DATA+AI SUMMIT 2022

Auto Encoder Decoder-Based Anomaly Detection with the Lakehouse Paradigm

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Who am I?

Yinxi Zhang

- Sr Data Scientist @ Databricks
- ML Development and Deployment

databricks ACADEMY

We are going to talk about

- Challenges in Anomaly Detection
- The Autoencoder Approach
- Train Autoencoders Distributedly
- Deploy the Models

Brief on Anomaly Detection

Anomaly Detection

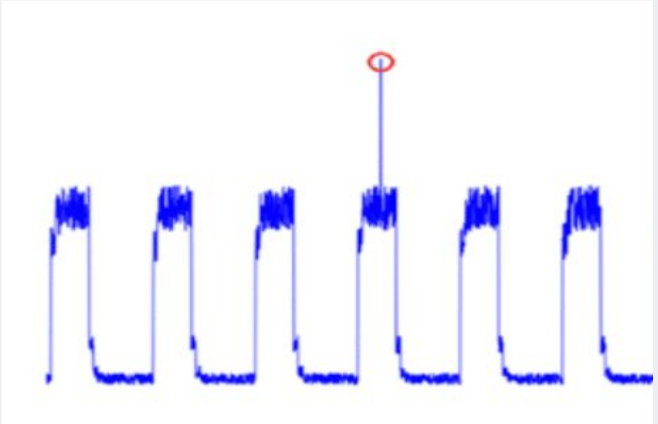
Use Cases

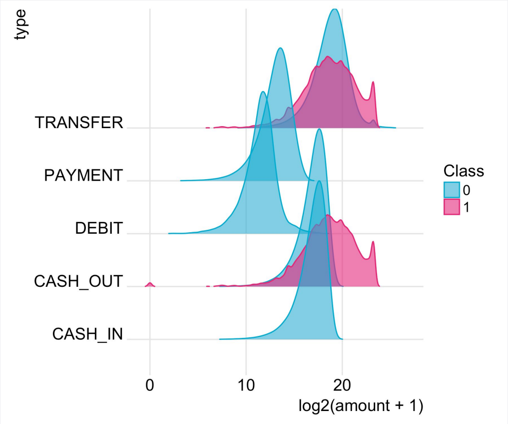
Predictive Maintenance

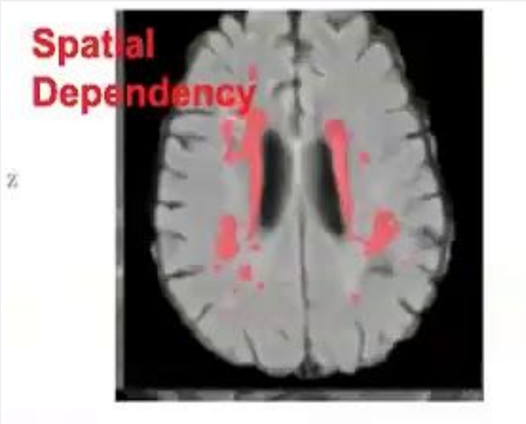
Fraud Detection

Medical Image Diagnose

Surveillance Image Monitor







Anomaly Detection

Challenges

- Anomaly labels are subjective and expensive to acquire
- Even when labels are available, anomalies are rare
- Boundaries between normal and abnormal data are unclear

Extremely imbalanced data + High dimensional features

→ non-linear, unsupervised model is preferable

Autoencoder

Autoencoder

Encoder + Decoder Hourglass Architecture

Encoder

It translates the original high-dimension input into the latent low-dimensional code.

Non-linear Dimension Reduction

Decoder

The decoder network mirrors the encoder architecture recovers the data from the input.

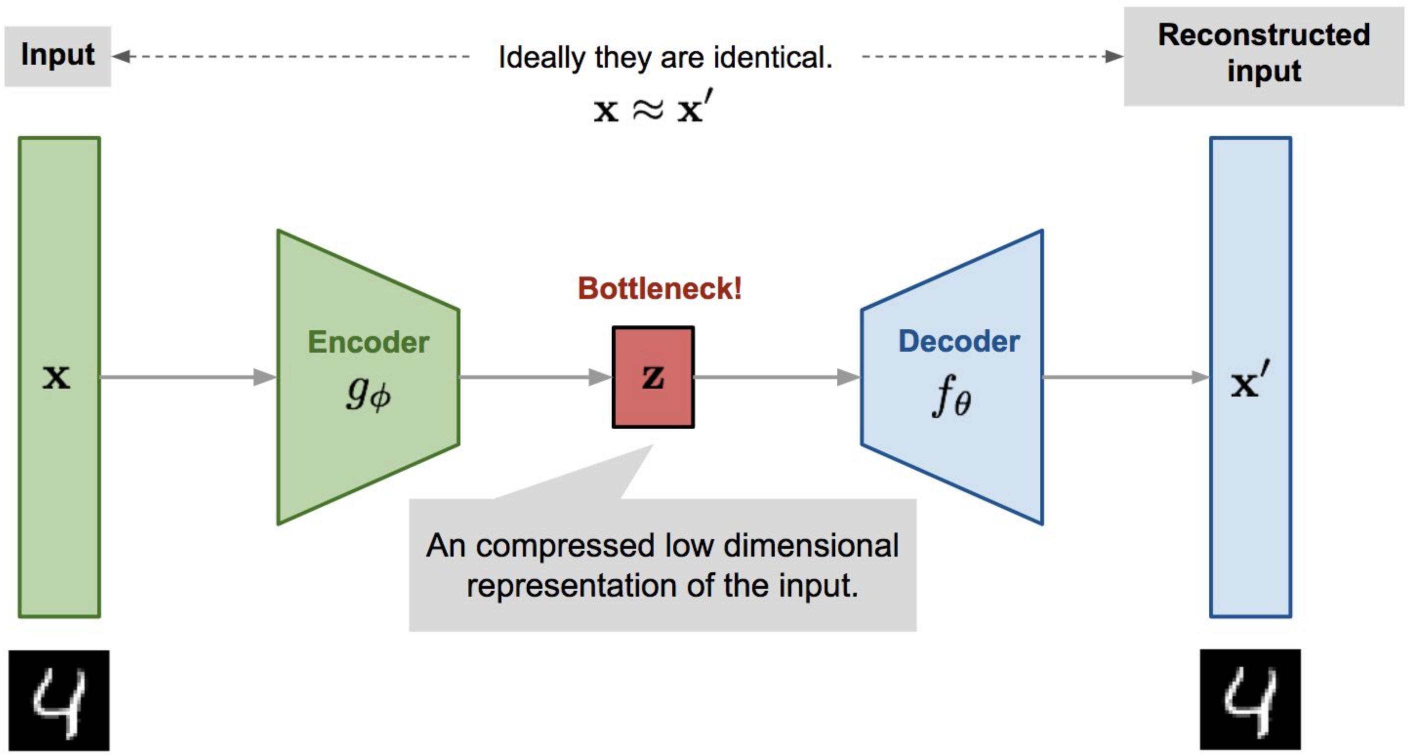
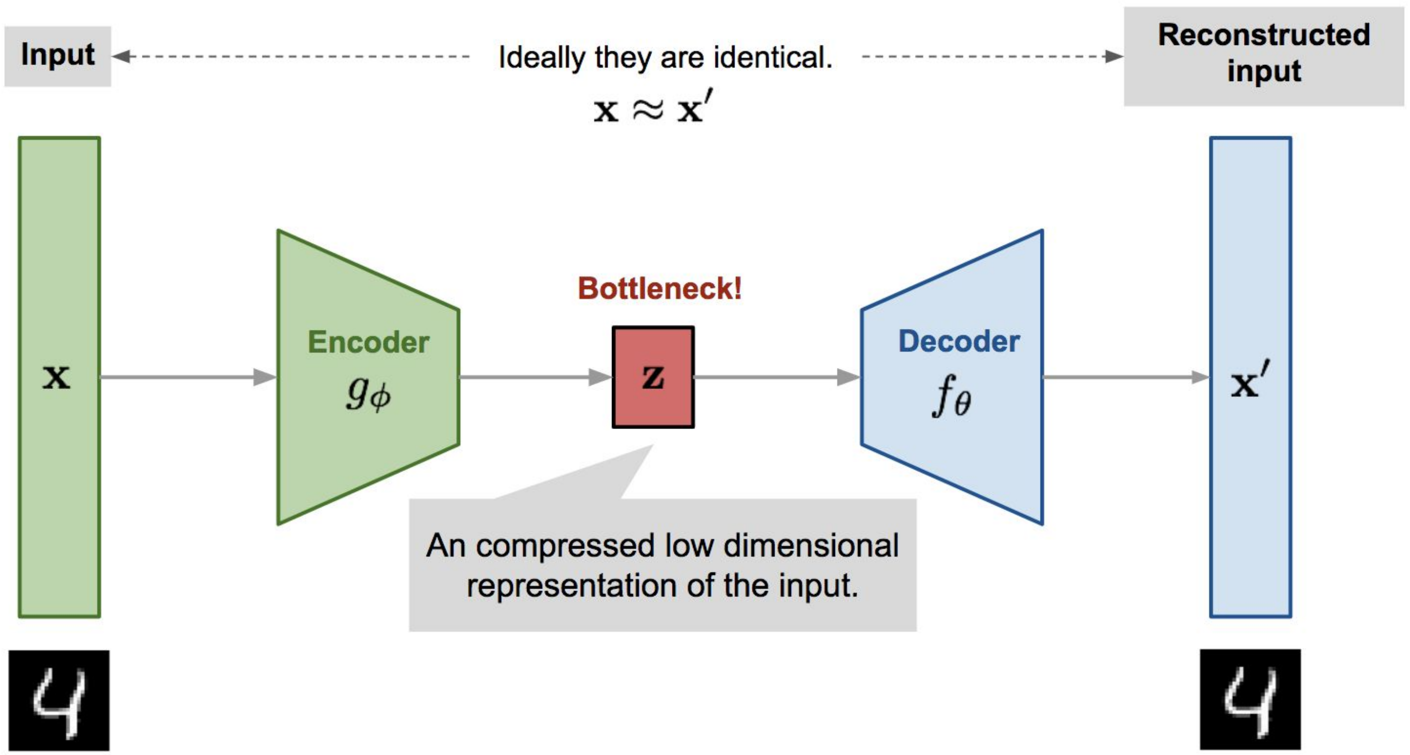


Image source – https://lilianweng.github.io/posts/2018-08-12-vae

Autoencoder

Anomaly Detection Modeling Steps

1. Train AE on normal data only
2. Compute reconstructed error distribution of normal data
3. Choose reconstructed error threshold
4. Test the model and threshold, reconstructed error of anomalies need to be higher than chosen threshold



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Autoencoder

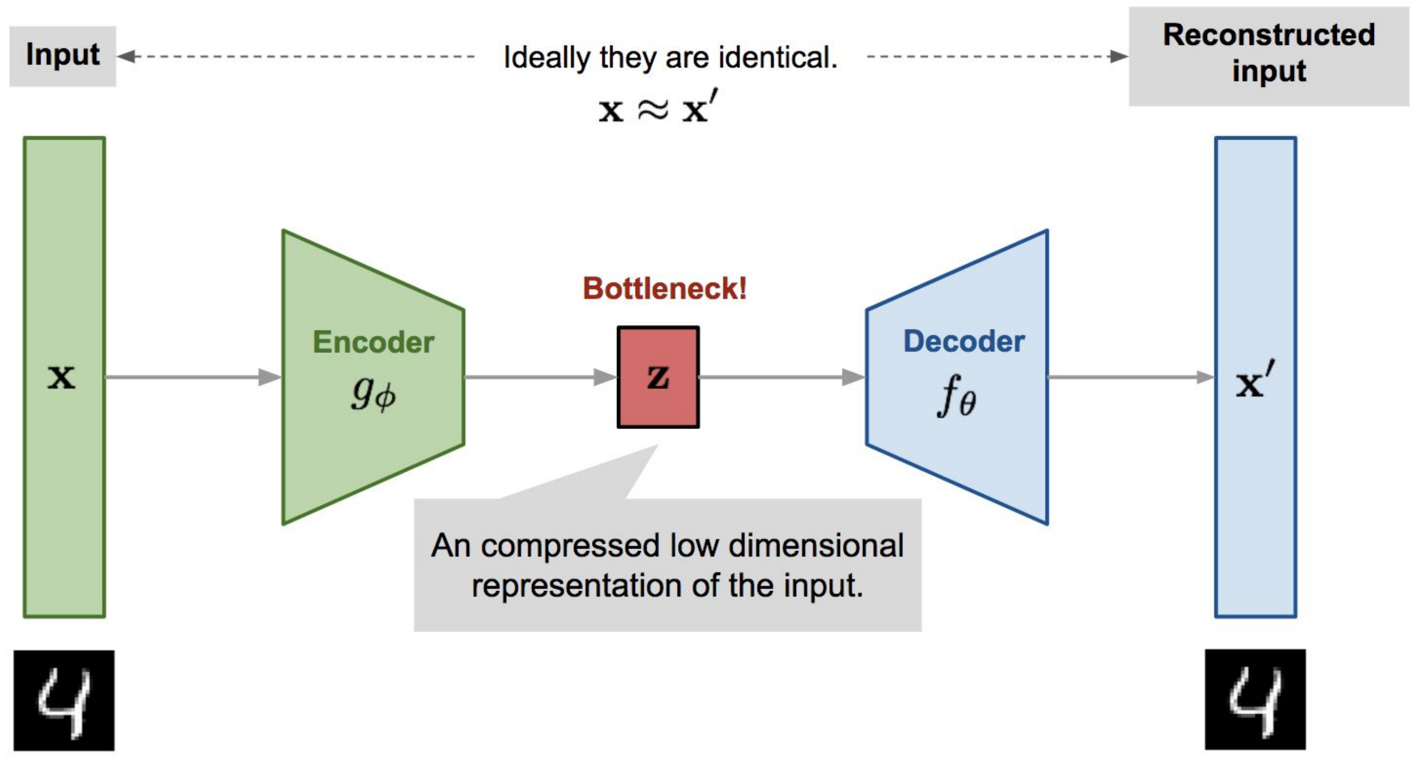
Encoder + Decoder Hourglass Architecture

Flexible Architecture

- Dense
- CNN
- LSTM
- Custom

Latent Space

- Lower dimensional
- Non-linear data representation
- Suitable for downstream tasks, e.g. cluster failure types



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Autoencoder

Limitations and variants

AE limitations

- Mapping between latent space and data space is deterministic
- Interpolating/Extrapolating latent space is challenging

Extensions

- Variational Autoencoder (generative model)
  - Encoder maps inputs to parametric latent **distribution**
  - Minimize KL divergence between parametric posterior and true posterior
  - keras implementation
- Conditional Variational Autoencoder
  - Condition data and latent variables with label information
  - Improve control over generated results

Pitfalls when implementing AE?

Develop model

Build, train, and evaluate model

1. Which network type should I use? Dense, CNN or LSTM?
2. How to select reconstructed error threshold?

Develop model

Build model

1. Which network type should I use? Dense, CNN or LSTM?

- Time series
  a. Dense (Engineer time series features)
  b. LSTM (N_samples_per_window x N_features)
- Image
  a. CNN
  b. Concatenate frames or CNN LSTM

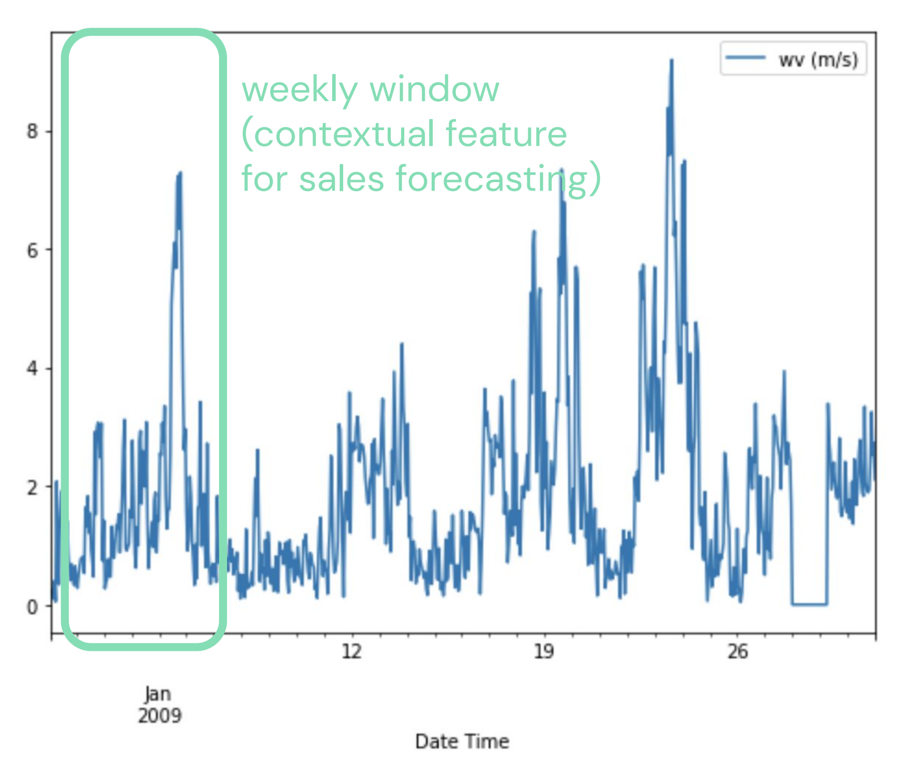
Data insights is the key

- Appropriate window size
- Extract key features from window aggregations or rolling statistics

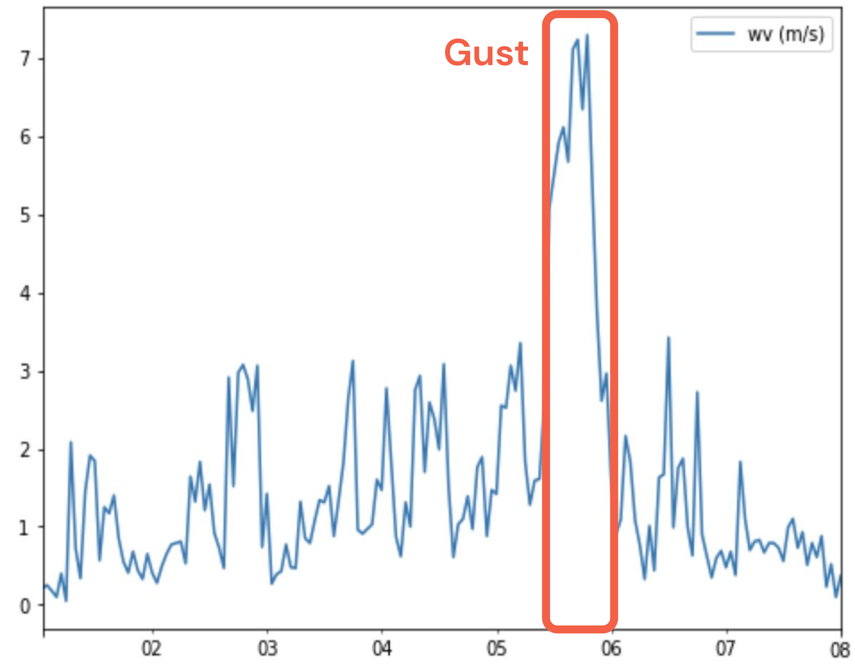
Choose AE model Architecture

Data Centric - Wind Speed Example (Time series)

Wind Speed of a month



Zoom in to a hour



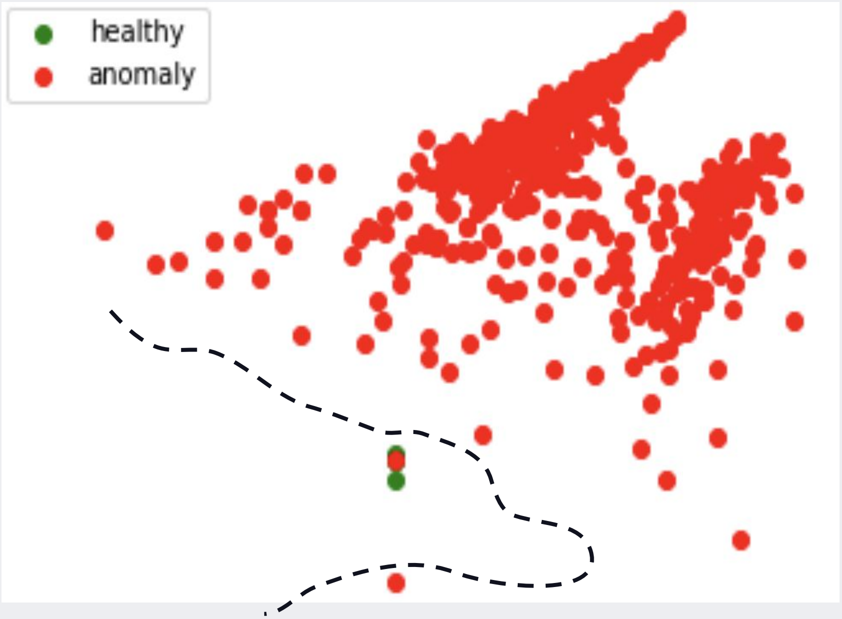
Develop model

Build, train, and evaluate model

1. Which network type should I use? Dense, CNN or LSTM?
    a. Data insights are more important than network choices
2. How to select reconstructed error threshold?
    a. Aggregate prediction outputs (rolling stats)
    b. Use both normal and abnormal data
    c. Use multiple metrics
        i. Duration metrics: Mean absolute percentage error (on normal periods), precision/recall (on anomaly duration time)
        ii. Instance metrics: precision/recall (on occurrence of alerts are sent)

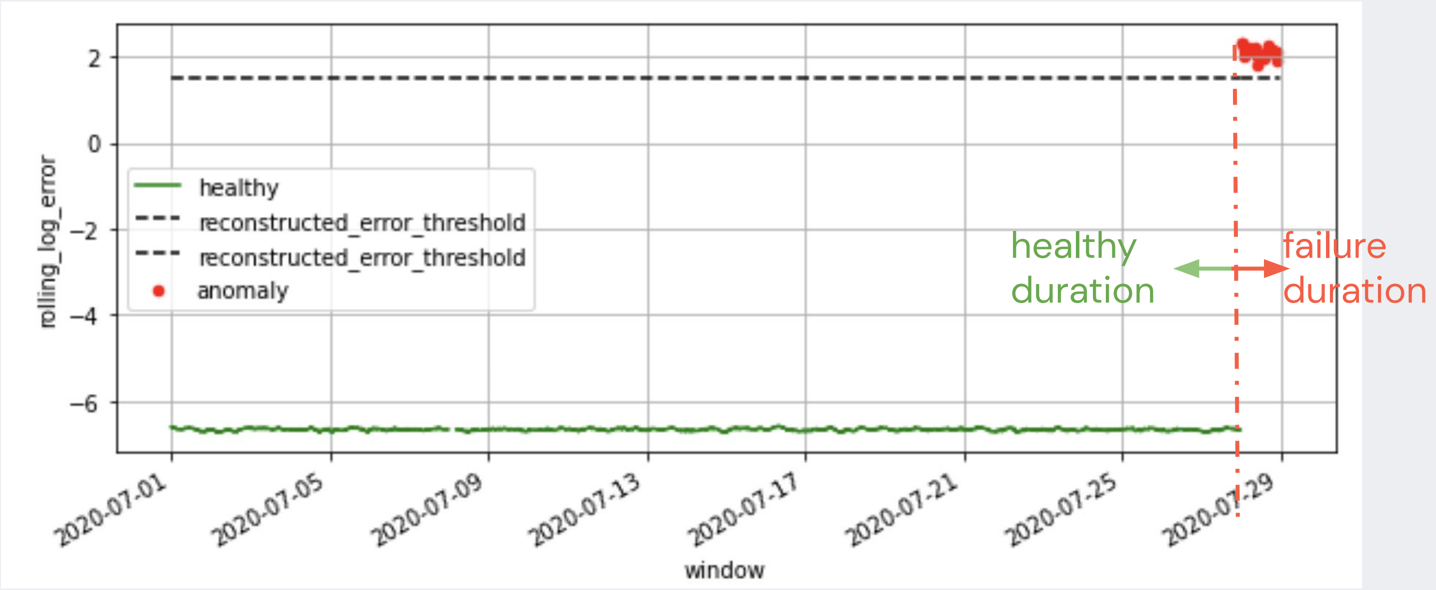
Devop model

Choose reconstructed error threshold



more realistic decision boundary with both healthy and anomaly data

Duration Metrics Example:



Instance Metrics Example:

num of alerts sent in healthy period/total num of alerts sent	3/20
num of failure instances detected by model/total num of failures	6/7

Scale AE Training and Deployment

Scale model training

`Train an individual model per group instance`

1. Naive approach
   a. use a for loop, iterate through data of each group instance
   a. manage training experiments per instance manually
   b. slow process and cumbersome codes

2. Pandas Function API
   a. Write users defined python functions (train, pred, eval)
   b. groupby.applyInPandas() maps each group of the current DataFrame and execute the user defined pandas udf function in parallel

Scale model training

Grouped map Pandas UDF

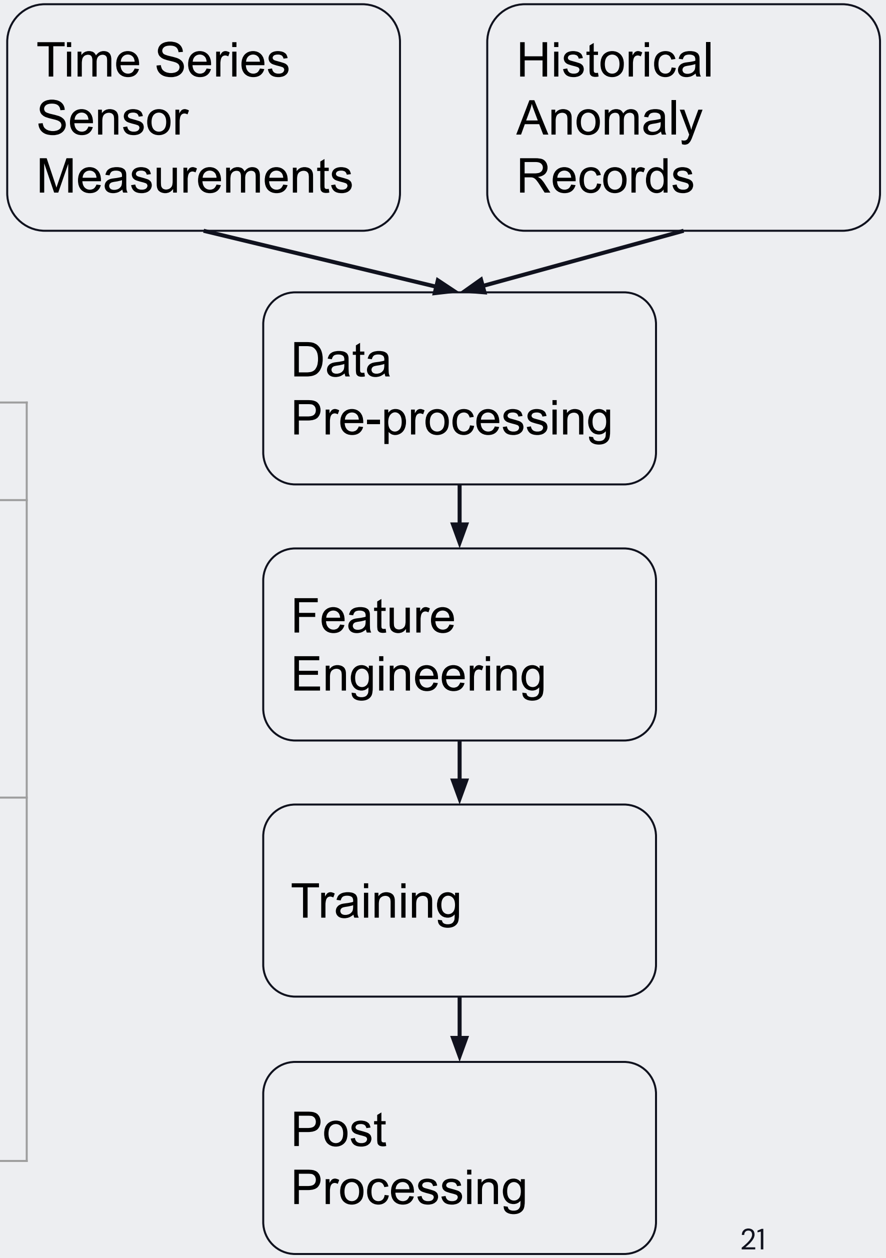
```
def train(self, df):
        schema =  <return-schema>
        def train_udf(df_pandas: pd.DataFrame) -> pd.DataFrame:
            '''Trains an Autoencoder model on grouped instances'''
            device_id = df_pandas['device_id'].iloc[0] # Pull metadata
            # Train the model
            X = df_pandas[features]
            ae_model = build_auto_encoder_decoder(df_pandas)
            ae_model.fit(X, X, **model_fit_kwargs)
           artifact_uri = f"{self.train_model_path}{device_id}.pickle"
            cloudpickle.dump(ae_model, open(artifact_uri, 'wb'))
            returnDF = pd.DataFrame([[device_id, artifact_uri]],
                        columns=["device_id", "model_path"])
            return returnDF

        return df.groupby("device_id").applyInPandas(train_udf, schema)
```

Deploy Model

Featurization

- Within the model or prior to model training?

	Pros	Cons
Prior to Model Training	- Compute once and reuse - Leverages full dataset	- Increases production footprint - Slower to iterate
Within the Model	- Easier to iterate - Smaller production footprint	- Model latency depends upon transformation overheads - Data visibility



Deploy model

with MLflow and Pandas UDFs

1. Batch Inference
    a. groupby.applyInPandas(pred_udf)
    b. can be used in DLT pipelines
2. Custom MLflow model
    a. feature engineering + post-processing encapsulated in the model
    b. multi-model ensemble
    c. serving as a REST endpoint

Demo

Questions?