

Anomaly Detection for Infrastructure Monitoring

Model Training

Model Used: We used a **Variational Autoencoder (VAE)**. This model is good at learning what normal (non-cracked) concrete looks like. It helps find strange images (anomalies) by checking how different a new image is from what it learned.

Data Preparation and Training Steps:

- **Images Used:** Only images of **concrete without cracks** were used for training the model.
- **Preventing Data Mix-Up:** We saved images in separate folders (new_non_crack, new_crack) and added labels to the names (nc_, c_) to avoid mixing the training, test, and validation images.
- **Data Splits:**
 - For non-cracked images: 80% were used for training, 10% for validation (to set a threshold), and 10% for testing.
 - For cracked images: 10% were used for validation and 90% for testing.
- **Image Processing:**
 - All images were resized to **128×128 pixels**.
 - Images were turned into **grayscale** (black and white).
 - Images were **normalized** (values scaled to help the model learn better).
- **Training:** The VAE model was trained for 10 rounds (called "epochs"). It used the **Adam optimizer** and two types of errors to learn: **reconstruction error** (MSE) and **Kullback-Leibler divergence (KLD)**.

Anomaly Detection (Finding Cracks)

How it Works: The model compares the original image to the image it rebuilt. If the difference (called **MSE**) is high, it means the image might have a crack.

Threshold Used: We set a limit of **0.011993**. If the error is above this, the image is marked as "**CRACKED_Concrete**".

Evaluation Results

Performance:

- **ROC-AUC: 0.9905** – The model is very good at telling cracked and non-cracked images apart.
- **Precision: 0.9812** – Very few normal images were wrongly marked as cracked.
- **Recall: 0.9649** – Most cracked images were correctly found.

- **F1-Score: 0.9730** – A good balance between finding cracks and not making mistakes.

Confusion Matrix (Results Summary):

- **1417** non-cracked images were correctly identified as **non-cracked**.
- **83** non-cracked images were **wrongly marked as cracked**.
- **4342** cracked images were correctly identified as **cracked**.
- **158** cracked images were **wrongly marked as non-cracked**.

Test on New Images:

- Out of 5,000 new non-cracked images, **4,735** were correctly marked as "NON_CRACK_Concrete."
- Out of 15,000 new cracked images, **14,475** were correctly marked as "CRACKED_Concrete."

Visual Results and Analysis

We looked at pictures, their reconstructions, and the difference between them (error maps).

- **Non-Cracked Images:** These were rebuilt well with low error, and the model said they were normal.
- **Cracked Images:** The cracks were not rebuilt properly, so the error was high, and the model marked them as cracked.
- **Correct Predictions:** Most images were classified correctly.
- **False Positives (Normal marked as cracked):** Only 83 cases. These had small changes that confused the model.
- **False Negatives (Cracked marked as normal):** Only 158 cases. These had very tiny or light cracks that the model missed.