2020 embedded VISION summit®

Image Based Deep Learning for Manufacturing Fault Condition Detection

Janghwan Lee, Wei Xiong, Wonhyouk Jang
Samsung Display America Lab and Display Research Center
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Agenda

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- Introduction
- Challenges for the dataset
- Data processing & baseline solution
- Issue Analysis and Solutions
- Experiments and Result
- Conclusion

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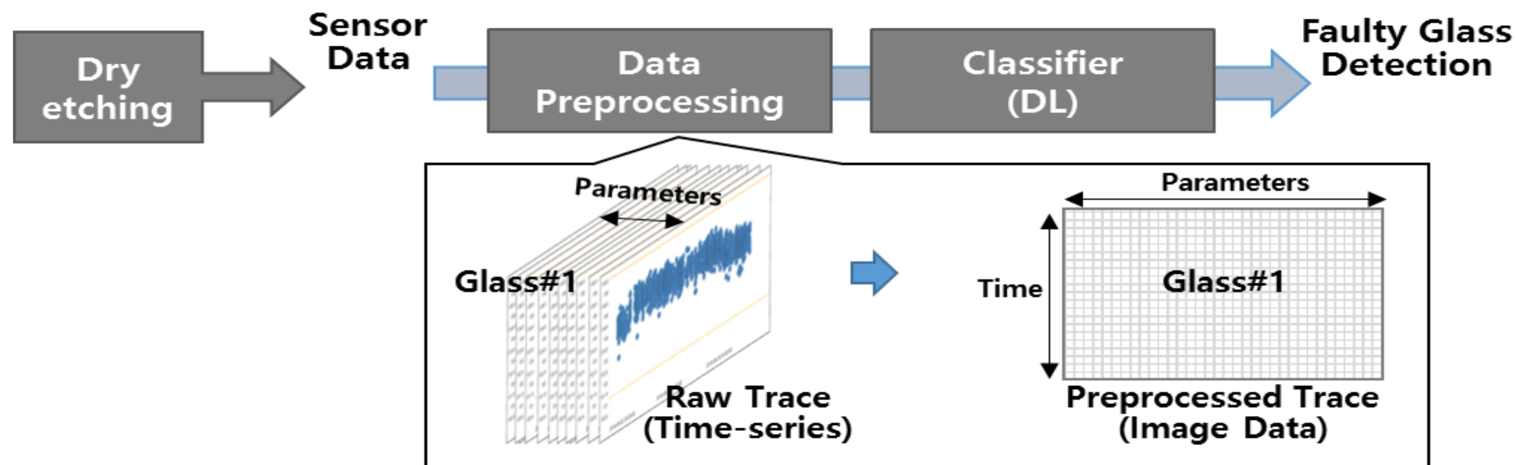
Trace Data Analytics:

- To understand **the nature of fault conditions** in display panel manufacturing process using multivariate time series sensor signals
- **Digital trace data** is defined as **records of activity undertaken** through an information system. A trace is a mark left as a sign of passage; it is recorded evidence that something has occurred in the past. For trace data, the system acts as a data collection tool*



*: Validity issues in the use of social network analysis with digital trace data

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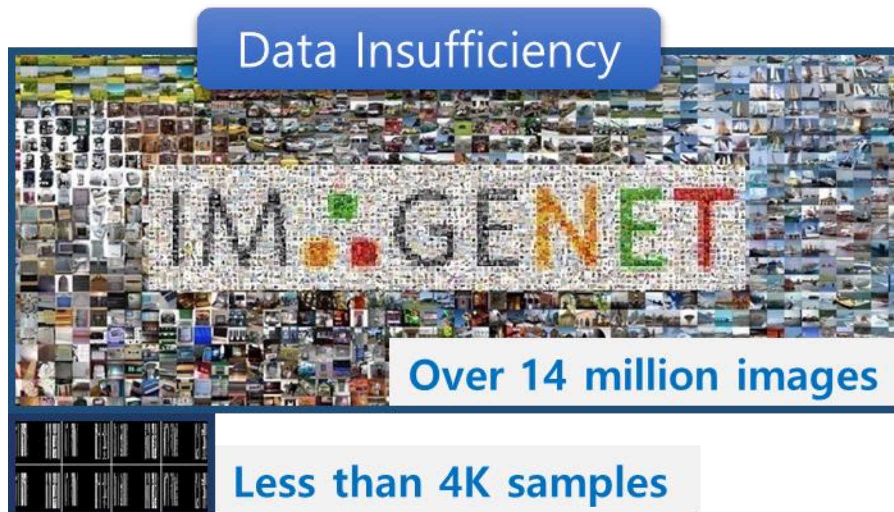
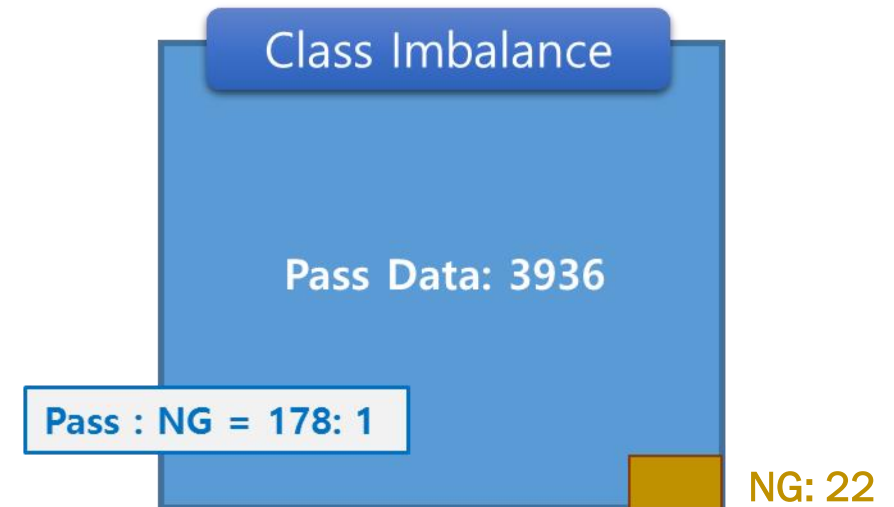
Challenges for the Dataset

- **Trace data from multivariate numerical data**
  - multiple time series input from sensors
- **Generalized ML model generation**
  - **Dataset insufficiency:** too sparse to train deep neural network
  - **Class imbalance:** lack of fault data samples





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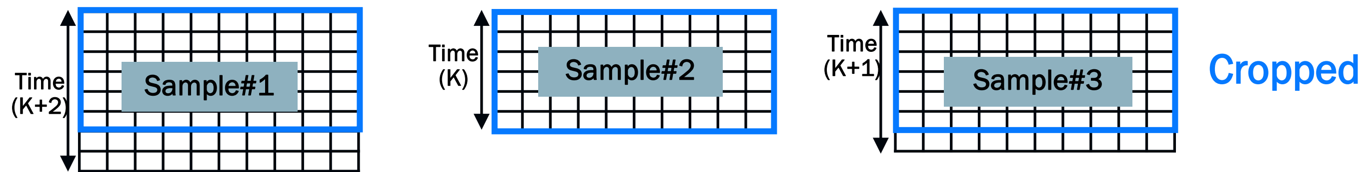
Trace Data Processing

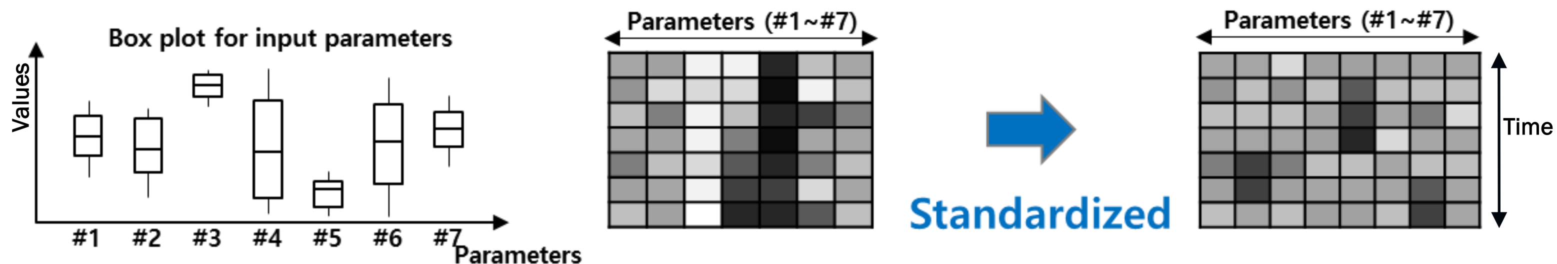
2D trace data generation from multiple time series input signals from sensors:

⇨ ***empirical** approach*

- Sample size alignment for unit task



- Merge parameters



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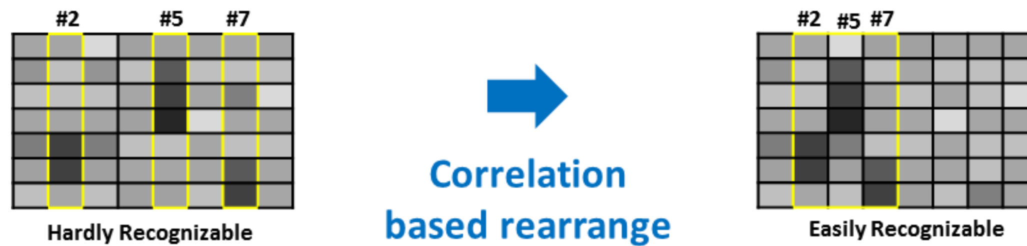
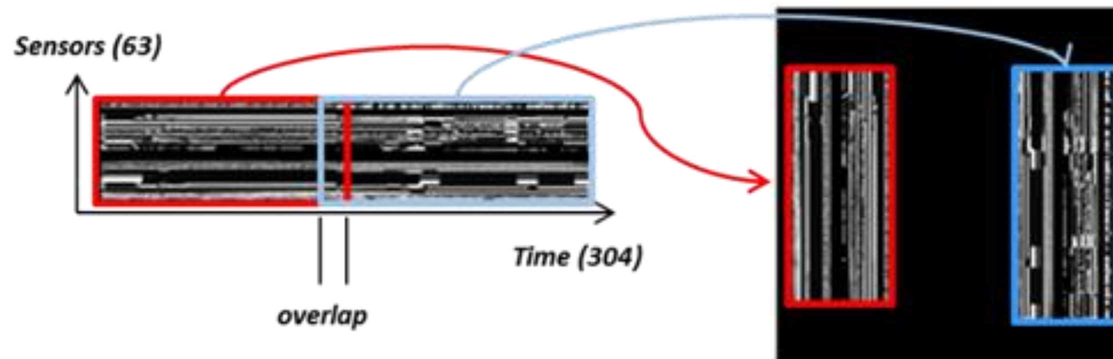
Trace Data Processing

- Parameters order rearrangement



- Data conversion for CNN model



224x224 image to
use transfer learning
with SqueezeNet*

*: SqeezeNet
https://arxiv.org/abs/1602.07360

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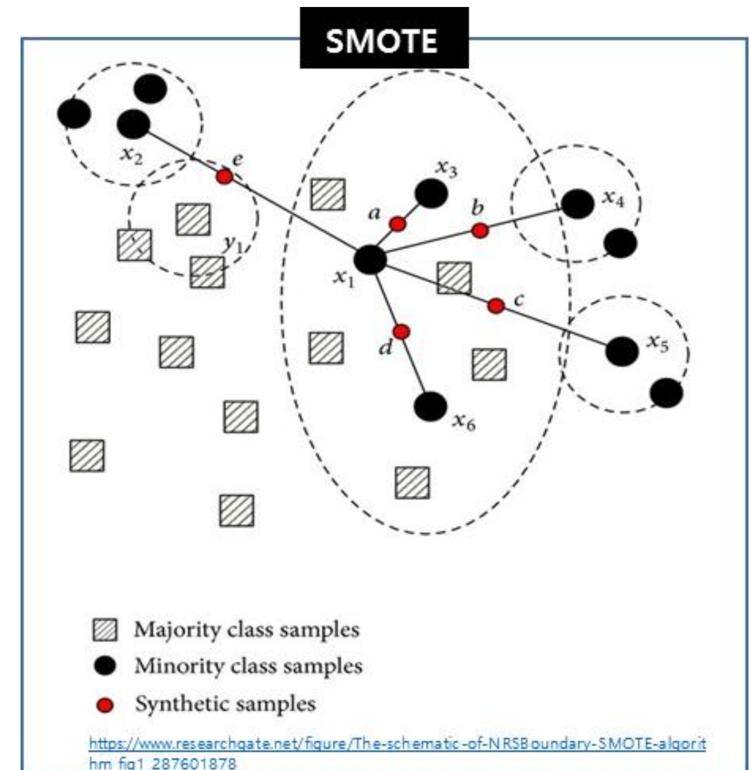
Baseline Model

- **Evaluate** that if **2D trace data** has enough information to identify fault conditions
- Input data processing
  - To overcome the **class imbalance** in input dataset: **oversampling** minority class (SMOTE and ADASYN)
- Dataset construction

Type	Train set	Test set
Pass	3149	787
Fault	500(OVS)	22



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Intermediate Results

- Results (with SqueezeNet)

Type	Train set	Test set	Train Acc.	Test Acc.
Pass	3149	787	0.9546	**0.9111**
Fault	**500**(OVS)	22	1.0000	**0.8182**

- Verified that it is possible to generate fault condition classifier using 2D trace data
- Remaining Issues for model generalization
  - Insufficient data and class imbalance
  - Solve with Model Instance Distillation

Comparison with other works	
ImageNet	**Our Research**
14,197,122 images	3,958 samples
1000 classes	Binary classes
14K images/class	**2K images/class**
Class balanced	Class imbalance (3936 : 22 (+500))
Fully trained	Transfer learning
97% / 86.4%	**91% / 82%**

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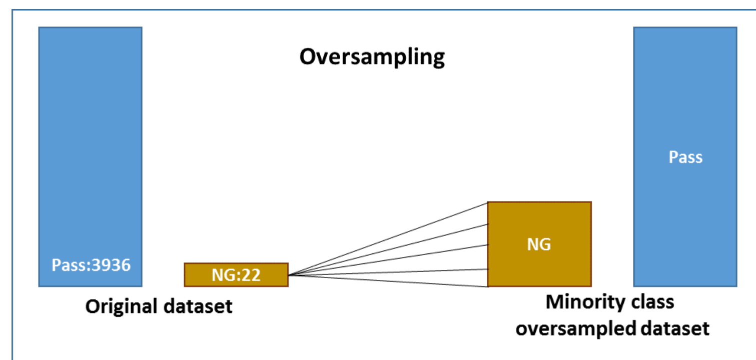
Solution for Class Imbalance

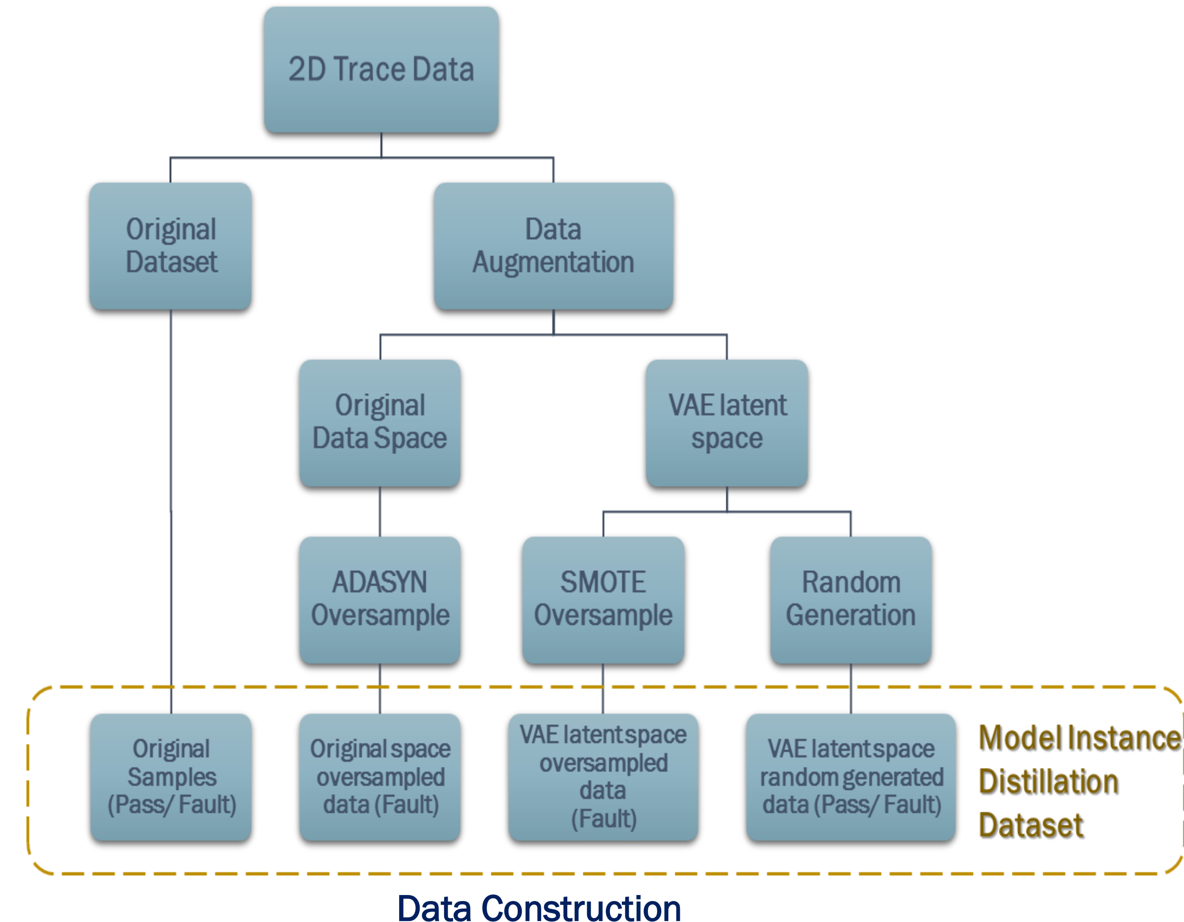
Minority Class Data Oversampling

- Original data space
- Latent space

Synthetic Data Generation

- Random data generation using deep generative model





Data Construction

SMOTE (https://arxiv.org/pdf/1106.1813.pdf),
ADASYN (https://ieeexplore.ieee.org/document/4633969)
VAE (Variational Autoencoders: reference 2 in the resource slide

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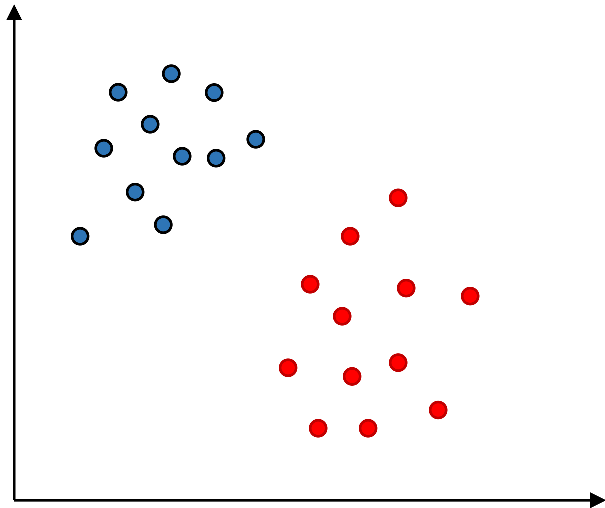
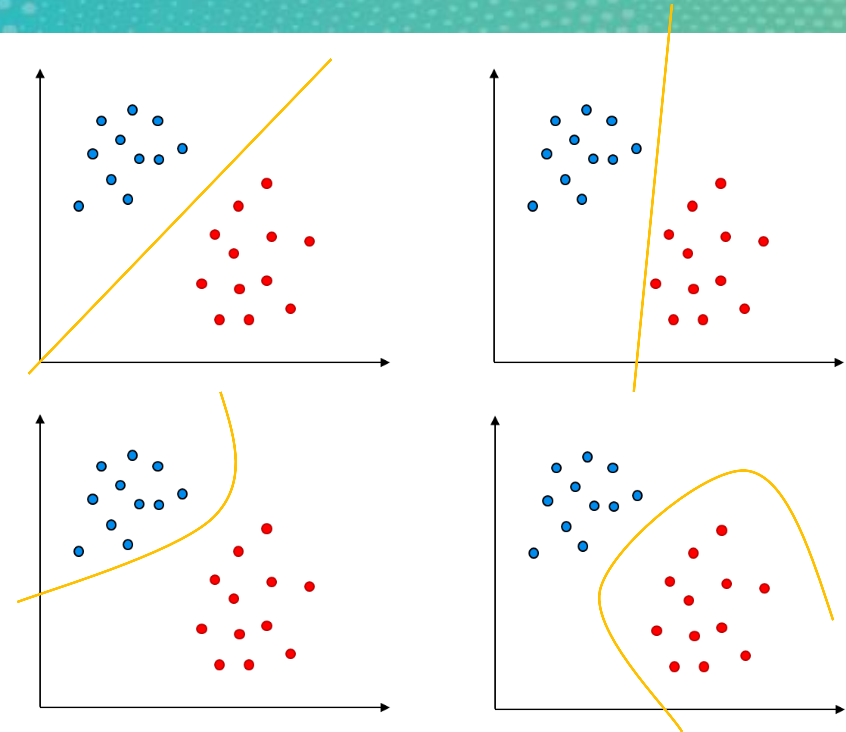
Issue for Data Insufficiency: Generalization

- **Lack of generality**





Small dataset to train a deep Learning model ➡ *Multiple decision boundary from multiple instantiation of ML models*

With a given dataset, all ML/AI models make same classification ➡ *These ML/AI models will make different decisions for future data*

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Issue for Data Insufficiency: Explanation

- To train complex DNN model with limited amount of data samples is a challenging task.
- The curse of dimensionality:

Hypothesis
The major issue for generating a generalized model with limited dataset is the **sparsity** of input dataset and this issue could be improved by **augmenting dataset with enough variance**

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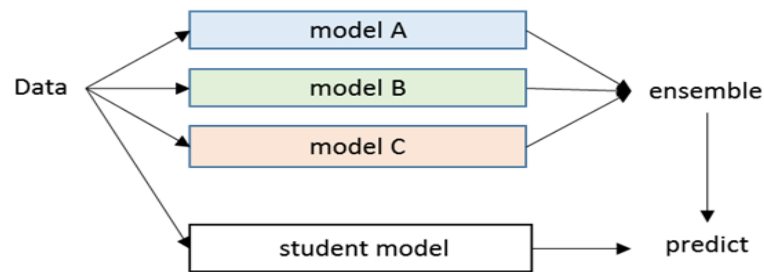
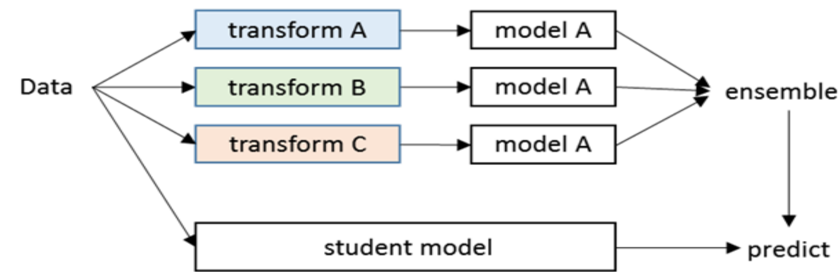
Knowledge Distillation: Model Instance Distillation

- Existing models

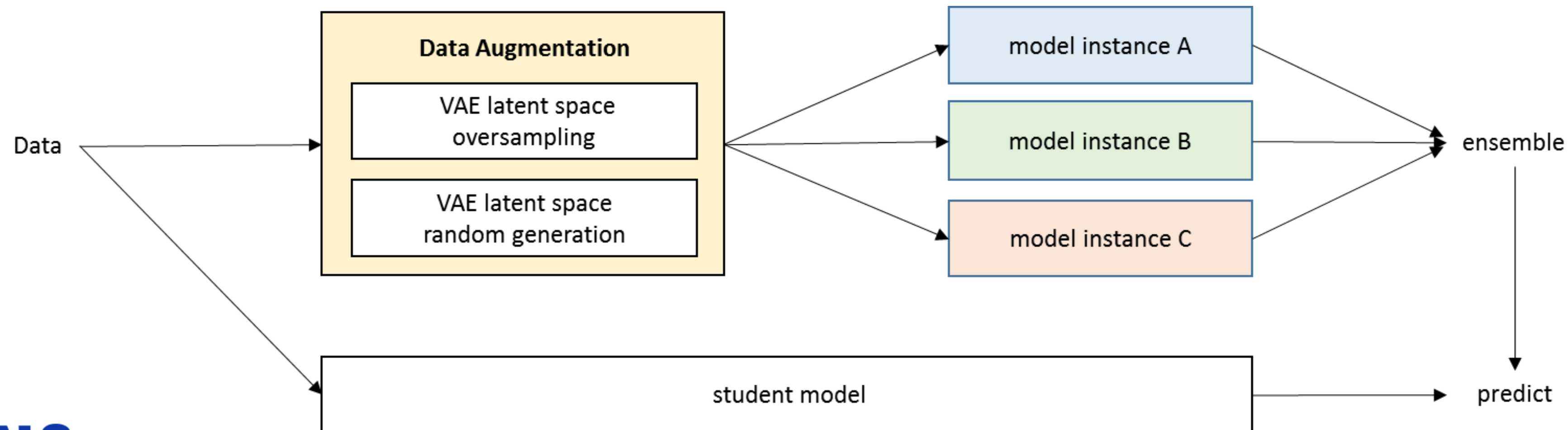


(a) Model distillation



(b) Data distillation

- Model Instance Distillation (MID)



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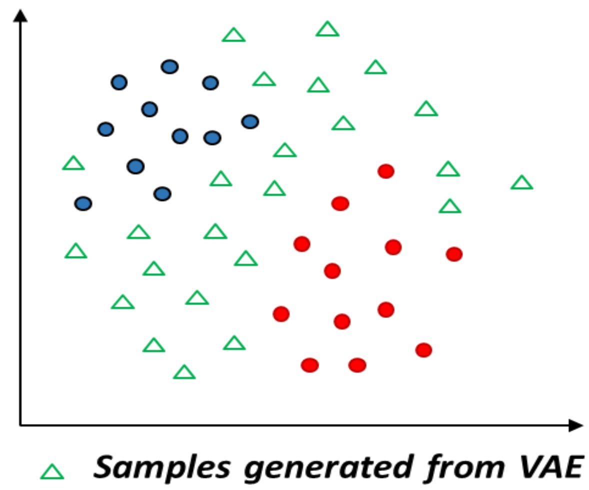
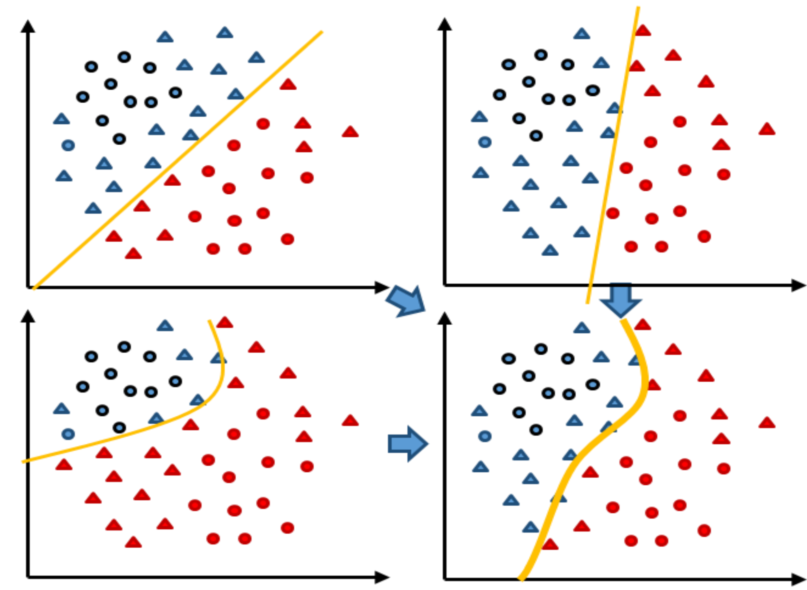
Data Augmentation





- Searching for a method to augment variability in input data
  - (a) Spatial transform (b) Obtain unlabeled dataset (c) **Generative model**

Could we generate data points to clarify the decision boundary?
⇨ Deep Generative Models (VAE)

Knowledge distillation from multiple instances of AI/ML models into a dataset
⇨ Generate a new dataset annotated with a new decision boundary

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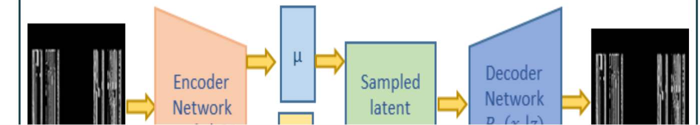
Deep Generative Models

Variational Autoencoder (VAE)

- Generative model comparison

Original Data				
Reconstructed Data				

Architecture



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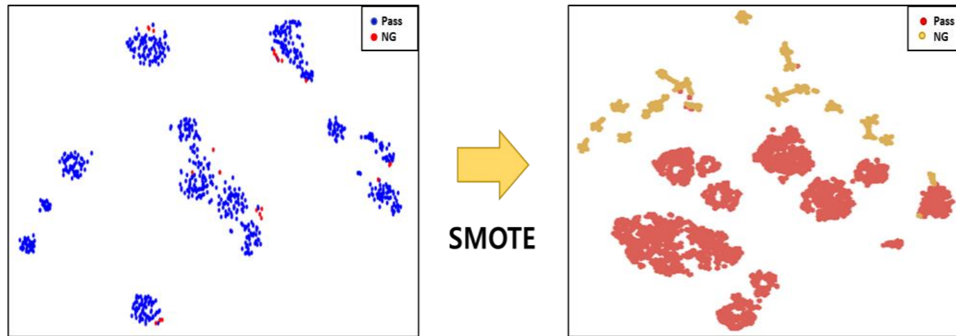
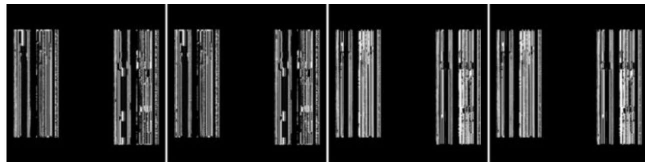
Dataset : Data Augmentation for MID

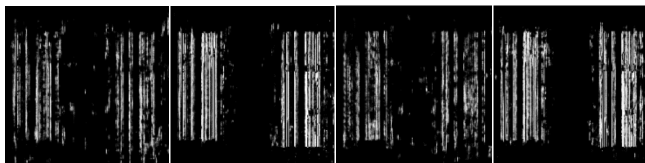
VAE Latent Space Oversampling



- ***Generate samples with label in latent space***
- ***Cluster analysis and classification in latent space***

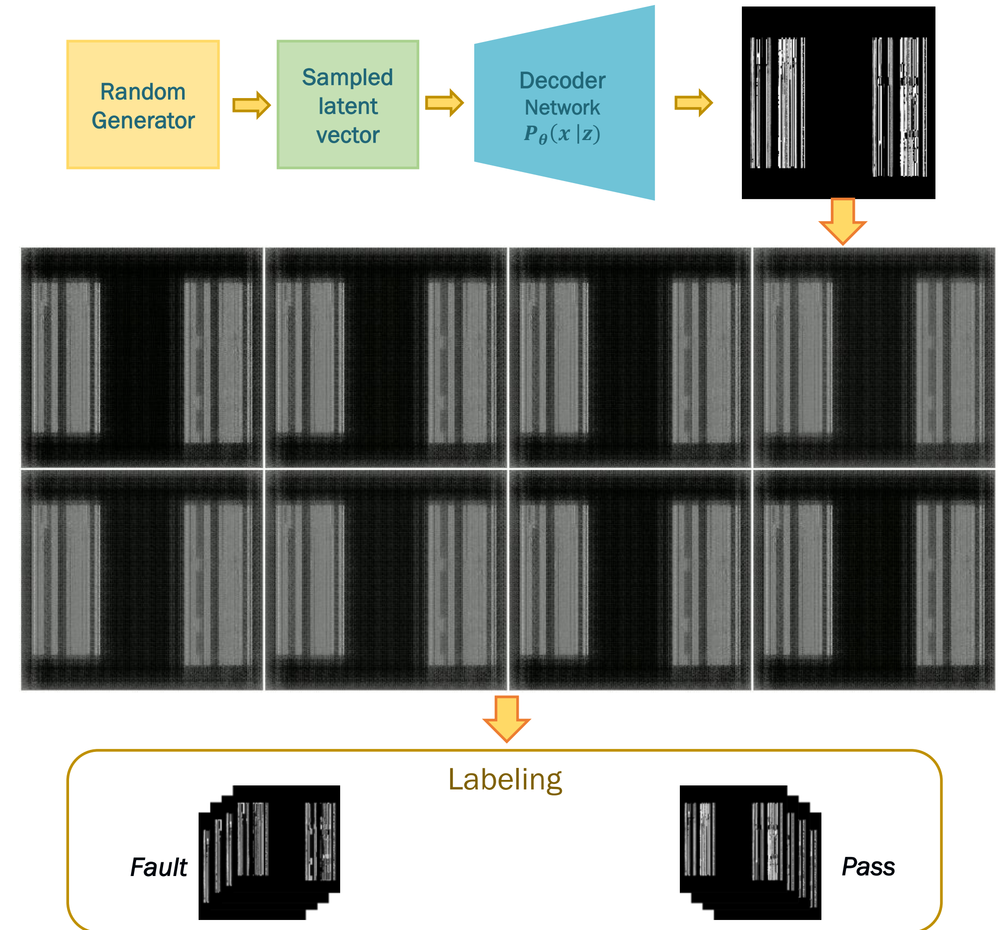


VAE latent space oversampling



Bad case of oversampling

VAE Latent Space Random Generation



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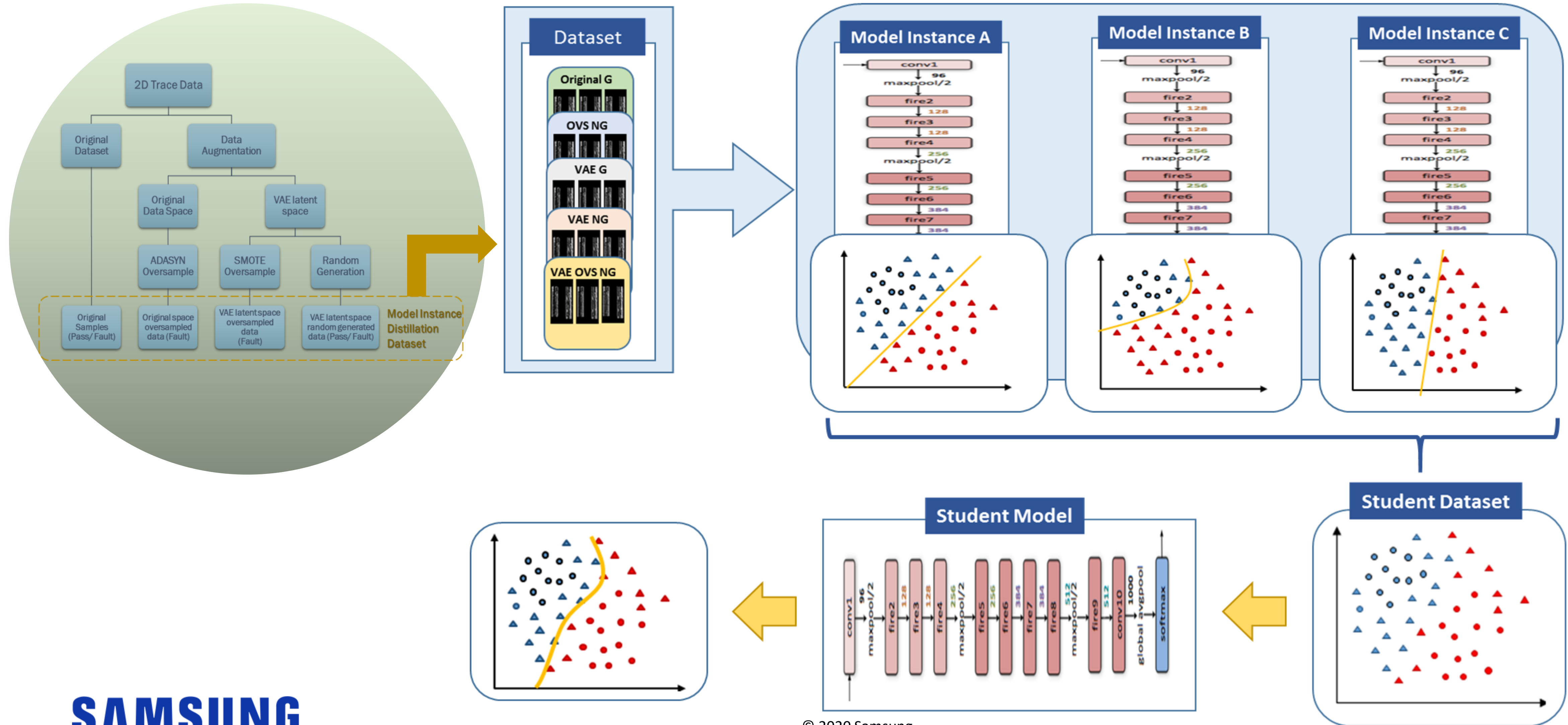
Model Instance Distillation (MID)



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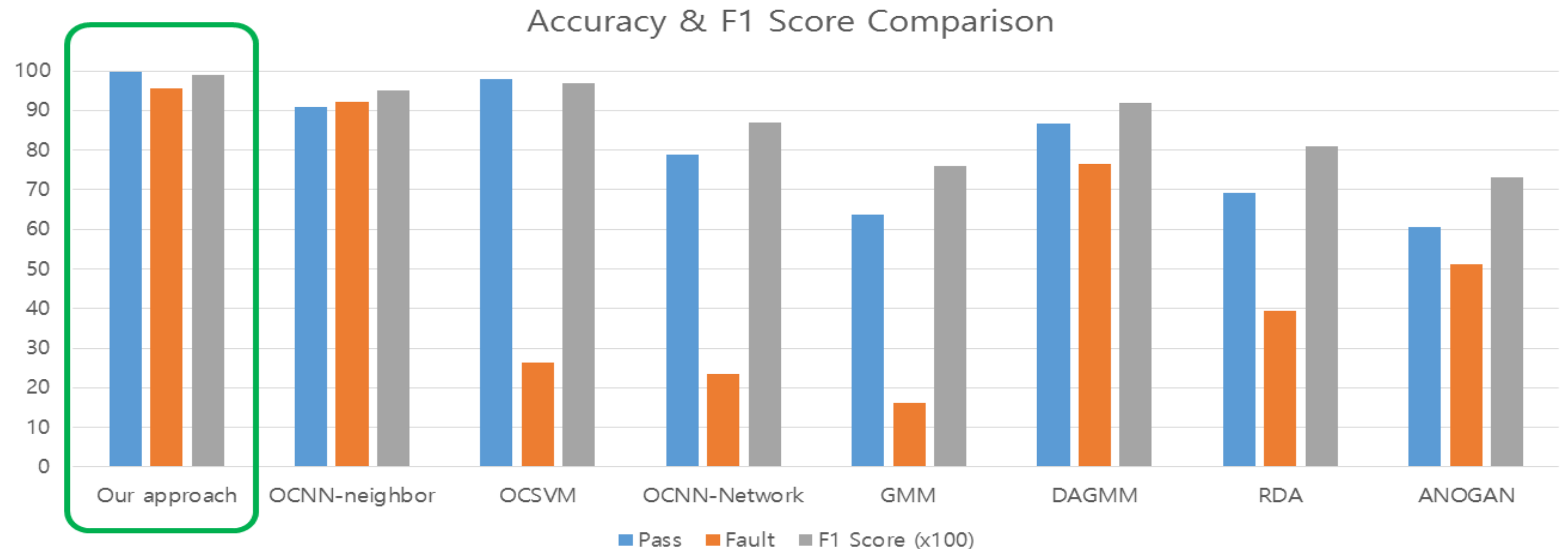
Results

- Fault condition classification results
- Comparison with other approaches
  - High Accuracy
  - Model Consistency
  - Light weight comparing to ensemble models

Classification Results		
Type	Training Accuracy	Test Accuracy
Pass	1.000	0.9975
Fault	0.9997	0.9545

Classification Results w/o VAE OVS		
Type	Training Accuracy	Test Accuracy
Pass	1.000	0.9988
Fault	0.9997	0.9091

Comparison with other methods



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Conclusion

- **High accuracy fault condition classification** using supervised trace data together with large amount of synthetically generated data in VAE latent space.
- **Knowledge distillation from model instances** over augmented dataset to overcome class imbalance and data insufficiency.
- Proposed a method to **generate 2D trace data** from multivariate manufacturing sensor signals.

Future works

- Deploy to monitor manufacturing processes
- Extend to other display manufacturing datasets
- Cluster analysis in latent space

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Resource

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