POLITECNICO DI MILANO

Image Analysis & Computer Vision

Anomaly Detection Based on Autoencoder and Denoising Convolutional Neural Network

Project Presentation

Supervised by: Giacomo Boracchi, Vincenzo Caglioti

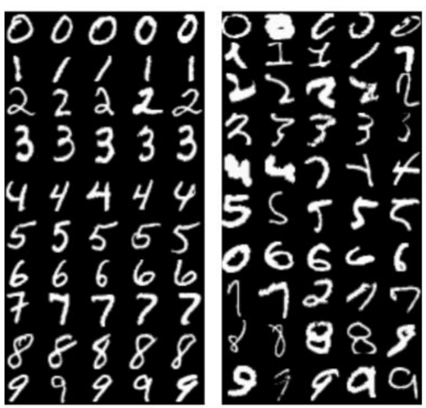
Yusuf Yiğit Pilavcı
Şemsi Yiğit Özgümüş

Presentation Outline

- Introduction
- Problem Definition
- Proposed Architecture
- Experiment Results
- Conclusion

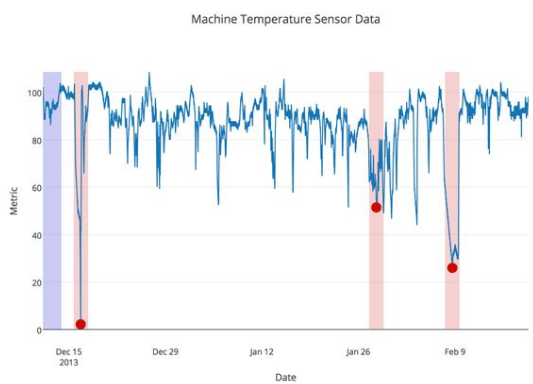
What is Anomaly Detection ?

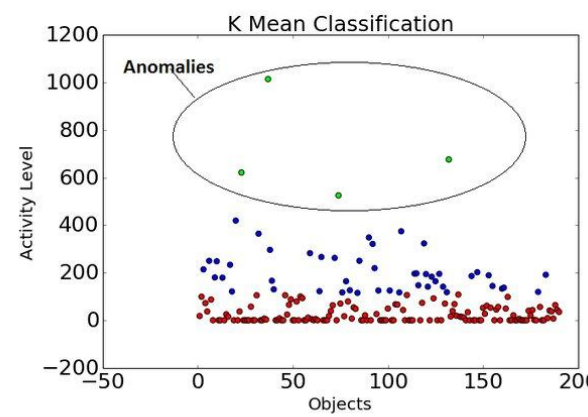
- **(Hawkins' Definition of Outlier, 1980)** " An outlier (or anomaly) is an observation that differs so much from other observations as to arouse suspicion that it was generated by a different mechanism."
- "Finding patterns in given data that has new or unexplained characteristics."
- Depending on the context term may change: novelty, outlier, aberration, discordant observation etc.



(a) Normal samples. (b) In-class anomalies.

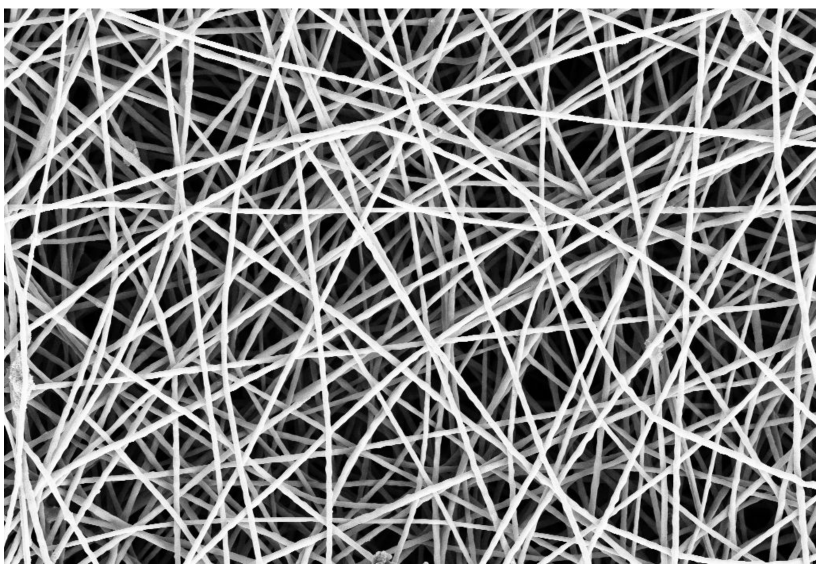
Figure 3: MNIST Most normal and in-class anomalous MNIST digits detected by RCAE.

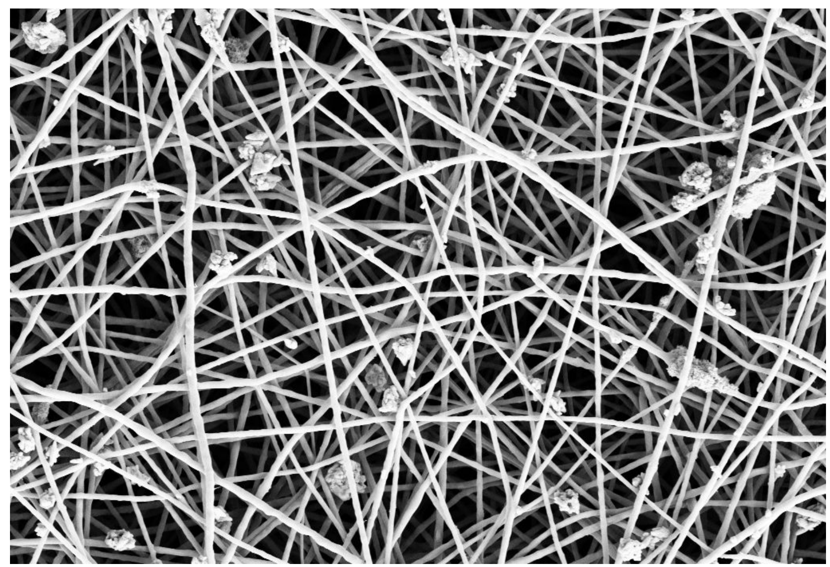




Problem Definition

- We particularly examine automated detection of defects in nanofibrous materials
- Dataset is set of Scanning Electron Microscope (SEM) images
- Challenges
  - Filament pattern is geometrically pseudo random. (Does not align with a predefined texture)
  - Trade off between patch size, resolution and accuracy.
  - High variation in between images without defects.





Architecture Overview

- Architecture consists of an Autoencoder Network and a Denosining Network combined.
- Training of the architecture is sequential
- Considering :

$$\hat{x} = x + \epsilon : x \sim X \in \mathbb{R}^d, \quad \epsilon \sim \mathcal{N}\left(\mu, \sigma^2\right)$$

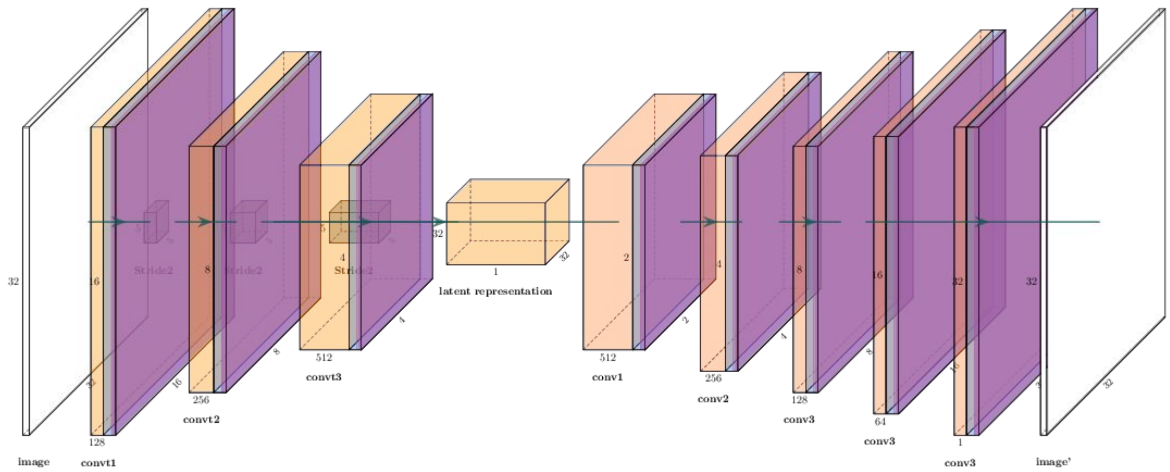
First the Autoencoder Network with the following objective function:

$$\mathcal{L}_{DAE} = \|x - (\psi \circ \phi)(\hat{x})\|^2$$

Then the Denoising Network is trained with fixed autoencoder network outputs with the following objective function:

$$\mathcal{L}_{Den} = \|x - \mathrm{Den}((\psi \circ \phi)(x))\|^2$$

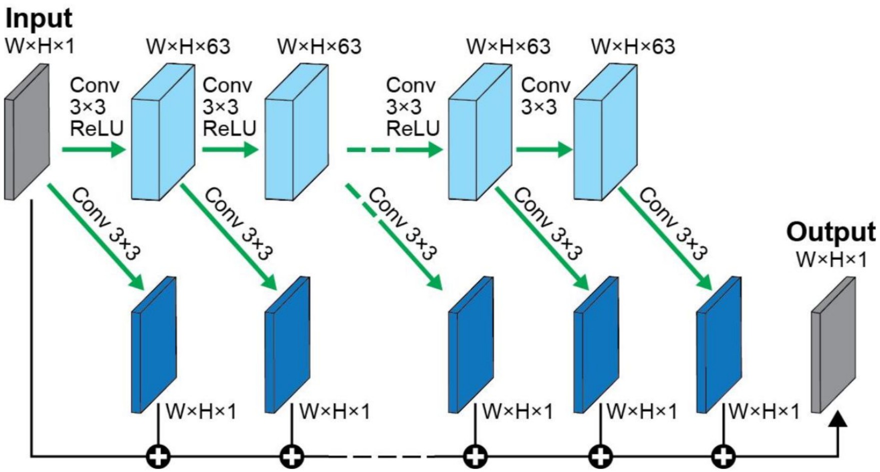
Autoencoder Network



- Encoder and Decoder Networks
- Encoder Network :
  - 3 Layers of Convolution + Batch Normalization + Leaky ReLU with
    - Kernel size (5 x 5)
    - Stride (2 x 2)
    - Filters 128 > 256 > 512
  - Dense Layer with number of Nodes equal to the latent representation
- Decoder Network :
  - 5 Layers of Transposed Convolution + Batch Normalization + Leaky ReLU with
    - Kernel size (5 x 5)
    - Stride (2 x 2)
    - Filters 512 > 256 > 128 > 64 > 1

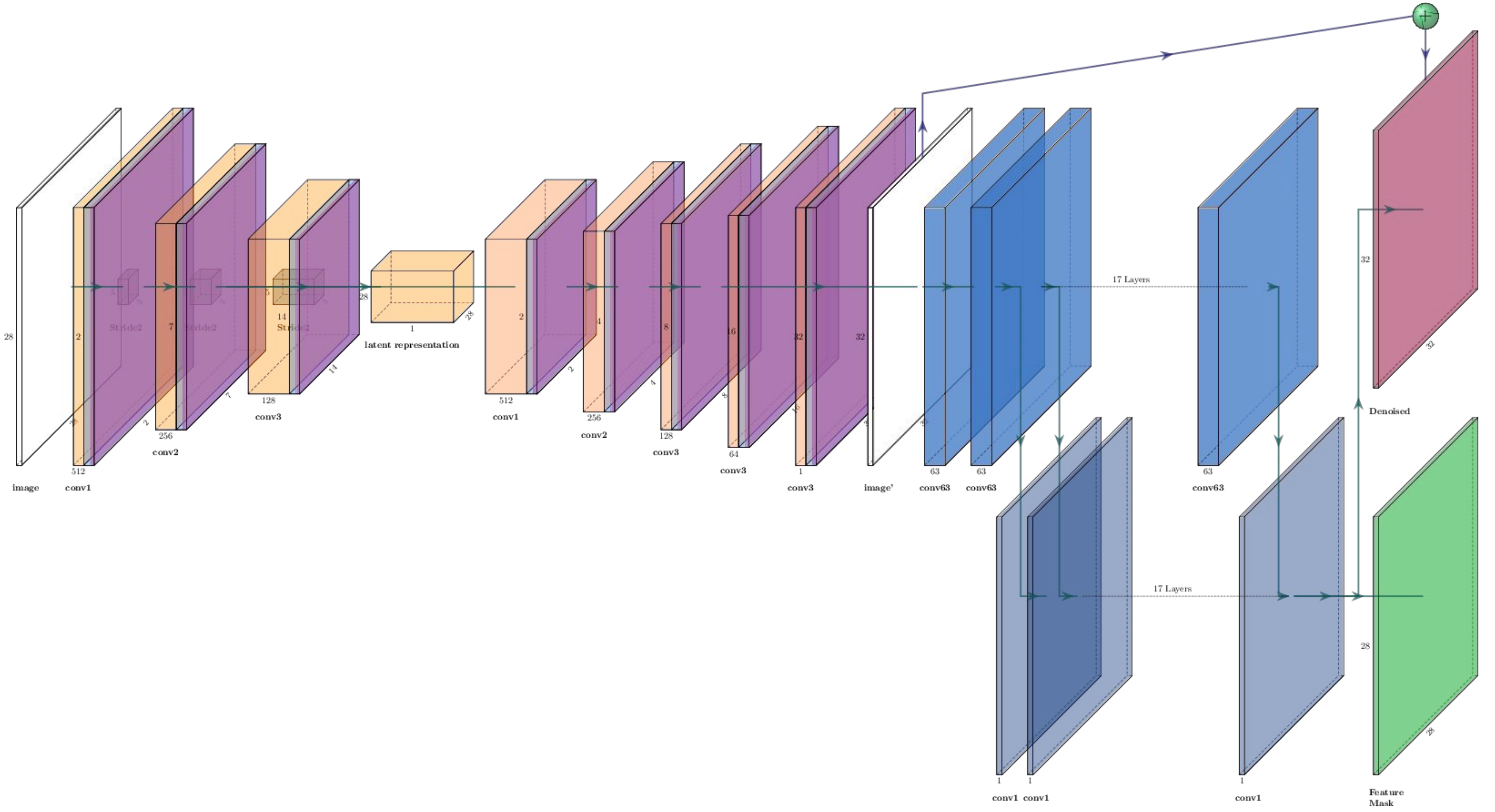
- Trained with reconstruction error
- Anomaly score is defined with ℓ_2 norm of the reconstruction error

Denoising Network



- 20 fully convolutional layers of network with two branches:
  - 63 3x3 Conv filters trained
  - 1 3x3 Conv filter trained and accumulated through layers
- Trained by reconstruction error
- For anomaly score, residual computed with
  - Smooth Reconstruction or
  - Feature mask

Proposed Architecture

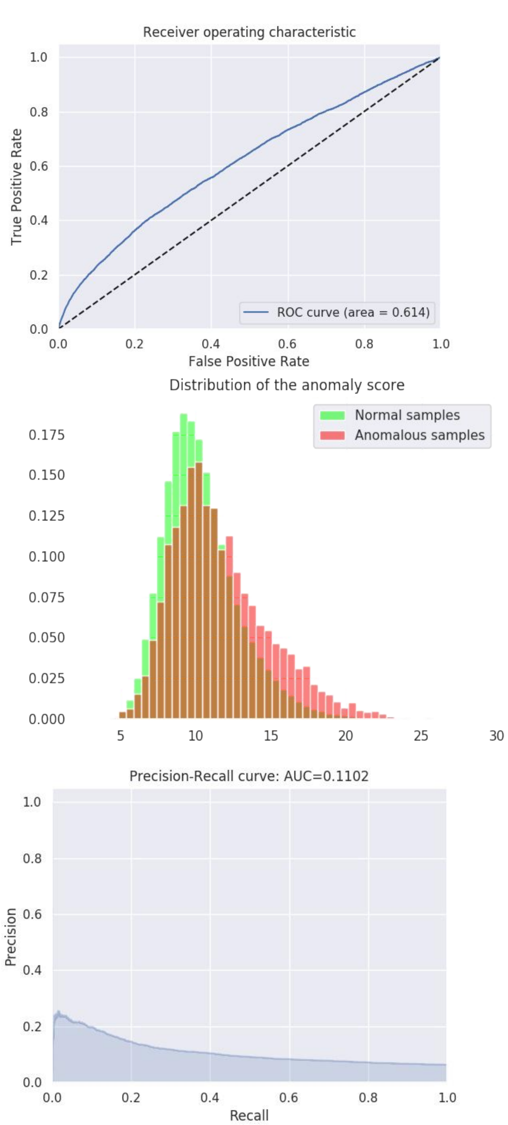


Experiment Results

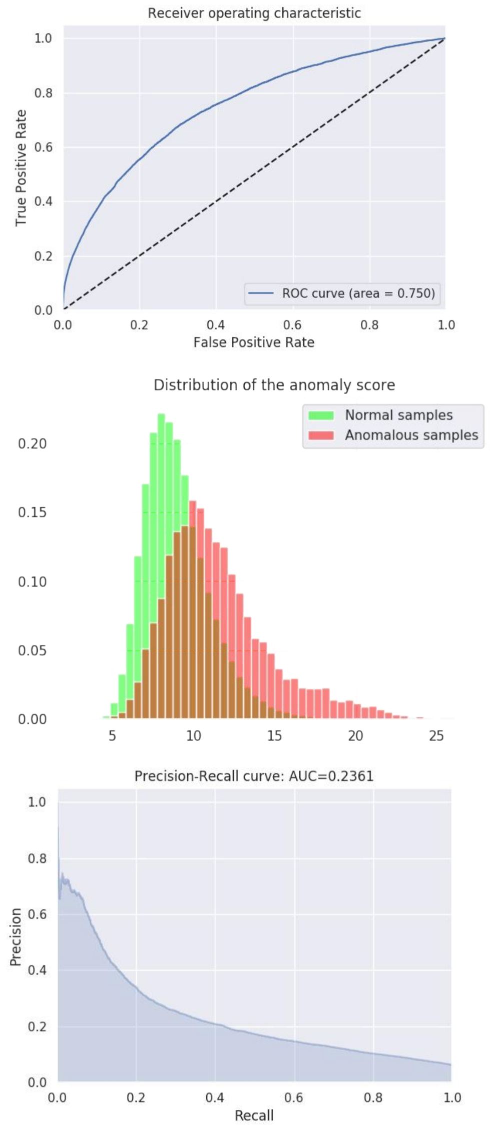
	Performance Metrics			
Score Type	**AUROC**	**Precision**	**Recall**	**F1 Score**
Reconstuction	0.6135	0.12040	0.28527	0.16933
Smooth Reconstruction	0.75003	0.22560	0.35636	0.27629
Feature Mask	**0.80022**	**0.60295**	**0.38098**	**0.46692**

- Experiment results for Denoising Autoencoders are considered.
- Smoothing reconstruction improves the precision and recall capacity of the model.
- Computing residual with feature mask instead of the smooth reconstruction for anomaly score greatly increases precision while also improving the recall capacity.

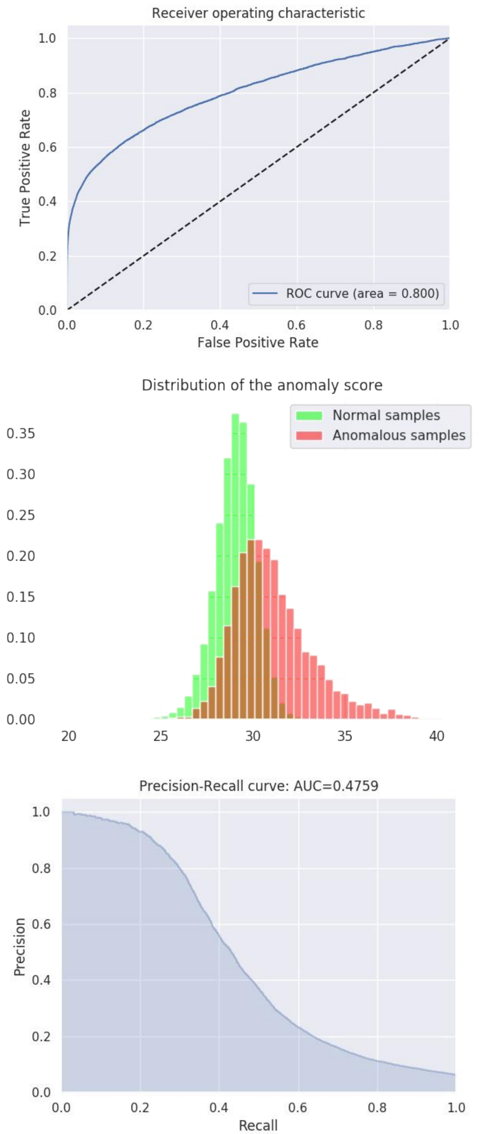
Experiment Results



Reconstruction



Smooth Reconstruction



Feature Mask

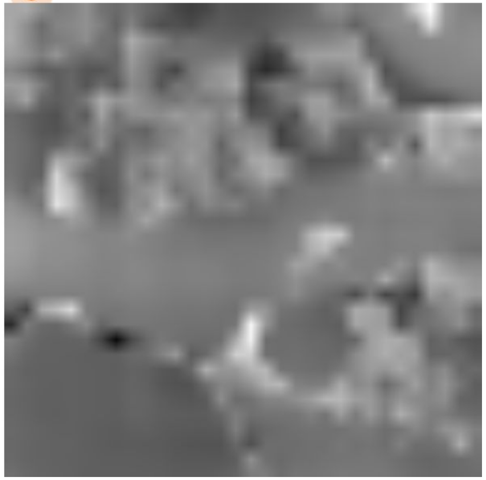
Qualitative Results

Query Sample

Reconstruction

Denoised Reconstruction

Residual Image



Feature Mask

Conclusion

- Automated Anomaly Detection is implemented with autoencoder and fully convolutional denoising network.
- Three different autoencoder methods are tested.
- Different outputs from denoising network explored for anomaly score.

Future works are possible with extension on Generative Adversarial Networks and further examinations of FC denoising network.

Thank you for your attention