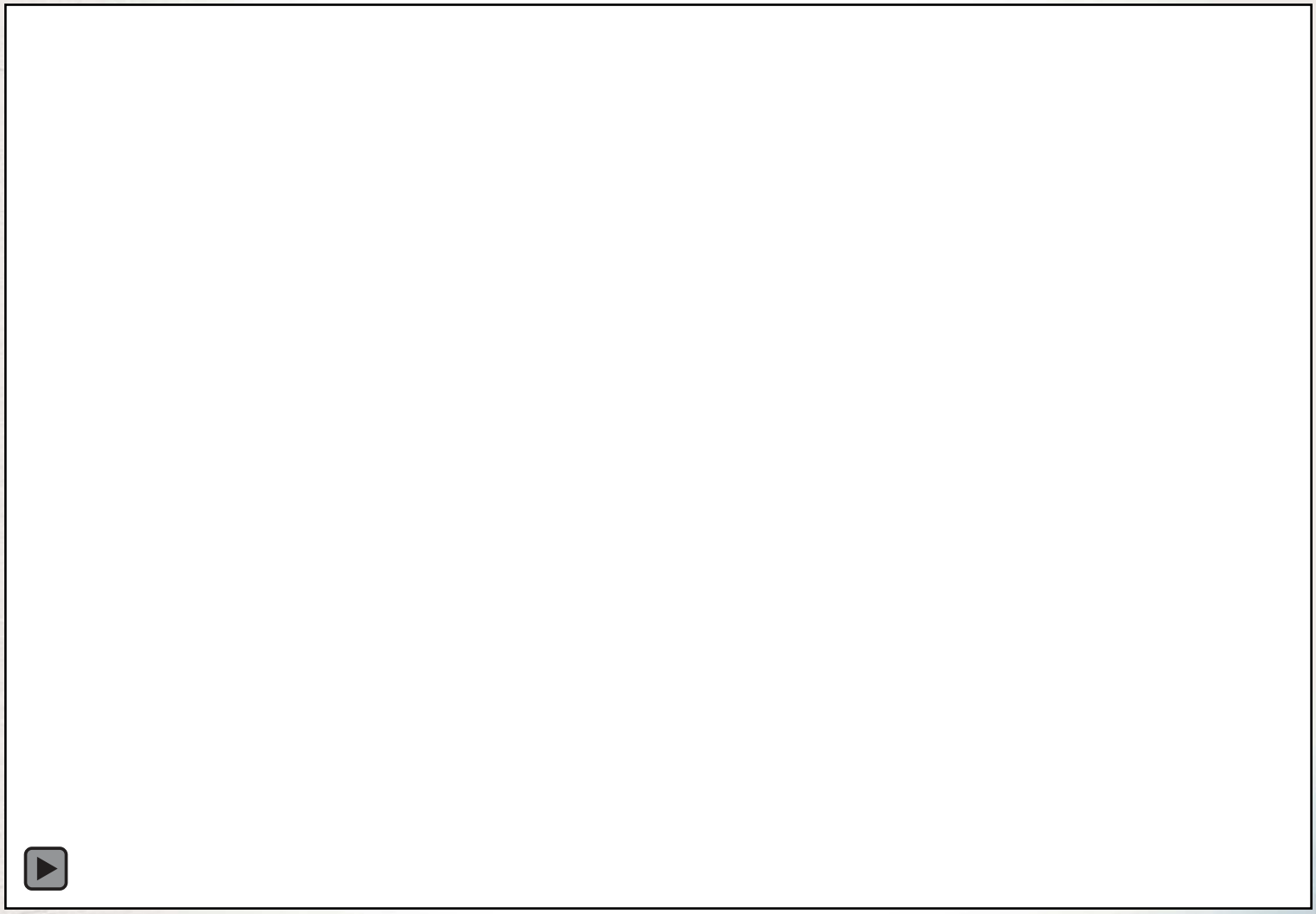



- Korean Highway Bridge Technical Standard (1972 ~ Present)

| Climate | Steel bridge (Steel plates) | Steel composite bridge (Steel girder & concrete slab) | Concrete bridge |
|---|---|---|---|
| Common area | -10 ℃ ~ 50 ℃ | -10 ℃ ~ 40 ℃ | -5 ℃ ~ 35 ℃ |
| Cold area | -30 ℃ ~ 50 ℃ | -20 ℃ ~ 40 ℃ | -15 ℃ ~ 35 ℃ |

# Road Damages due to Abnormal Temperatures in Korea

- **Case of Blow-ups in Concrete Pavements (2018)**

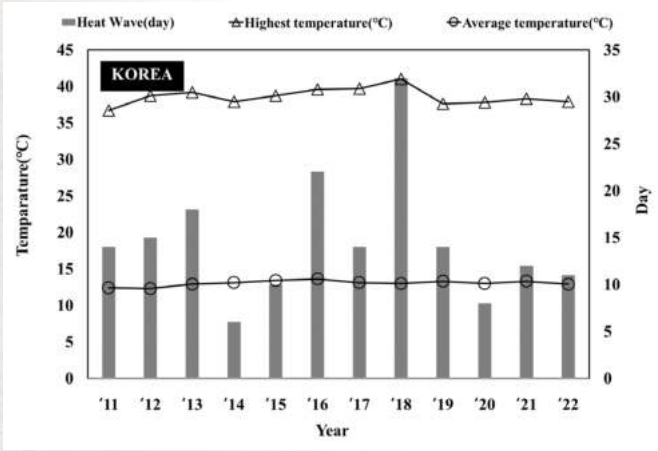


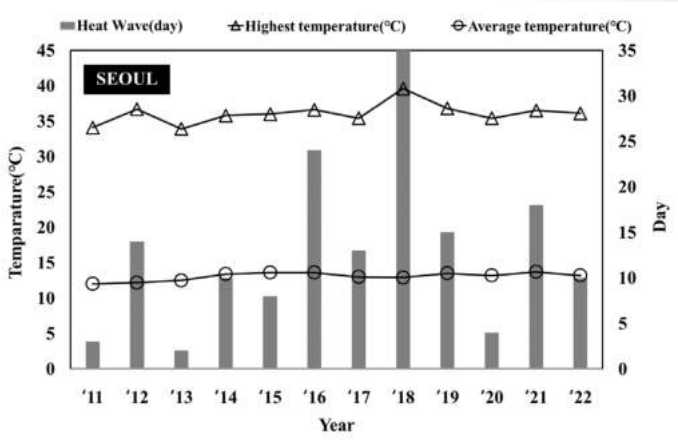
# Road Damages due to Abnormal Temperatures in Korea

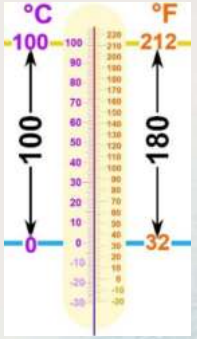
## ▪ Correlation between Climate Change and Road Damages

H.W(Heatwave) : A condition where the daily maximum temperature remains at or above 33℃ (91 ℉) for two consecutive days or more

| Year | '11 | '12 | '13 | '14 | '15 | '16 | '17 | '18 | '19 | '20 | '21 | '22 | Average ('11~'22) | Annual Average ('81~'10) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $T_{average}$ (℃) | 12.4 | 12.3 | 12.9 | 13.1 | 13.4 | 13.6 | 13.1 | 13.0 | 13.3 | 13.0 | 13.3 | 12.9 | 13.0 (0.6℃↑) | 12.4 |
| $T_{highest}$ (℃) | 36.7 | 38.7 | 39.2 | 37.9 | 38.7 | 39.6 | 39.7 | 41.0 | 37.6 | 37.8 | 38.3 | 37.9 | 38.6 (1.1℃↑) | 37.5 |
| H.W (Days) | 14 | 15 | 18 | 6 | 10 | 22 | 14 | 32 | 14 | 8 | 12 | 11 | 14.7 (45%↑) | 9.8 |
| $H.W_{Cont}$ (Days) | 6 | 21 | 20 | 7 | 17 | 34 | 9 | 37 | 13 | 11 | 19 | 13 | - | - |

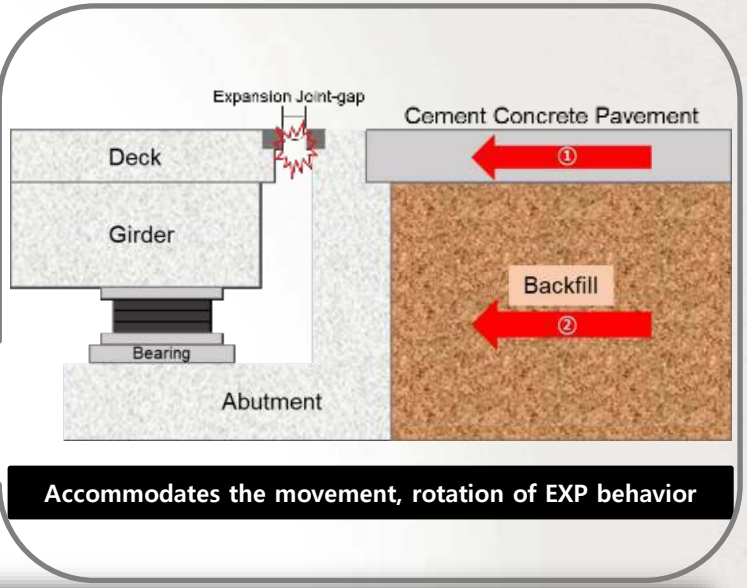



➡ Heatwaves are related to road damage during the summer season

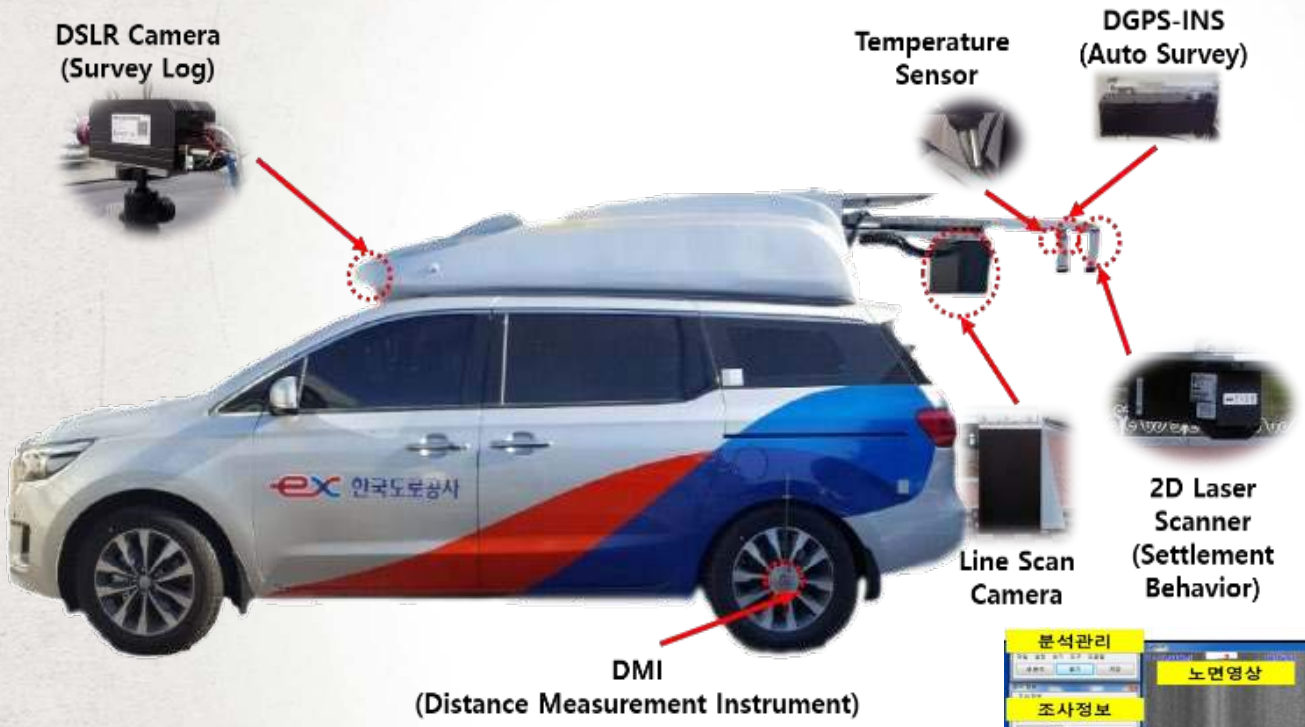
# Development of a Machine Vision-Based Preventive Maintenance System




- Movement of Abutment Ground
- Heat from Abnormal Temperatures
  - Swelling of Concrete Pavement
- Alkali Aggregate Reaction

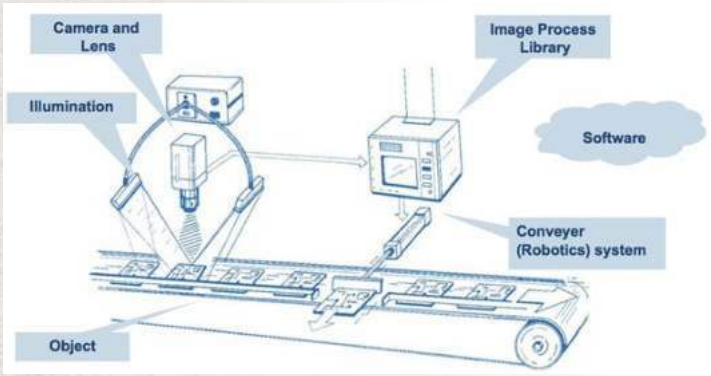
# Development of a Machine Vision-Based Preventive Maintenance System

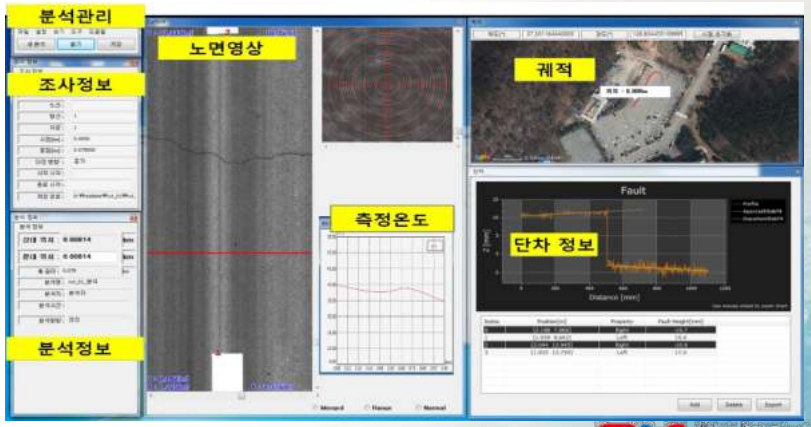
## ● Development System(NEXUS) and Main Function Configurations




- Spec (Line scan camera)
  - **Teledyne DALSA** (CANADA)
  - **Max. Line rate : 68 kHz**

- **Required performance**
  - **Resolution :**
    0.5mm/80km/hour
    **1.0**mm/100km/hour
  - **Auto survey with GPS**



# Development of a Machine Vision-Based Preventive Maintenance System

- **Expansion Joint Device Analysis Process for AI Method**

**1. Step 1: Finding Device Location (Classification)**

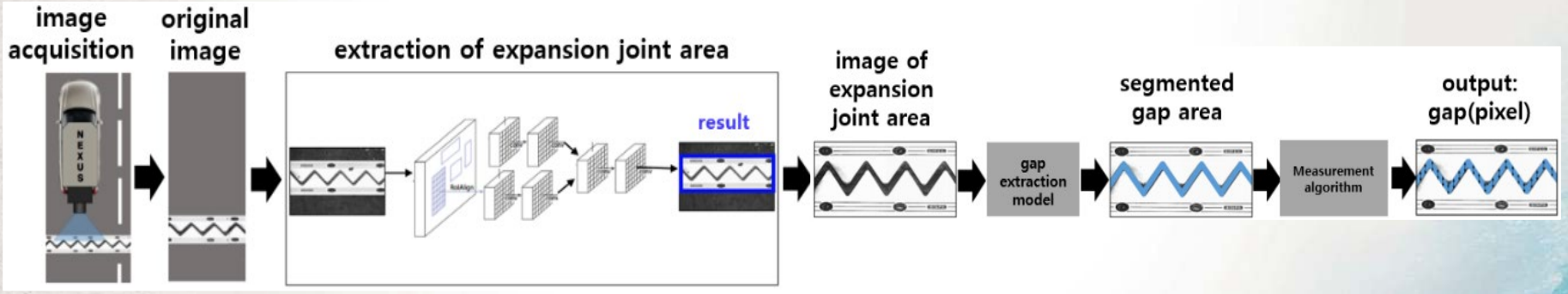
Objective: Accurate image detection of NEXUS system survey results.

Approach: Classification techniques to identify the device location.

**2. Step 2: Finding Minimum Pixels (Segmentation)**

Objective: Determine the device openings value.

Approach: Segmentation methods to extract relevant pixels.

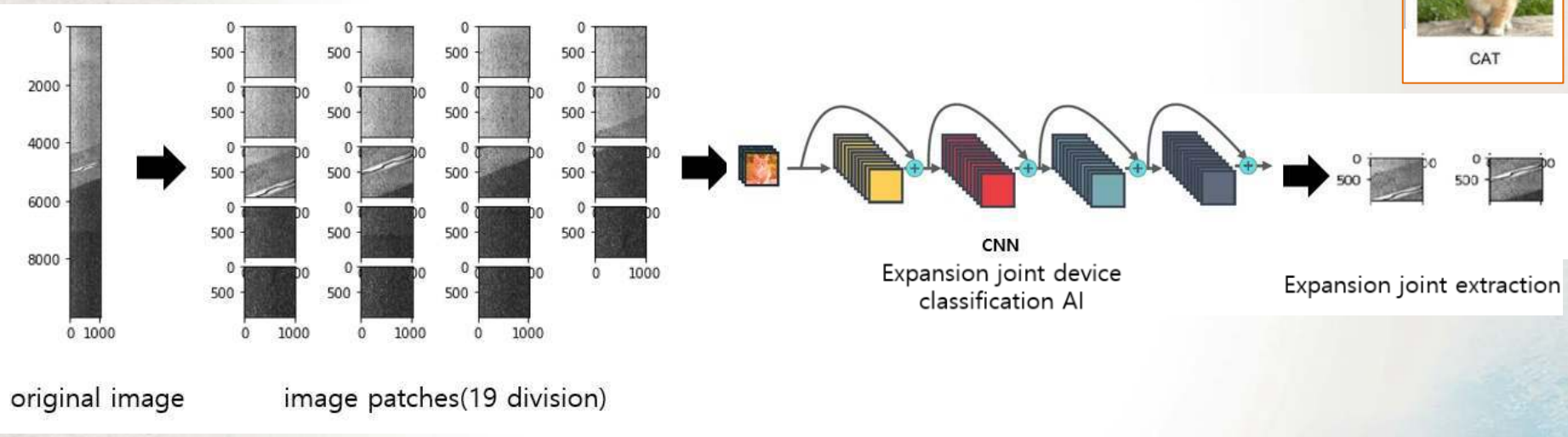


# Development of a Machine Vision-Based Preventive Maintenance System

## Step 1. Finding Device Location (Classification)

Objective: Accurate image detection of NEXUS system survey results.

Approach: Classification techniques to identify the device location.

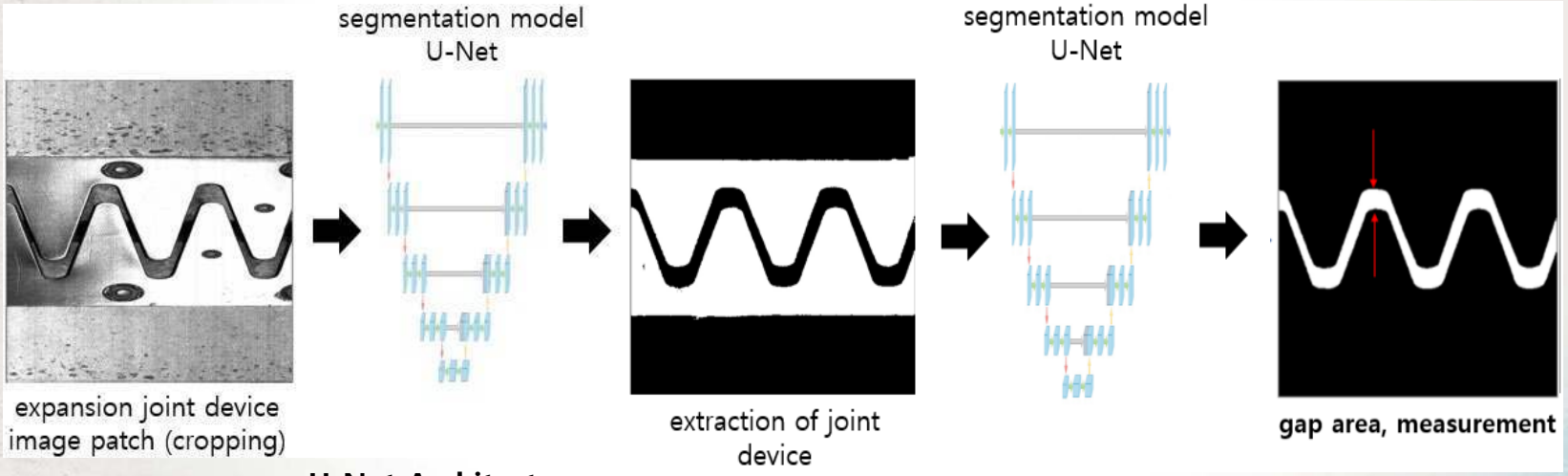


# Development of a Machine Vision-Based Preventive Maintenance System

## Step 2. Finding Minimum Pixels (Segmentation)

Objective: Determine the device openings value.

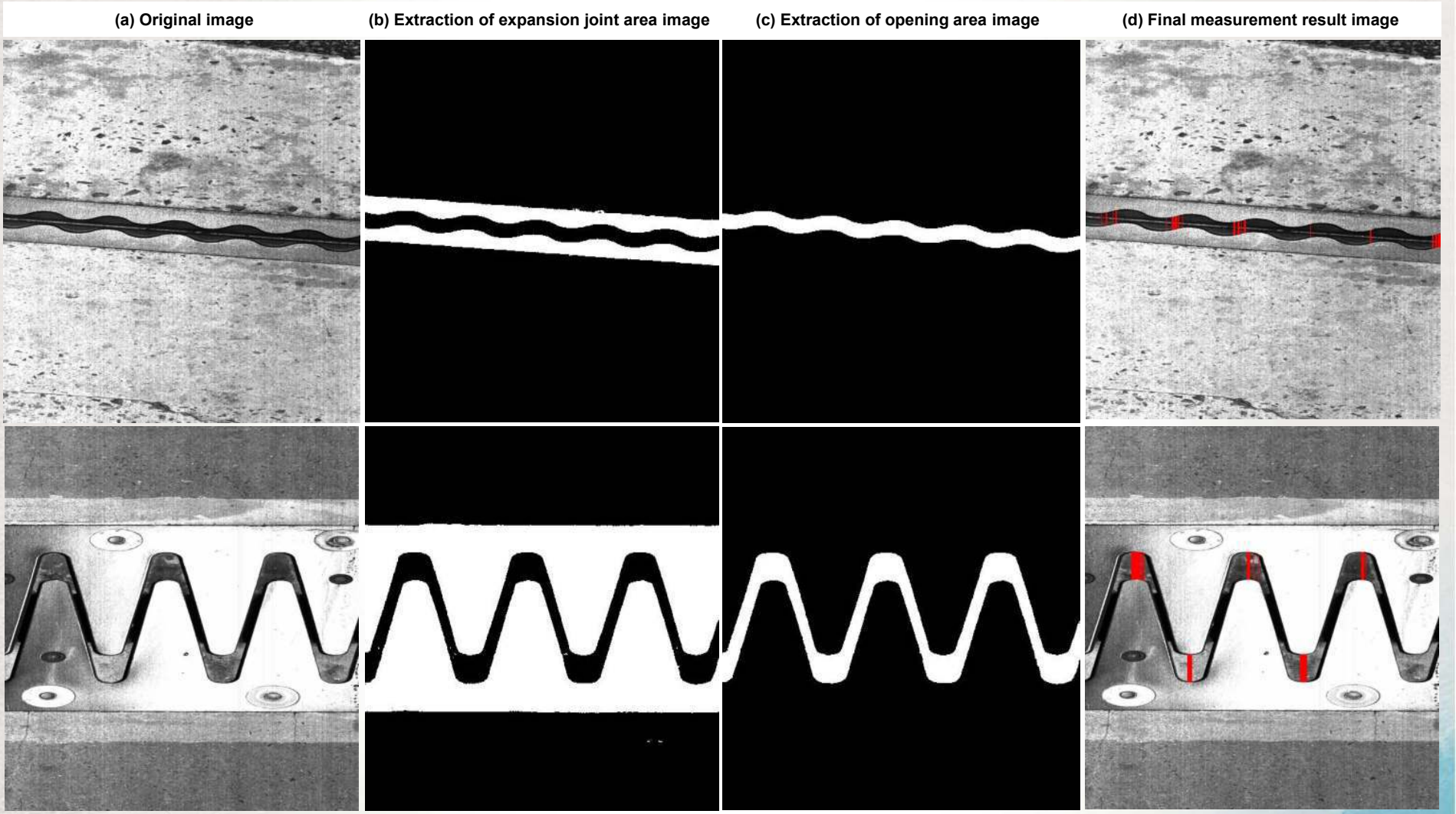
Approach: Segmentation methods to extract relevant pixels.


**<U-Net Architecture>**
(Ronneberger et al. 2015)

# Development of a Machine Vision-Based Preventive Maintenance System

- **Example of Processing Results**



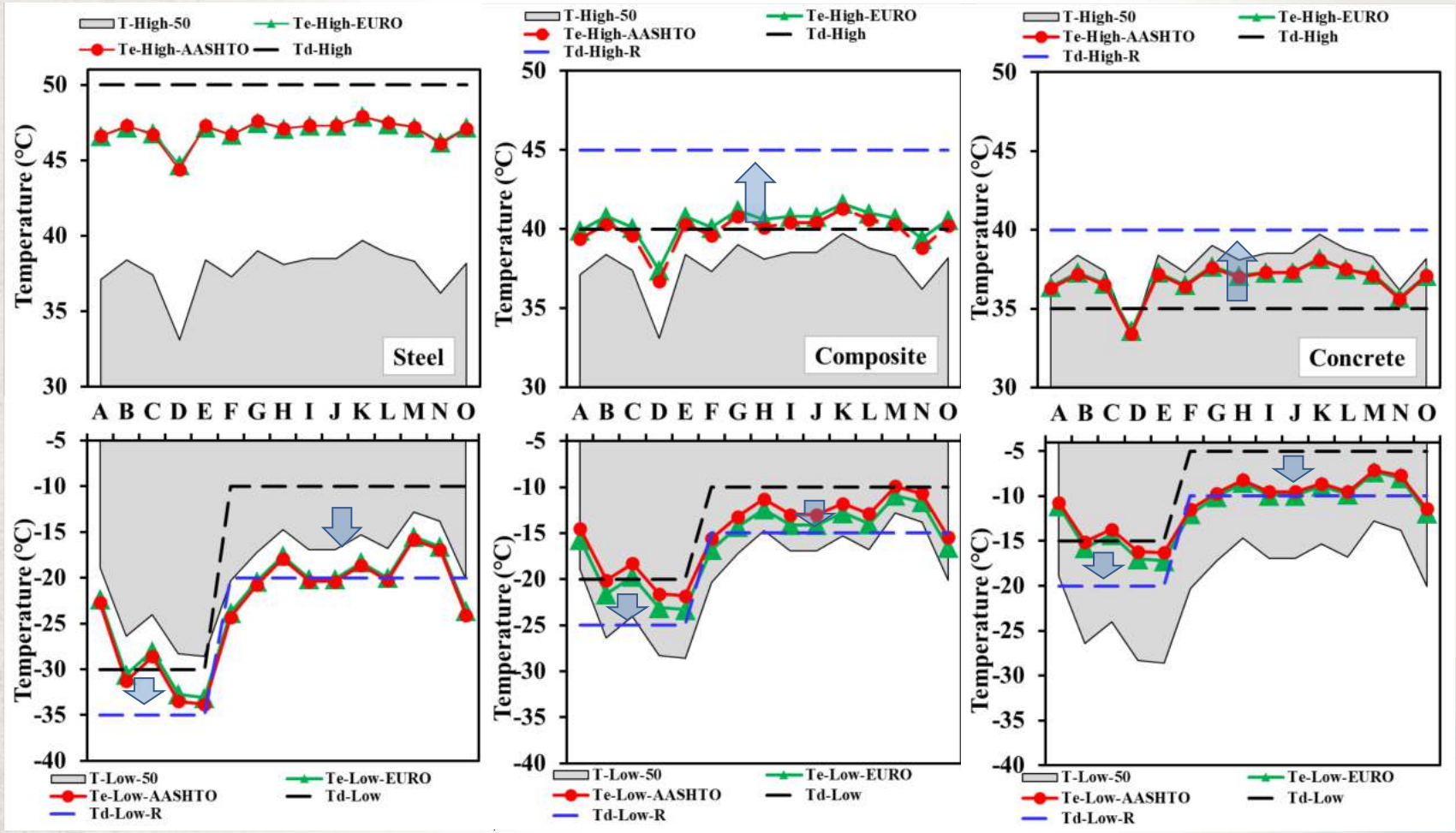
# Conclusion

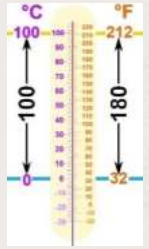
- **Saving Inspection Time by 90%**
  1 hr → 5 min / each bridge (Average)
- **Annual Cost-saving Effect:** Approximately **30% ( $3.3 million ) on a budget of $11 million (USD)** for KEC's expansion joints annual replacement expenses
- **Database Management:** It is possible to **track and monitor variations in joint-gap**
- **Preventive Maintenance** through **Bridge Response Monitoring**


Ministry of Land,
Infrastructure and Transport

# Ⅱ. Review of Temperature Design Standards by Country

- **Experimental studies by type are needed to establish the effective temperature of bridges suitable for the climate of Korea**




- Steel -　　- Composite -　　- Concrete -

# Conclusion