The University of Texas at Austin
Cockrell School of Engineering

February 15, 2023

Detecting Steel Defects with Computer Vision

Scientific Machine Learning

Vishal Porwal
Construction Engineering and Project Management

Jacob Shusko, Soorya Sriram
Operations Research and Industrial Engineering

Steel Defect Detection

Problem:

- Steel strips contain different categories of defects on the surface. e.g., crazing, inclusion, scratches, and rolled-in scale
- These visually observable defects cause changes in steel material properties such as corrosion resistance, wear resistance, and fatigue strength.
- The manual inspection process is highly subjective, labor-intensive and too slow to facilitate real-time inspection tasks. (Fu et al. 2019)

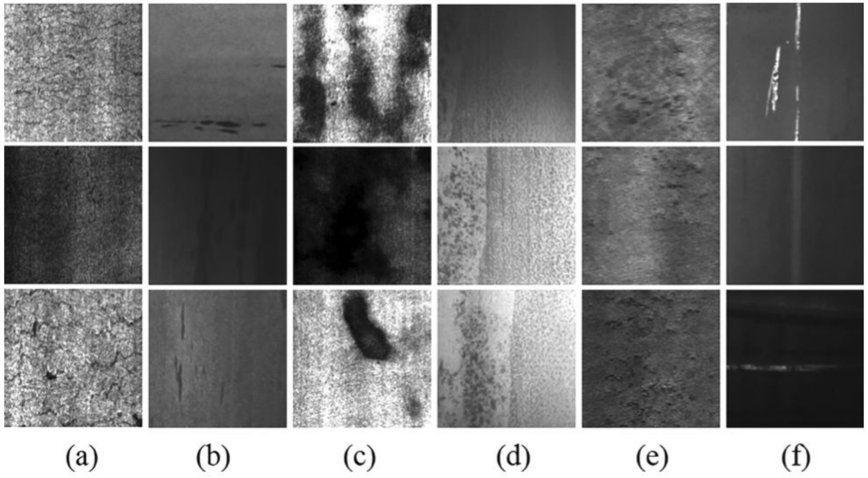


Fig. 3. Samples images of six typical surface defects in the NEU surface defect database including (a) Crazing; (b) Inclusion; (c) Patches; (d) Pitted surface (e) Rolled-in scale; (f) Scratches.

Steel Defect Detection

- Solution: Accurate and fully automatic machine vision-based inspection solutions can help produce defect-free steel products.
- Null Hypothesis:
  - The segment does not contain a defect
  - The segment does not contain defect of class i

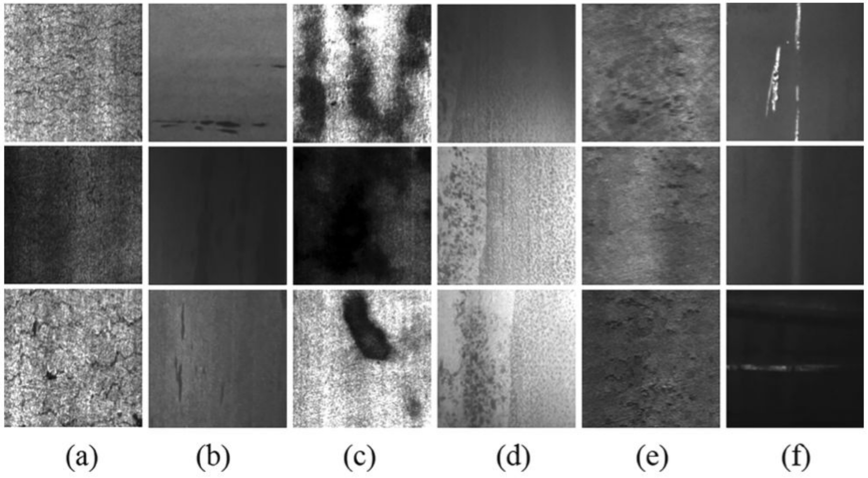
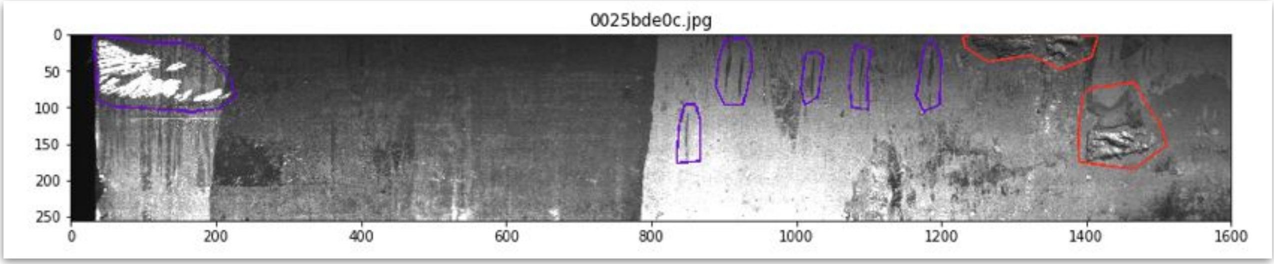


Fig. 3. Samples images of six typical surface defects in the NEU surface defect database including (a) Crazing; (b) Inclusion; (c) Patches; (d) Pitted surface (e) Rolled-in scale; (f) Scratches.

Severstal: a Kaggle Challenge

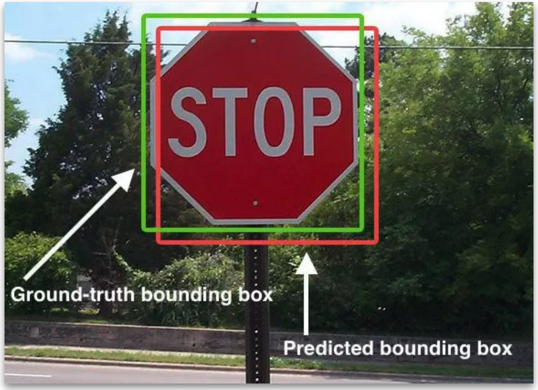
https://www.kaggle.com/competitions/severstal-steel-defect-detection/overview

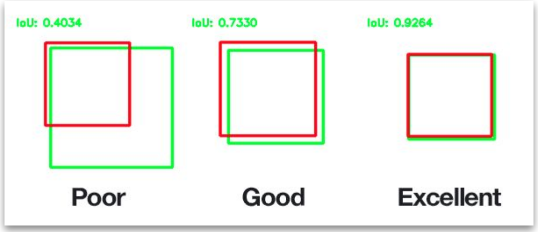
- Predict location and type of defect found in steel manufacturing.
- 18.1k total images (.jpg): 70% training / 30% test
  - Each image may have no defects, a defect of a single class or defects of multiple classes (`ClassId = [1, 2, 3, 4]`).
- Labeled dataset (train.csv): each `ImageId` has a set of encoded pixels (segments) that belong to a particular `ClassId`.



Modeling Approach

- Classification problem
  - First pass: determine whether there is a defect or no defect in an image
  - Second pass: determine defect `ClassId` in segmented pixels in an image
- Cost function
  - Binary Cross-entropy (BCE)
  - Dice, IoU (Intersection over Unions)
- Model types
  - CNN (R-CNN and Faster R-CNN)
  - Pre-existing models: YOLO, etc.





https://pyimagesearch.com/2016/11/07/intersection-over-union-iou-for-object-detection/

Test Evaluation

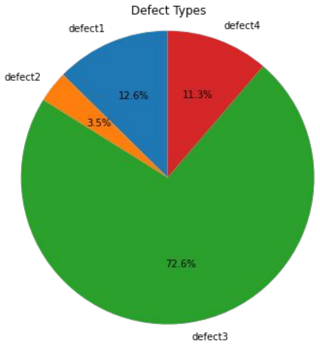
- The Dice coefficient (DSC) will be used to evaluate our performance of our models on the test set.
    - This measure compares the pixel-wise agreement between a predicted segmentation (X) and its ground truth (Y).
    - If X and Y are empty, then the Dice coefficient is defined as 1.
    - Mean Dice coefficient is calculated using all pairs of `<ImageId, ClassId>` in the test set.

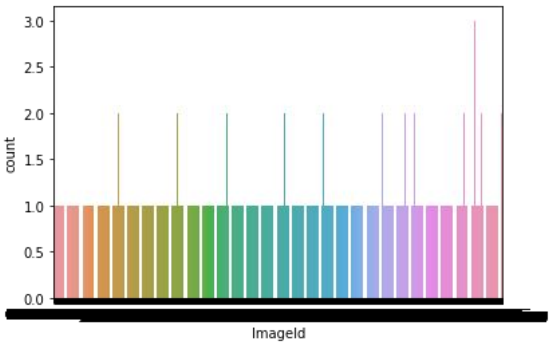
$$DSC = \frac{2|X \cap Y|}{|X| + |Y|}$$

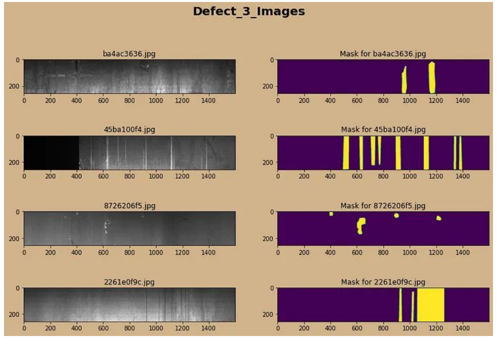
$$DSC = \frac{2TP}{2TP + FP + FN}.$$

Visualization

- Each image may have no defects, a defect of a single class, or defects of multiple classes. Almost half of images don't contain any defects.
- Use of Venn diagrams to get count of different types of defect
- Using filters to visualize the defects in the images
- Distribution of defects indicates the number of defects of each type to be unevenly distributed





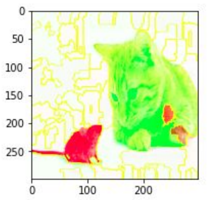


References: https://dipanshurana.medium.com/steel-defect-detection-image-segmentation-using-keras-and-tensorflow-6118bc586ad2

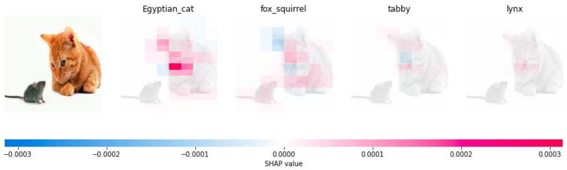
Interpretation and Discovery

- It has become extremely important to be able to explain the predictions of these "black boxes". Interpretability has to do with how accurate a machine learning model can associate a cause to an effect.
- If a neural network or CNN is being implemented, the number of layers, hyperparameters in each layer, the working of each layer and techniques used in the network can inform us better.
- Gradient Based Techniques - Saliency Map (a saliency map is an image that highlights the region on which people's eyes focus first.)

LIME Image Explainer:



SHAP Partition Explainer:



The University of Texas at Austin
Cockrell School of Engineering