A Study on the Evaluation of Rust on Weathering Steel Using Machine Learning

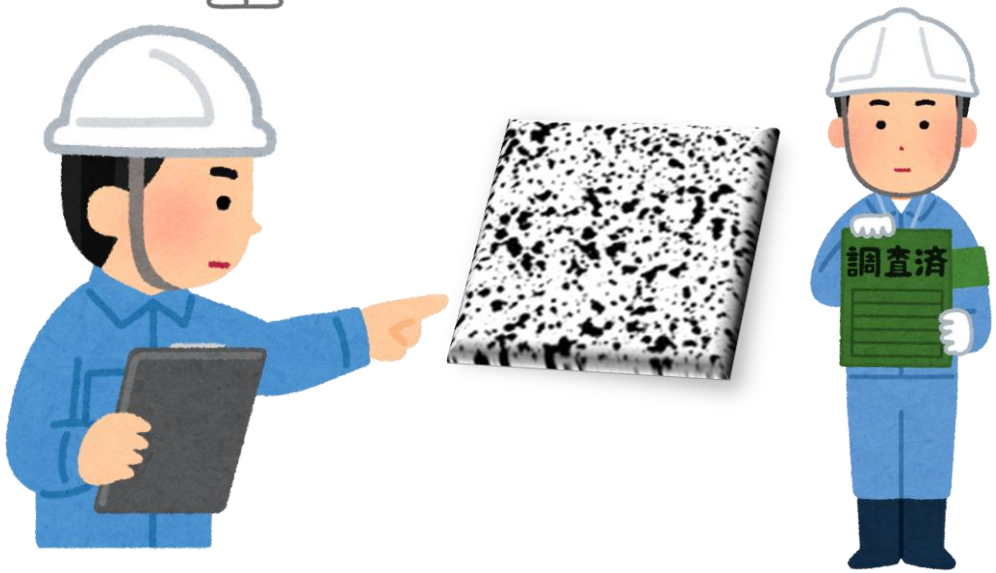
7022615 Ren Morii

1, About my research

- If we can build a system that can look at the rust and give consistent scores, inspections will become more reliable and efficient.

○Until Now

×**Many**



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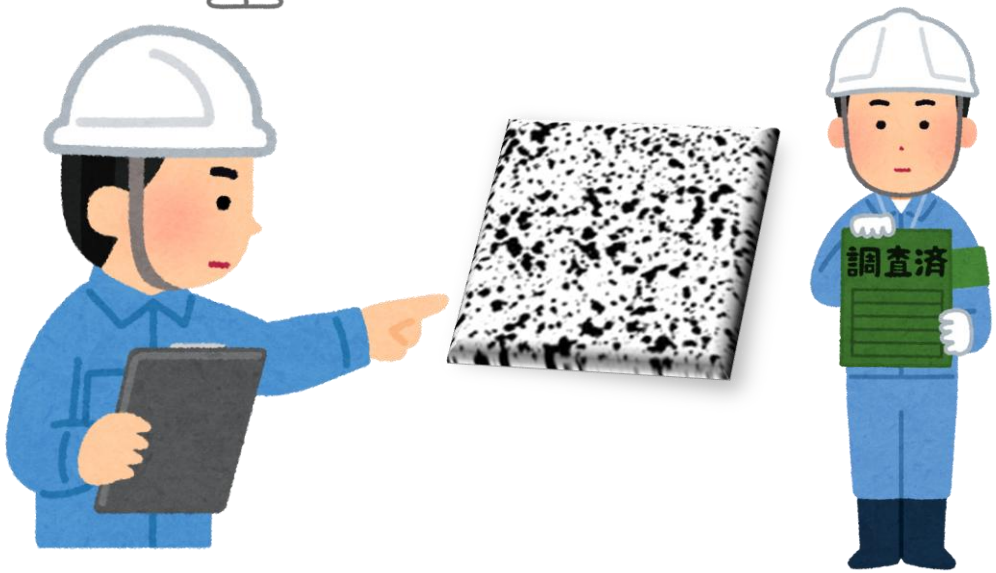
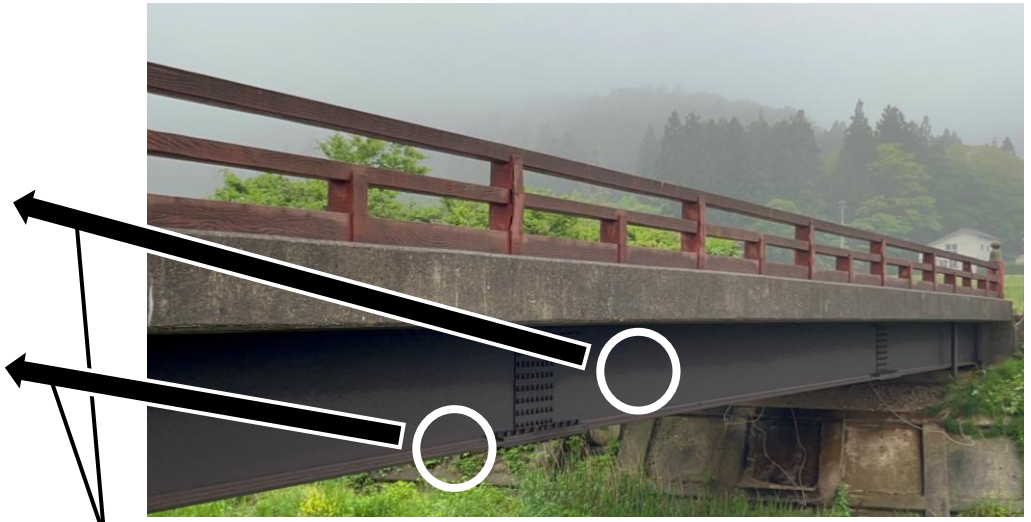


○In the future

×**Fewer**

1, About my research

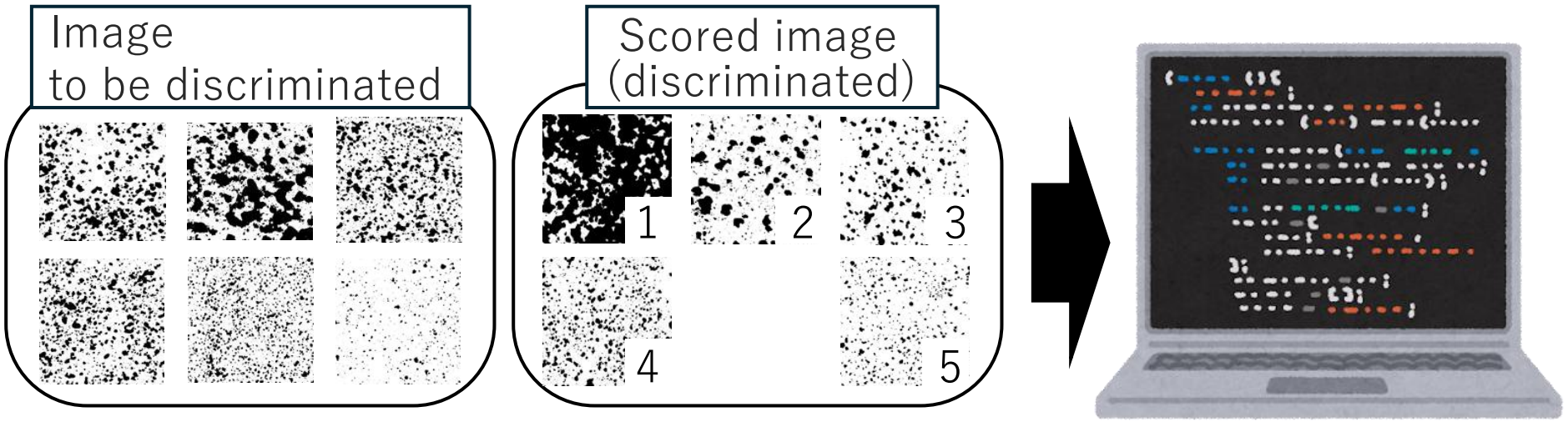
- My graduation research is …
  To automatically evaluate the condition of rust on weathering steel bridges.
- The goal of this research is …
  To create an AI system that can analyze images taken by drones to help with bridge inspections.



Extract as black-and-white image

1, About my research

- I am working with rust images collected from past field investigations and developing a machine learning model that can look at these images and assign them a rust severity score, from 1(very rusty = bad) to 5(very clean = good).
- This helps make infrastructure inspections safer and more consistent.



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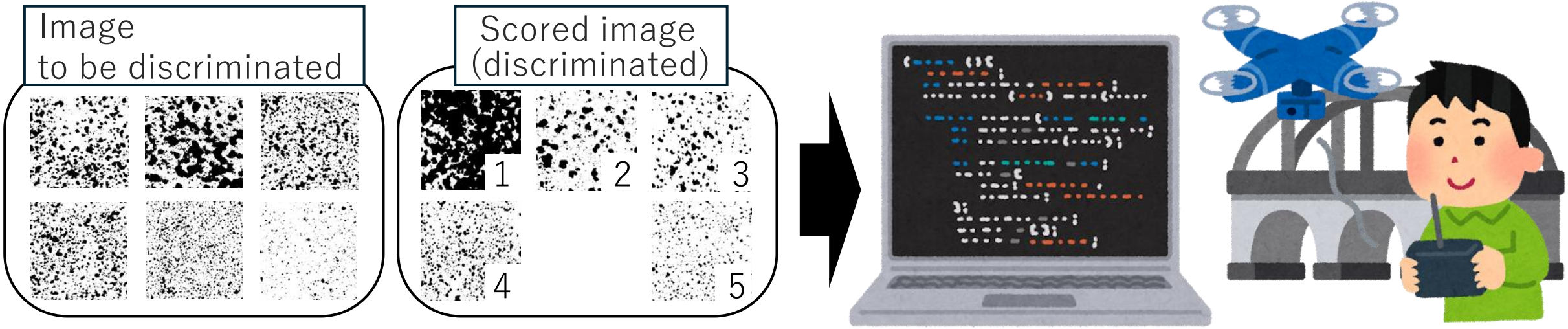
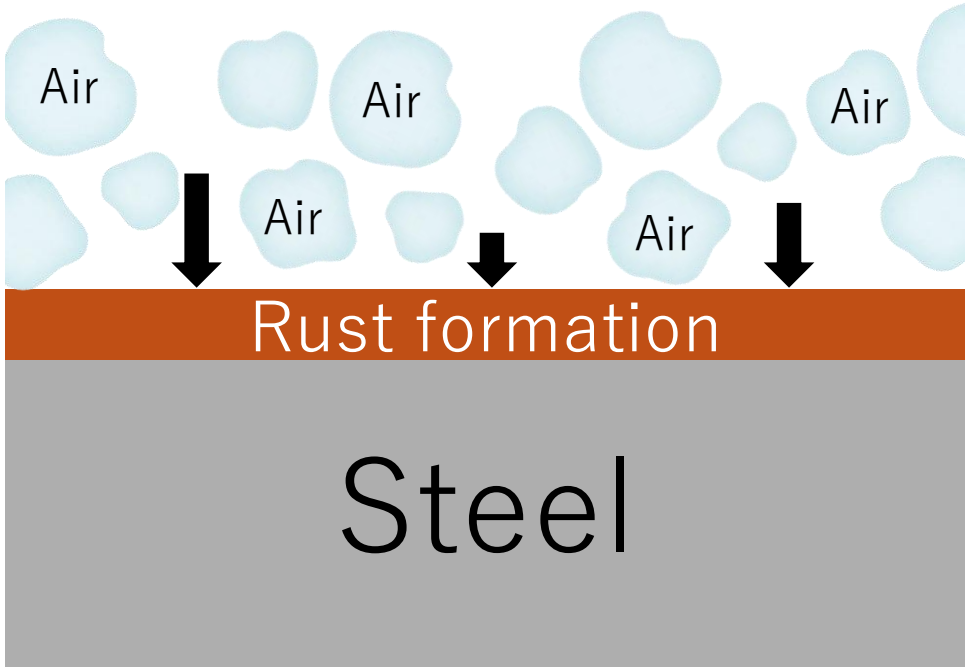


2, What is Weathering Steel?

- Weathering Steel is a type of steel designed to reduce the need for painting and periodic maintenance.
- By pre-dressing the surface with rust, it acts as a protective layer that protects the interior and prevents corrosion.

Weathering steel bridge (Yurihonjō City, Akita Pref)



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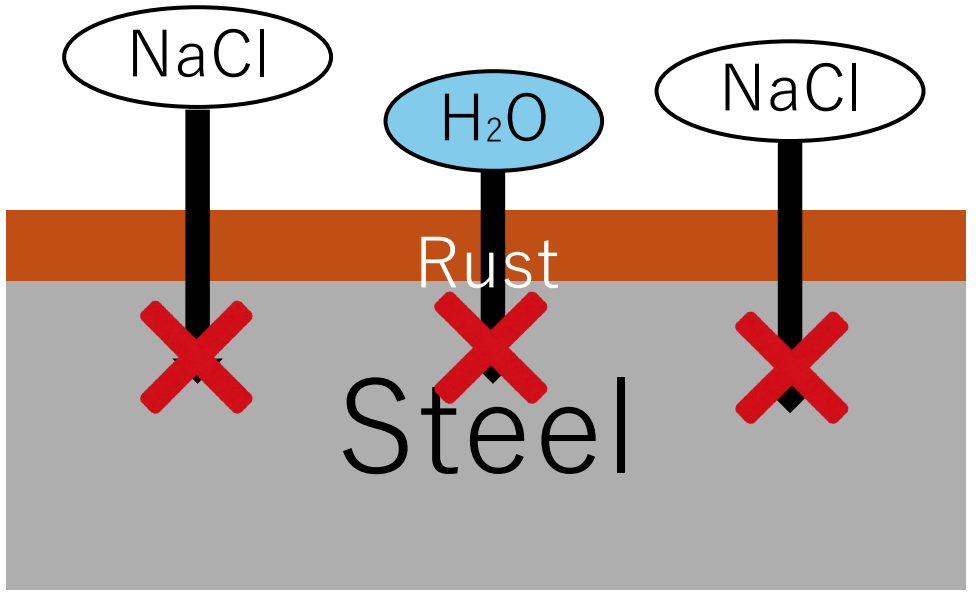

2, What is Weathering Steel?

○Merit

・Reduced maintenance costs.

⇒It does not need to be painted, except in areas facing the sea, thus reducing the time and cost required for painting.

・It is used for bridges and buildings not only in Japan but also in other countries.

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Tsunami Disaster Prevention Station on Awaji Island, Hyōgo Pref

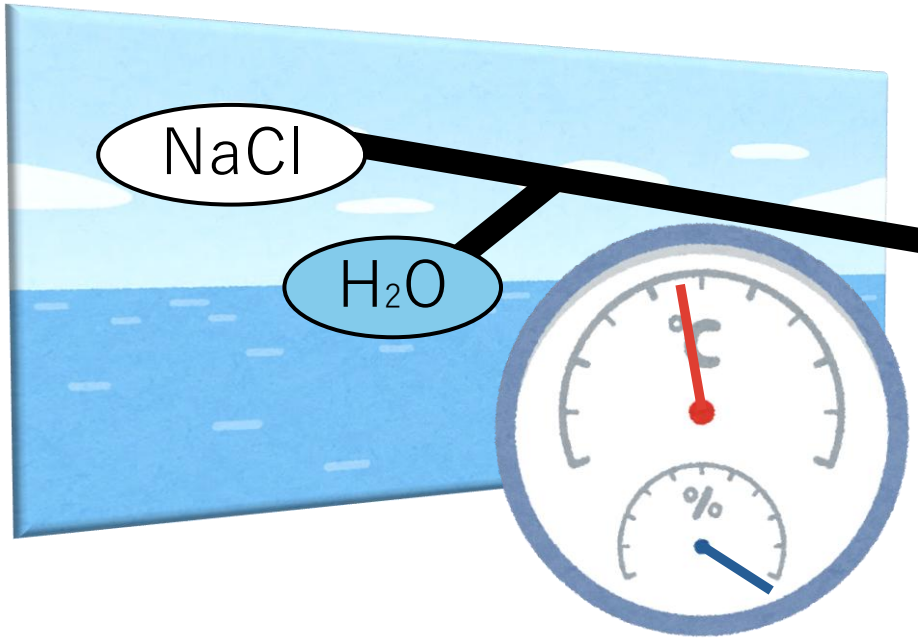
Student dormitory at a university in the UK

Mtaylor848 - Work created by contributor, CC Attribution-ShareAlike 3.0, https://commons.wikimedia.org/w/index.php?curid=8113650による

2, What is Weathering Steel?

○Things to watch out for

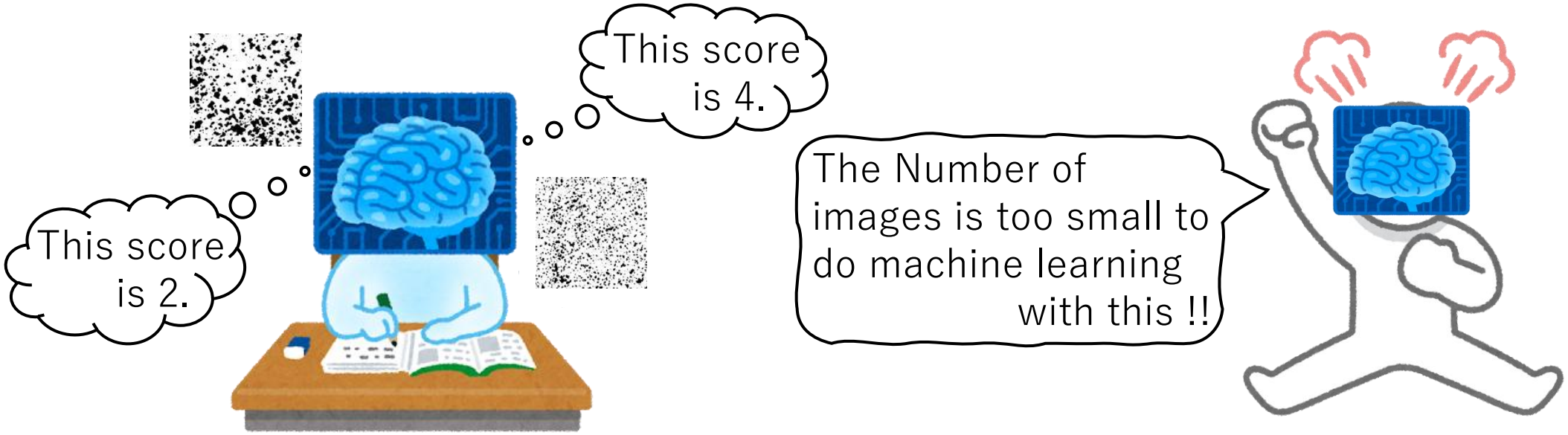
- The rust protection layer works only when the surface condition is properly managed, and if the rust grows too much or peels off, the service life will be reduced.
- Periodic inspections and surface coating are necessary in humid areas or areas where salt is blown in, such as the sea.



Sillyputtyenemies - Work created by the contributor, CC Attribution-ShareAlike 3.0, https://commons.wikimedia.org/w/index.php?curid=6498963による

3, How do we score rust?

- In this project
  I use AI to give rust images a score between 1 (bad) and 5 (good).
- I start with a small number of images that have already been scored by senior. There are 24 labeled rust images. These labels tell the AI what the “correct” score is.

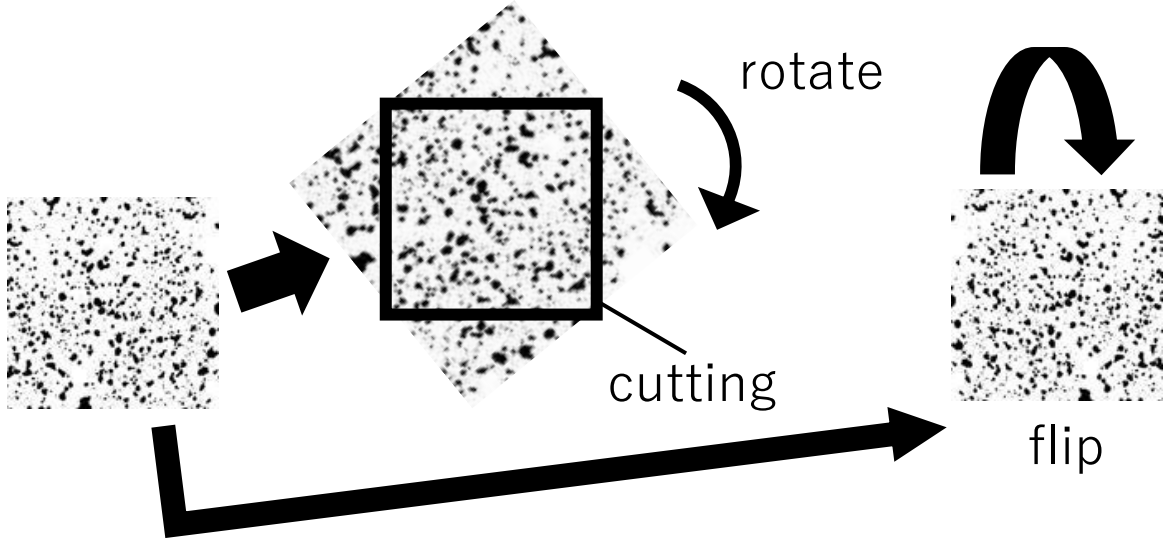


3, How do we score rust?

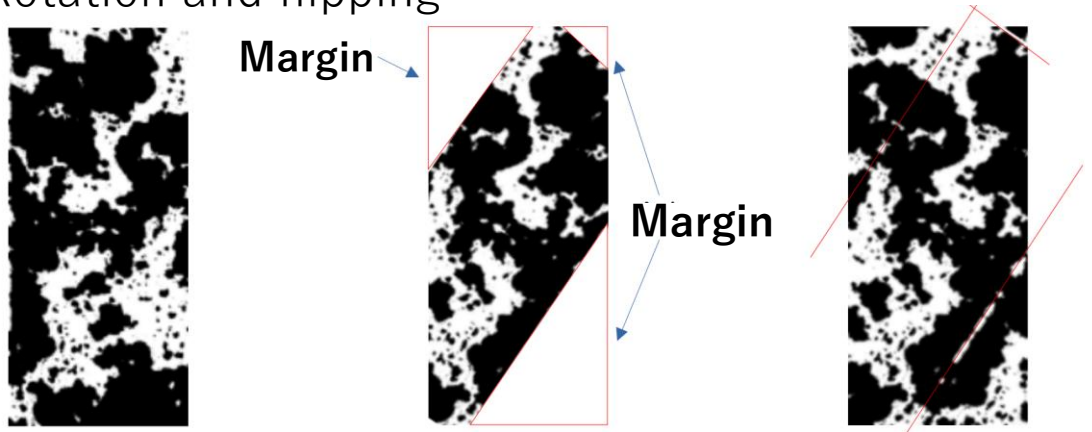
- To solve this problem
  using data augmentation. This means we create many new images from the original 24.

ex) rotate the image, flip it, or combine rotation and flipping

⇒ The number of images could be increased from 24 labeled rust images to approximately 4,000 by using data expansion techniques.



○Rotation and flipping



Before processing

After rotation/flipping

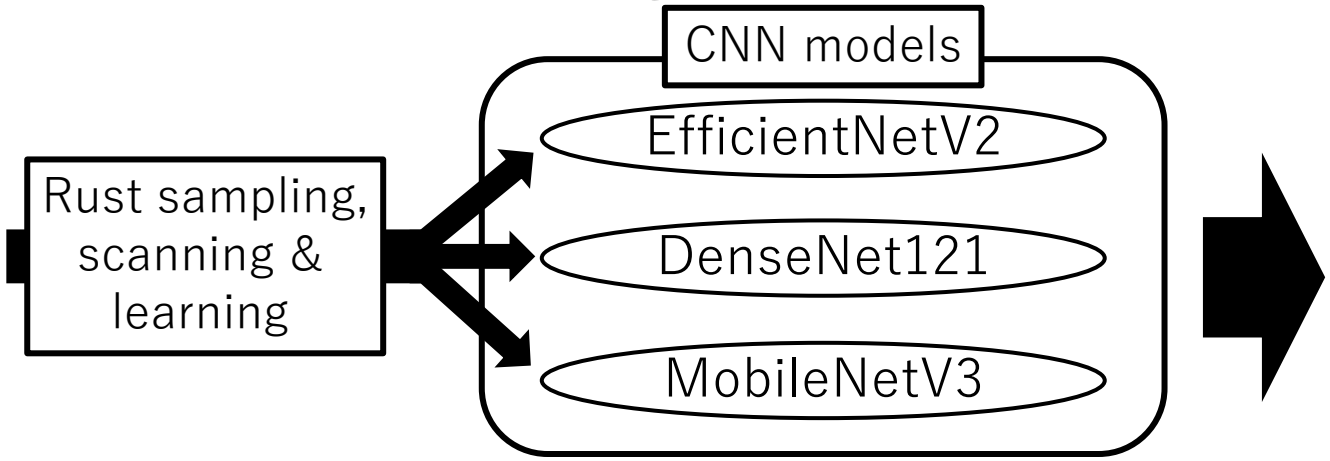
After margin processing

3, How do we score rust?

- CNNs are good at recognizing features in images. I tried different models, such as EfficientNetV2, DenseNet121, and MobileNetV3. These models were first trained on general images, and I retrain them with our rust images. } transfer learning
- The CNN looks at a rust image and outputs a score, like 3.45 or 4.10. Later, I round this score into one of five categories using a function called binning.

Rust image (example)

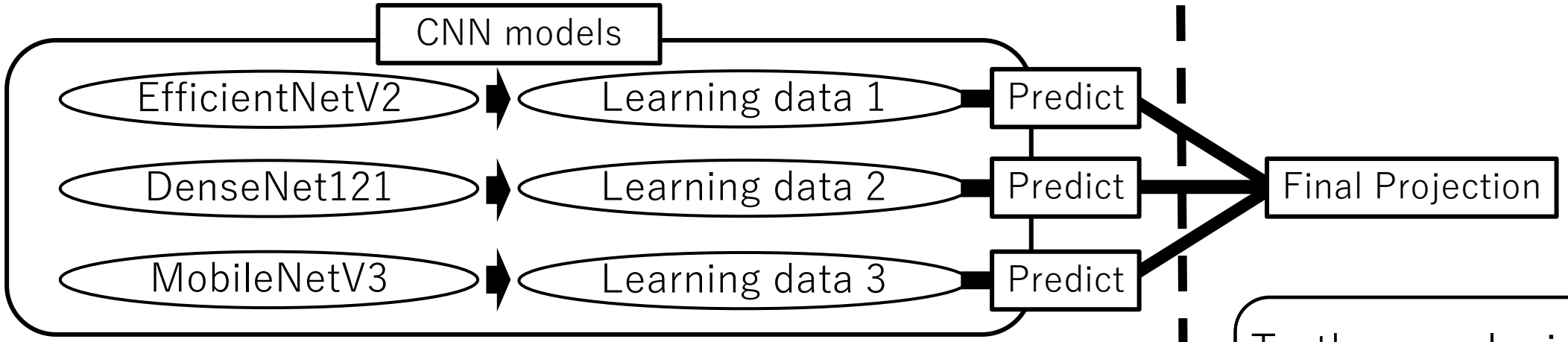
Retrieved from
https://www.nilim.go.jp/lab/bcg/siryou/tnn/tnn0828pdf/ks082805.pdf



※ Pre-trained with labeled rust images
(transfer learning)

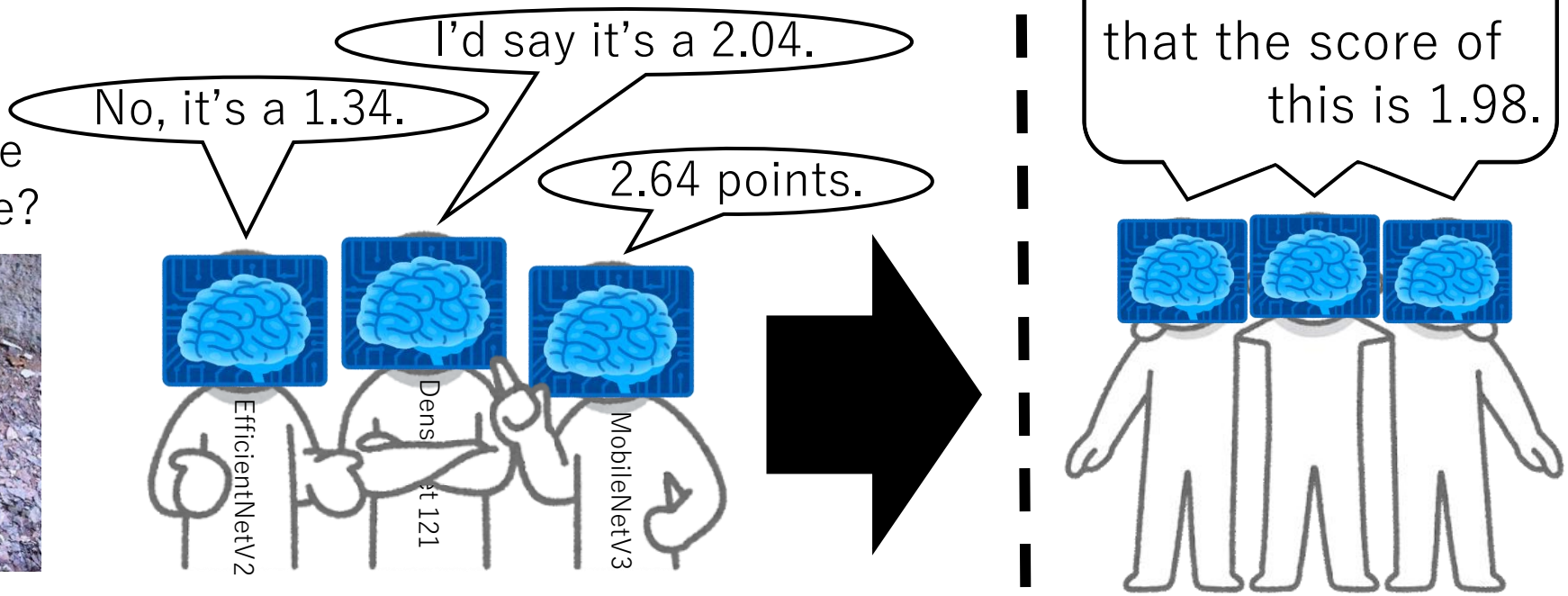
3, How do we score rust?

Previous slide



○Ensemble learning

Agenda Item :
What is prediction score
for this rust image?

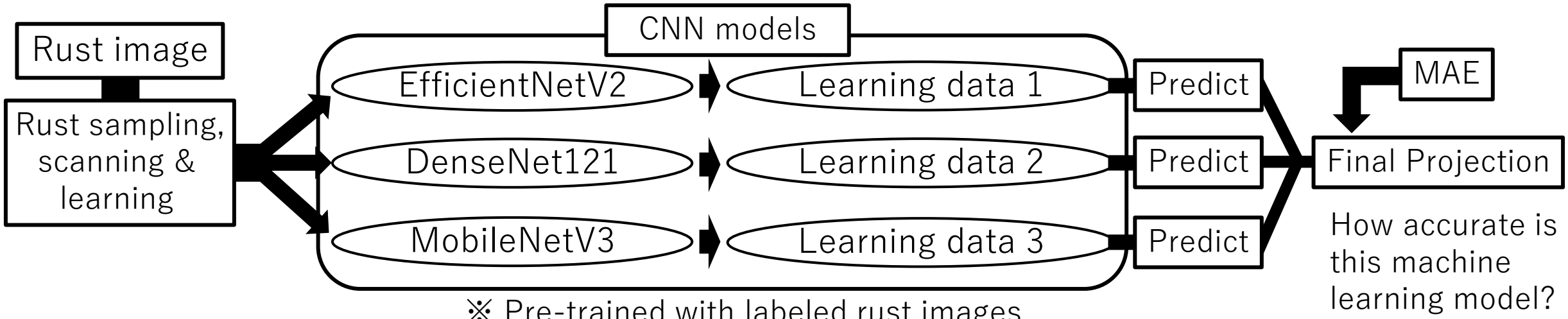


4, What I am doing now

1, Training multiple models (=EfficientNetV2, DenseNet121, MobileNetV3)

Each model learns in a slightly different way. After training, I check how well each model can guess the rust score. I use a measure called MAE — Mean Absolute Error — to check the accuracy.

※MAE…the absolute average of the difference between actual values and values based on multiple models.



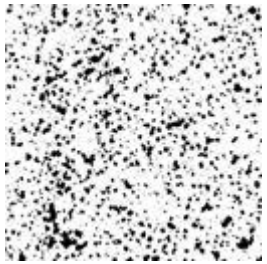
4, What I am doing now

2, Using visual features

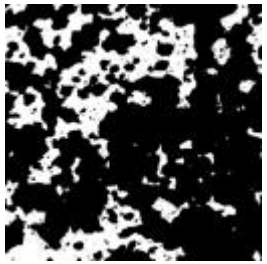
- Rust area ratio：What percent of the image is rust?
- Rust count　　：How many rust spots are there?
- Max rust size　：How big is the largest rust patch?

⇒ I make small adjustments to the AI's score.

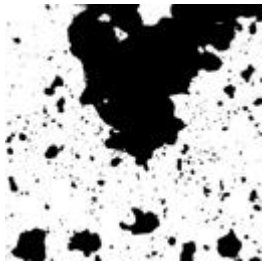
●Example



⇒Lots of rust



⇒High rust area raito



⇒Max area of rust is large

Extract the contour and tally the number of its rings.

Rust areas (black) are extracted by pixels.

Divide by total pixels.

4, What I am doing now

2, In python・・・

```
# Score correction function by features
def adjust_score_by_features(score, rust_ratio, rust_count, max_blob_area):
    correction = 0.0
    # rust ratio
    if rust_ratio >= 0.50:
        correction -= 0.5
    elif 0.25 <= rust_ratio < 0.50:
        correction -= 0.2

                        : 2632 (Pixel)
    # Number of rust
    if rust_count >= 800:
        correction += 0.3
```

```
# Maximum rust size
if max_blob_area >= 7500:
        correction -= 0.5
elif 2500 <= rust_ratio < 7500:
        correction -= 0.25
elif rust_ratio < 2500:
        correction += 0.1

return score + correction
```

・Binning

◯ If the predicted score is less than 1.9 ⇒ Rating 1
◯ If the predicted score is between 1.9 and 2.5 ⇒ Rating 2
◯ If the predicted score is between 2.5 and 3.1 ⇒ Rating 3
◯ If the predicted score is between 3.1 and 3.7 ⇒ Rating 4
◯ If the predicted score is greater than 3.7 ⇒ Rating 5

4, What I am doing now

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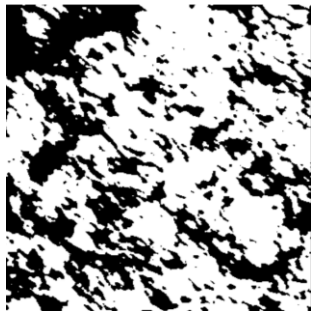


Regression Score : 2.71 (Rating 3)
・Max rust size : 2632 (Pixel)

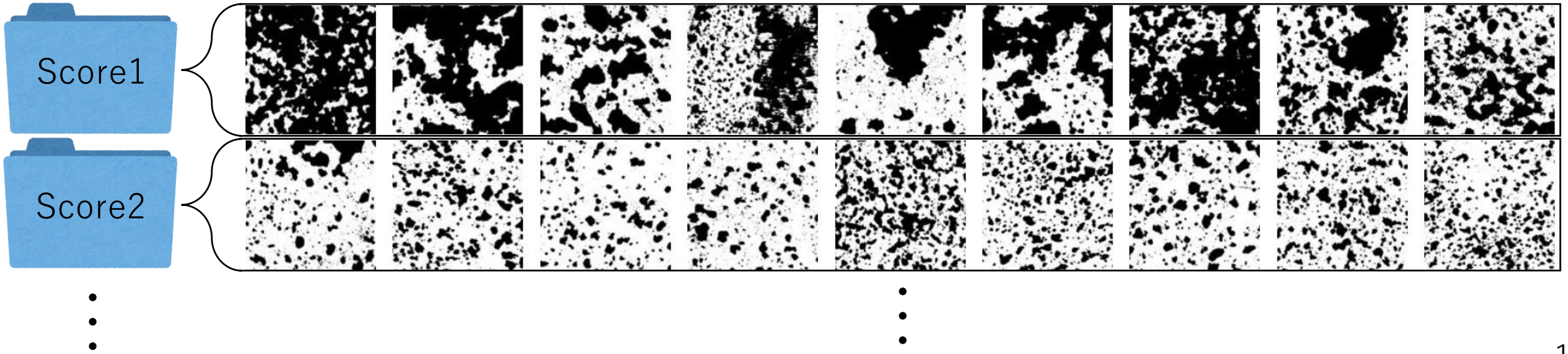
Corrected Score : 2.46 (Rating 2)

The Max rust size is relatively large.
Let's subtract 0.25 points from your score.

4, What I am doing now

3, Organizing the images into folders

- This makes it easy to distinguish between images of light and heavy rust.
- Rust comparisons can be made for each of the same scores to determine that this is a rust image that should be stored in a different score, leading to better programming.



4, What I am doing now

3, Writing logs that show how the AI makes decisions, including the original score, adjusted score, and final score. This helps me understand why a certain score was given.

・logs

```
ex)  1_001.jpg → Return: 2.62 → After correction: 2.52 → Rating: 2 | Rust ratio: 0.253, Rust count: 375, Max rust: 470
     1_002.jpg → Return: 3.14 → After correction: 3.14 → Rating: 3 | Rust ratio: 0.145, Rust count: 807, Max rust: 158
     1_003.jpg → Return: 2.71 → After correction: 2.71 → Rating: 3 | Rust ratio: 0.237, Rust count: 611, Max rust: 1188
     1_004.jpg → Return: 3.37 → After correction: 3.67 → Rating: 4 | Rust ratio: 0.086, Rust count: 728, Max rust: 106
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~  Omitted  ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
     4_094.jpg → Return: 2.58 → After correction: 2.48 → Rating: 2 | Rust ratio: 0.253, Rust count: 410, Max rust: 638
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~  Omitted  ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
    MAE:0.11544688538164781
```

⇒ Rewrite the feature functions shown in the previous to build a better discriminant model, and then display MAE to show which CNN models can be combined for better accuracy.

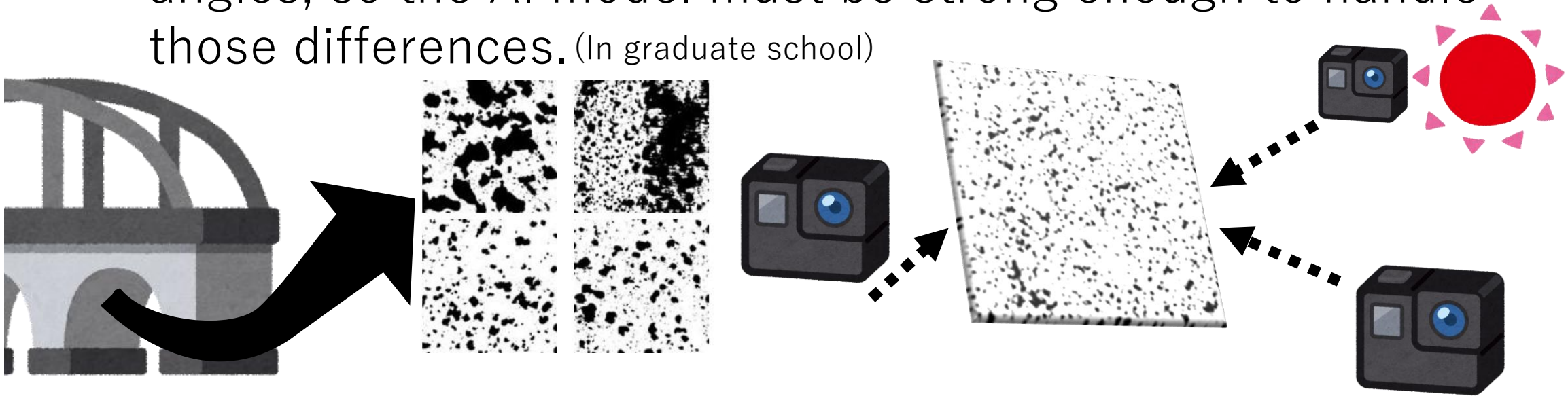
5, Challenges and Future Goals

・Challenge1：The small number of labeled images

⇒ More-labeled data will help the AI learn better and I hope to join future field investigations and collect more images myself.

・Challenge2：To use drone images

⇒ These images will be taken from different heights and angles, so the AI model must be strong enough to handle those differences. (In graduate school)



5, Challenges and Future Goals

- Creating a simple app or web system
  ⇒This allows engineers to load rusty images and instantly get an automatic score.
- My dream is to use technology to support infrastructure inspection, reduce human error, and protect public safety.

References

[1] 国土技術政策総合研究所, 耐候性鋼橋の表面性状の事例とさびの外観性状, https://www.nilim.go.jp/lab/bcg/siryou/tnn/tnn0828pdf/ks082805.pdf (Viewed July 18, 2025)
[2] 耐候性鋼, (Wikipedia, the free encyclopedia) http://ja.Wikipedia.org/wiki/耐候性鋼. (Viewed July 28, 2025, from the most recent version)