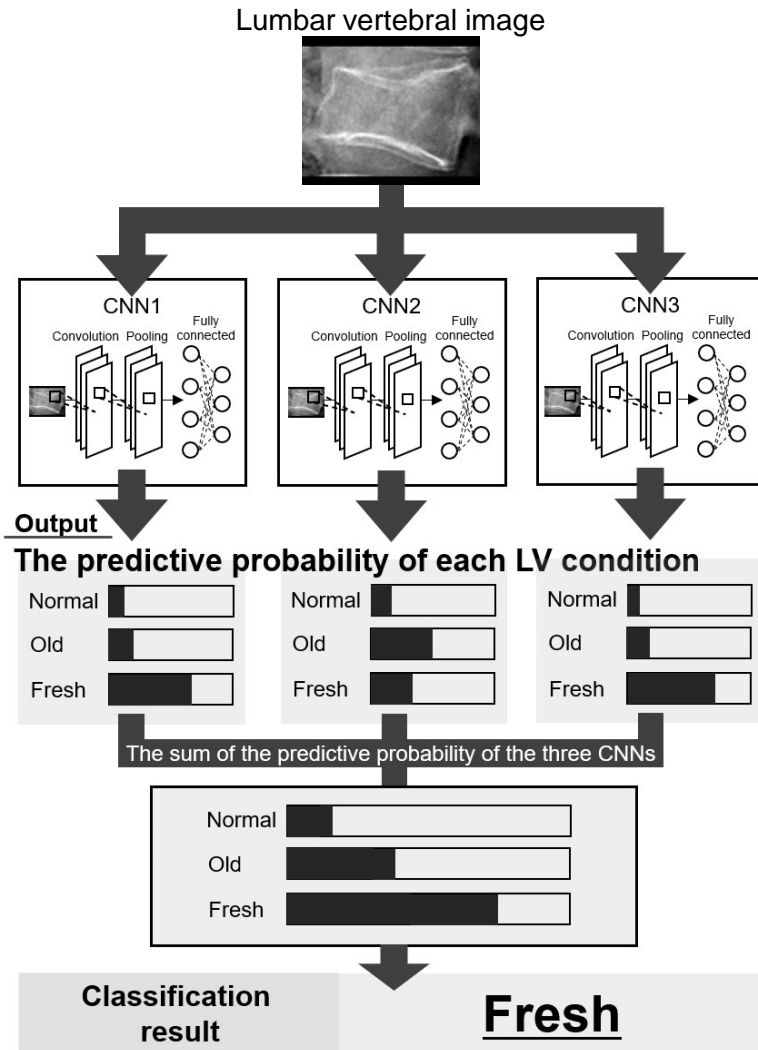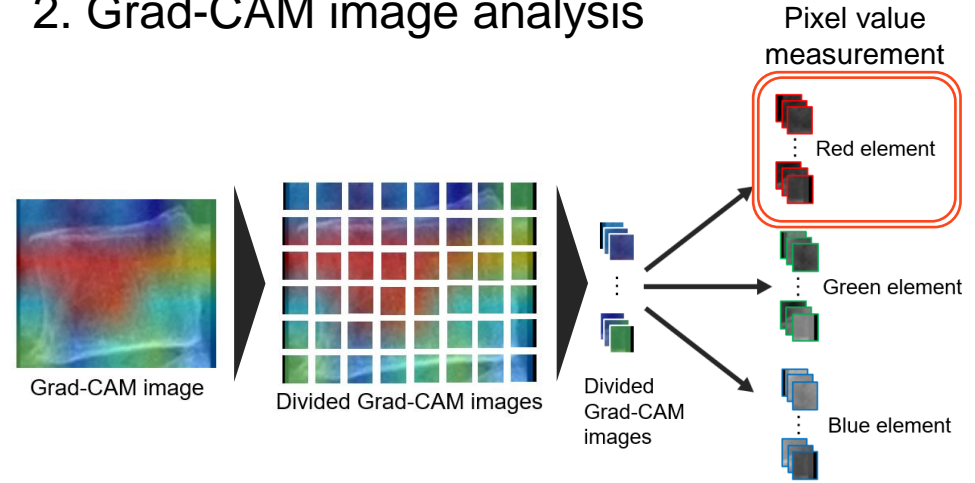# Deep Learning Classification and Grad-CAM-based Visualization for Osteoporotic Lumbar Vertebral Fractures on Radiographs

1. CNN classification

Lumbar vertebral image

CNN1 — Convolution Pooling — Fully connected
CNN2 — Convolution Pooling — Fully connected
CNN3 — Convolution Pooling — Fully connected

Output

The predictive probability of each LV condition

Normal / Old / Fresh

The sum of the predictive probability of the three CNNs

Normal / Old / Fresh

Classification result — **Fresh**

2. Grad-CAM image analysis

Pixel value measurement

Grad-CAM image → Divided Grad-CAM images → Divided Grad-CAM images

Red element
Green element
Blue element

1. **An ensemble model using three CNNs classified the condition of each lumbar vertebra on radiographs with high accuracy into one of three classes: normal, old, and fresh osteoporotic fractures.**

2. **Quantitative evaluation of the pixel values of the red element in the divided Grad-CAM images revealed that mainly the anterior vertebral wall and endplates are the areas of interest for accurate classification by CNN.**

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