

# MATLAB EXPO

November 13–14, 2024 | Online

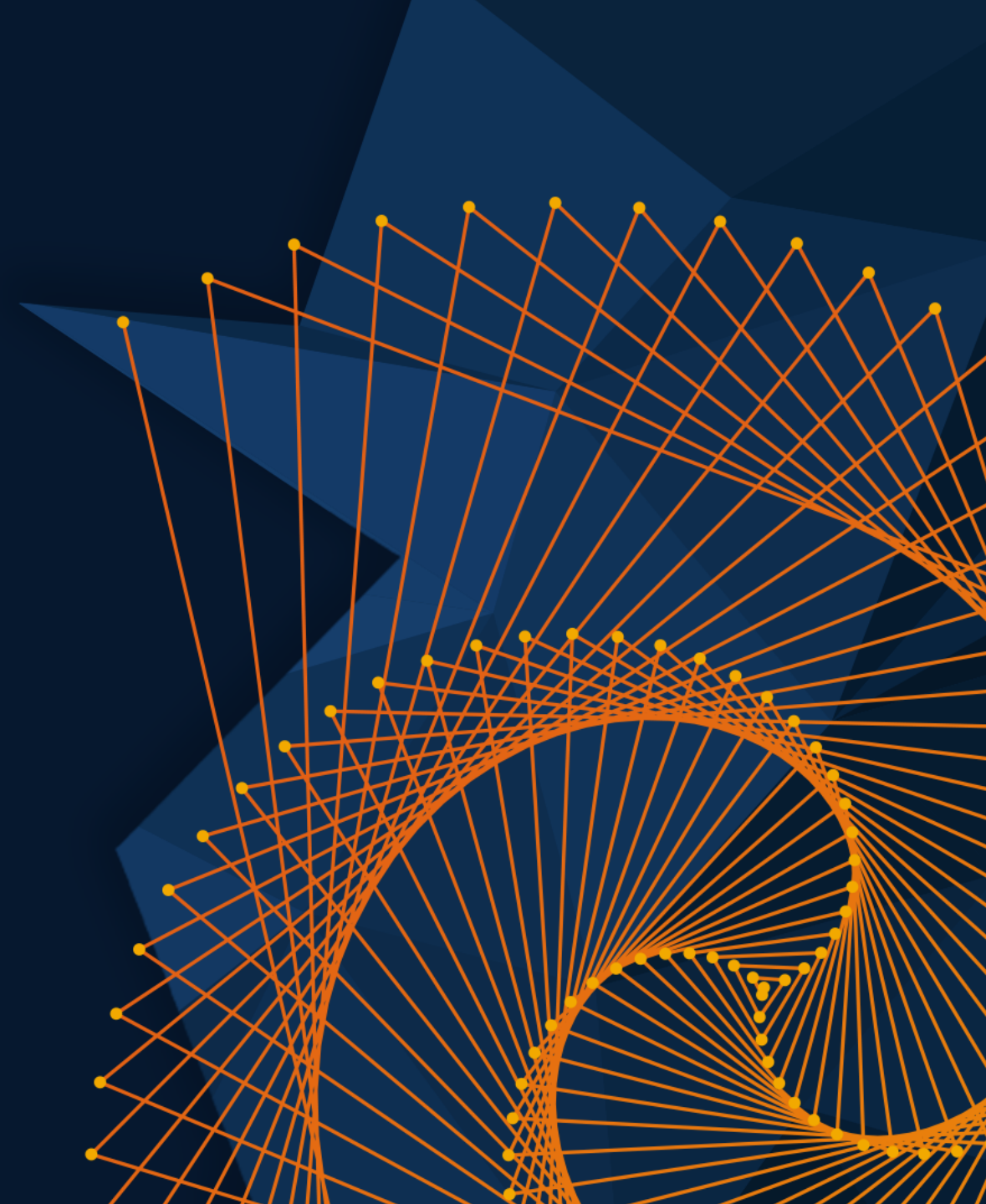
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## Leveraging AI for Superior PV Energy Predictions: A User-Friendly Approach

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*Koustubh Shirke, MathWorks*



# Eaton DERMS Offerings



# Content

- Background
- AI No Code Low Code Workflow
- PV Analytics Methodology
- Results
- App Development
- Summary

# Background

- **Problem Statement:**

- Accurate forecasting of photovoltaic (PV) power generation is crucial for efficient grid management and energy planning. However, PV power output is highly variable due to weather conditions, seasonal changes, and geographic location. Traditional forecasting methods often struggle to handle this complexity, leading to suboptimal energy management and increased operational costs.

- **Proposed Solution:**

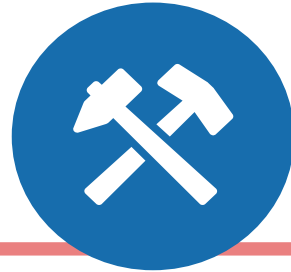
- Leveraging the AI toolchain of MathWorks, including MATLAB and Simulink, to develop a robust PV power forecasting model. This solution will utilize machine learning (ML) and deep learning (DL) techniques to accurately predict PV power output.
- Improved Accuracy: Leveraging advanced ML/DL techniques enhances the accuracy of PV power forecasts.
- Scalability: The solution can be scaled to accommodate different geographic locations and varying data volumes.
- Efficiency: Better forecasting leads to optimized grid management, reducing operational costs and improving energy efficiency.

# Challenges in Implementing a PV Predictions System



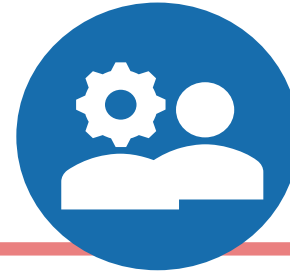
Data quality and  
availability

Weather  
dependency



Model  
Complexity

Maintenance &  
Updates



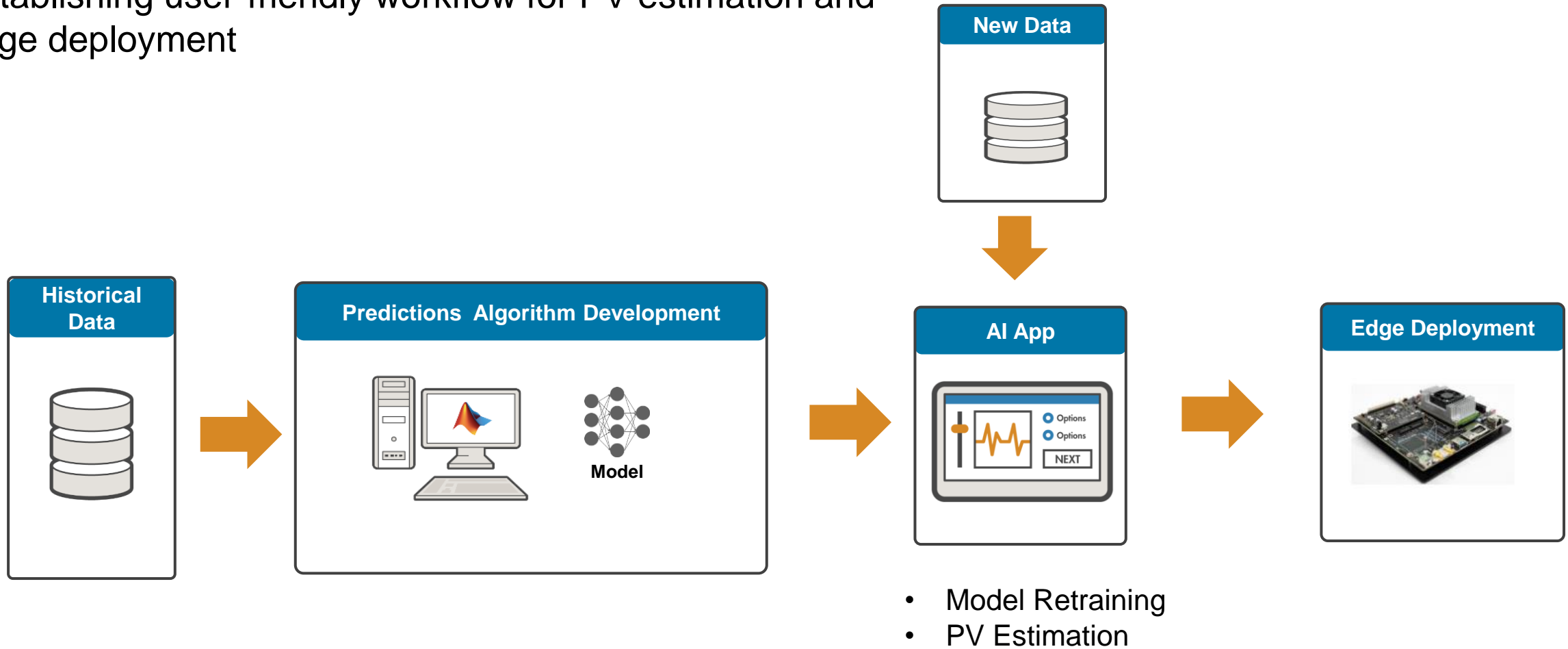
Integration and  
Deployment



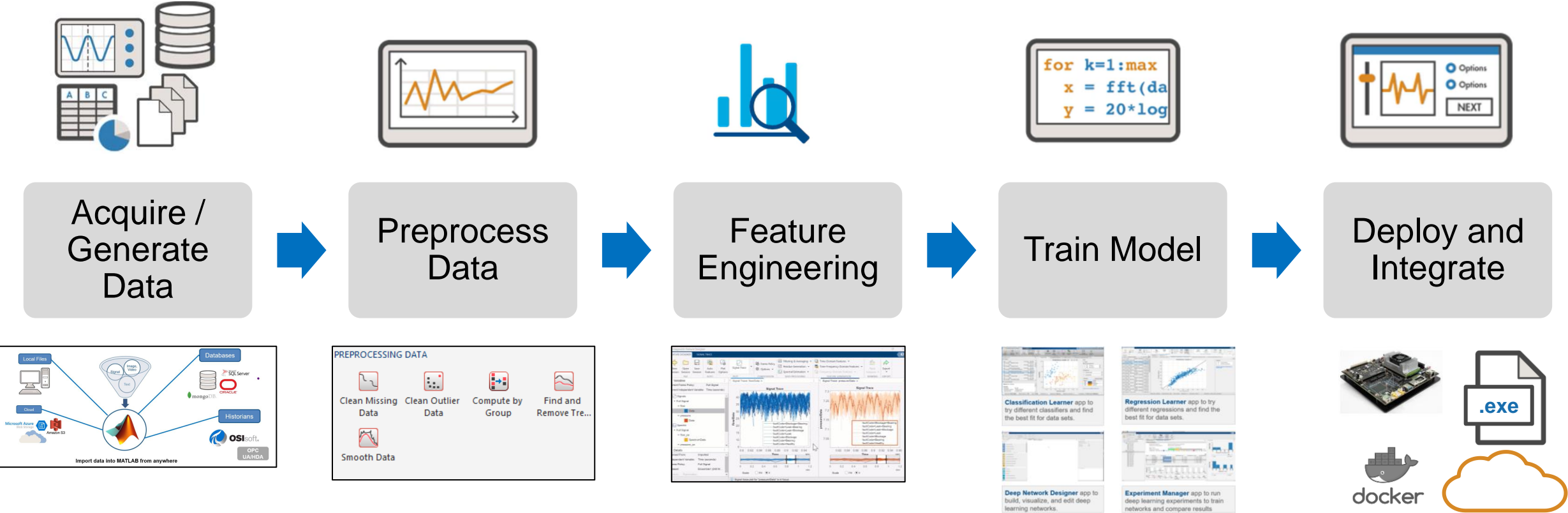
Regulatory and  
Compliance Issues

# Use Case

Establishing user-friendly workflow for PV estimation and edge deployment



# Low Code AI Workflow

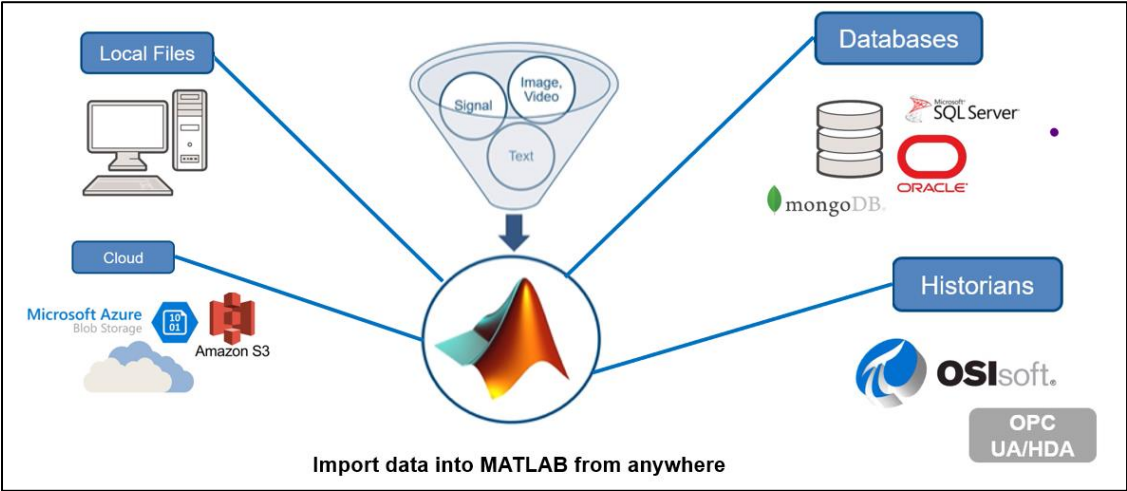




# Photovoltaic Analytics Methodology



Acquire / Generate Data



Import - C:\Users\kshrike\OneDrive - MathWorks\Desktop\AE\POC\Export\Forecasting\Historical\_Data.csv

IMPORT VIEW

Column delimiters: Comma Range: A2:Q10751 Output Type: Table Replace: unimportable cells with NaN

Variable Names Row: 1

DELIMITERS IMPORTED DATA UNIMPORTABLE CELLS

| Time           | PV       | air_temp | azimuth | cloud_opac. | dewpoint_t. | dhi   | dni   | ghi   | precipitabl. | relative_hu... | snow_water | surface_pre... | wind_dir... | wind_spe... | zenith | albedo |
|----------------|----------|----------|---------|-------------|-------------|-------|-------|-------|--------------|----------------|------------|----------------|-------------|-------------|--------|--------|
| 01-01-2023 ... | 12.95999 | 16.25    | -100.5  | 0           | 7.45        | 113   | 782.5 | 560   | 15.15        | 46.4           | 0          | 976.2          | 226         | 4.5         | 35.5   | 0.15   |
| 01-01-2023 ... | 13.44786 | 19.8     | -102.5  | 0           | 7.85        | 117.5 | 796.5 | 605.5 | 15.45        | 45.8           | 0          | 976.2          | 226         | 4.65        | 32.5   | 0.15   |
| 01-01-2023 ... | 14.57639 | 20.4     | -106.5  | 0           | 8.15        | 122   | 814   | 649   | 15.75        | 45.2           | 0          | 976.1          | 227         | 4.75        | 49.5   | 0.15   |
| 01-01-2023 ... | 15.89306 | 21       | -109.5  | 0           | 8.5         | 126   | 826   | 690   | 16.15        | 44.6           | 0          | 976.1          | 227         | 4.9         | 47     | 0.15   |
| 01-01-2023 ... | 15.79105 | 21.6     | -113    | 0           | 8.85        | 131   | 835   | 728.5 | 16.45        | 44.1           | 0          | 976            | 227         | 5           | 44.5   | 0.15   |
| 01-01-2023 ... | 17.06582 | 22.2     | -116.5  | 0           | 9.15        | 140.5 | 833.5 | 762.5 | 16.75        | 43.5           | 0          | 976            | 228         | 5.1         | 41.5   | 0.15   |
| 01-01-2023 ... | 17.26526 | 22.7     | -121    | 0           | 9.45        | 151   | 829   | 793   | 17.05        | 42.9           | 0          | 975.9          | 228         | 5.25        | 39.5   | 0.15   |
| 01-01-2023 ... | 18.12473 | 23.05    | -125.5  | 0           | 9.5         | 161   | 823   | 819.5 | 17.6         | 42.15          | 0          | 975.8          | 229         | 5.35        | 36.5   | 0.15   |
| 01-01-2023 ... | 18.6085  | 23.45    | -130    | 0           | 9.5         | 170.5 | 817.5 | 843.5 | 18.1         | 41.35          | 0          | 975.7          | 230         | 5.5         | 34.5   | 0.15   |
| 01-01-2023 ... | 19.56827 | 23.75    | -135.5  | 0           | 9.6         | 178   | 814.5 | 865   | 18.6         | 40.6           | 0          | 975.55         | 231         | 5.6         | 32.5   | 0.15   |
| 01-01-2023 ... | 19.74207 | 24.05    | -141    | 0           | 9.6         | 185   | 811.5 | 883   | 19.15        | 39.8           | 0          | 975.4          | 232         | 5.75        | 30.5   | 0.15   |
| 01-01-2023 ... | 18.82518 | 24.45    | -148    | 0.05        | 9.6         | 192   | 806   | 897   | 19.65        | 39.1           | 0          | 975.3          | 233         | 5.85        | 29     | 0.15   |
| 01-01-2023 ... | 18.68389 | 24.75    | -155    | 1.45        | 9.6         | 204   | 798   | 895.5 | 20.2         | 38.35          | 0          | 975.15         | 234         | 6           | 27.5   | 0.15   |
| 01-01-2023 ... | 12.78197 | 25.1     | -162.5  | 10.15       | 9.6         | 372.5 | 503.5 | 633   | 20.7         | 37.65          | 0          | 975.05         | 235         | 6.1         | 26.5   | 0.15   |
| 01-01-2023 ... | 19.65572 | 25.45    | -170.5  | 7.95        | 9.7         | 346   | 556.5 | 546.5 | 21.2         | 36.95          | 0          | 974.9          | 236         | 6.25        | 26     | 0.15   |
| 01-01-2023 ... | 20.23448 | 25.75    | 1       | 5.8         | 9.7         | 314   | 613   | 667   | 21.75        | 36.3           | 0          | 974.8          | 236.5       | 6.4         | 26     | 0.15   |
| 01-01-2023 ... | 19.1728  | 26.1     | 172.5   | 6.3         | 9.7         | 324   | 594.5 | 859   | 22.3         | 35.6           | 0          | 974.65         | 237         | 6.5         | 26     | 0.15   |
| 01-01-2023 ... | 18.57484 | 26.45    | 164.5   | 10.85       | 9.7         | 389.5 | 473   | 812.5 | 22.8         | 35             | 0          | 974.5          | 238         | 6.65        | 26     | 0.15   |

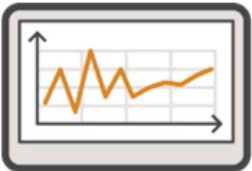
Data\_Analytics\_2\_1.mlx

Data Import

```
1 Total_Data = importfile1('Historical_Data.csv');
```



# Data Preprocessing



Preprocess  
Data

**PREPROCESSING DATA**

- Clean Missing Data
- Clean Outlier Data
- Compute by Group
- Find and Remove Tre...
- Find Change Points
- Find Local Extrema
- Normalize Data
- Preprocess Text Data
- Smooth Data

**TABLES AND TIMETABLES**

- Join Tables
- Pivot Table
- Retime Timetable
- Stack Table Variables
- Synchronize Timetables
- Unstack Table Variables

**Clean Missing Data** ▶  Autorun ? ⋮

newTable = Filled missing data in Total\_Data\_1.air\_temp using the spline interpolation method

▼ Select data

Input data: Total\_Data\_1 | Specified variables: | air\_temp | +

Output format: Table with specified variables replaced

X-axis: default

▶ Define optional missing value indicators

▼ Specify method

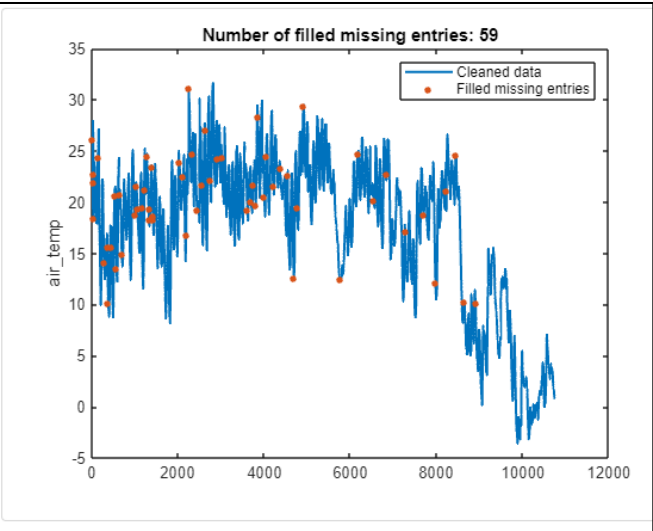
Cleaning method: Fill missing | Spline interpolation

Max gap to fill: Inf

▼ Display results

Cleaned data  Filled missing entries

▶ Show code



# Feature Engineering

## Redundancy check



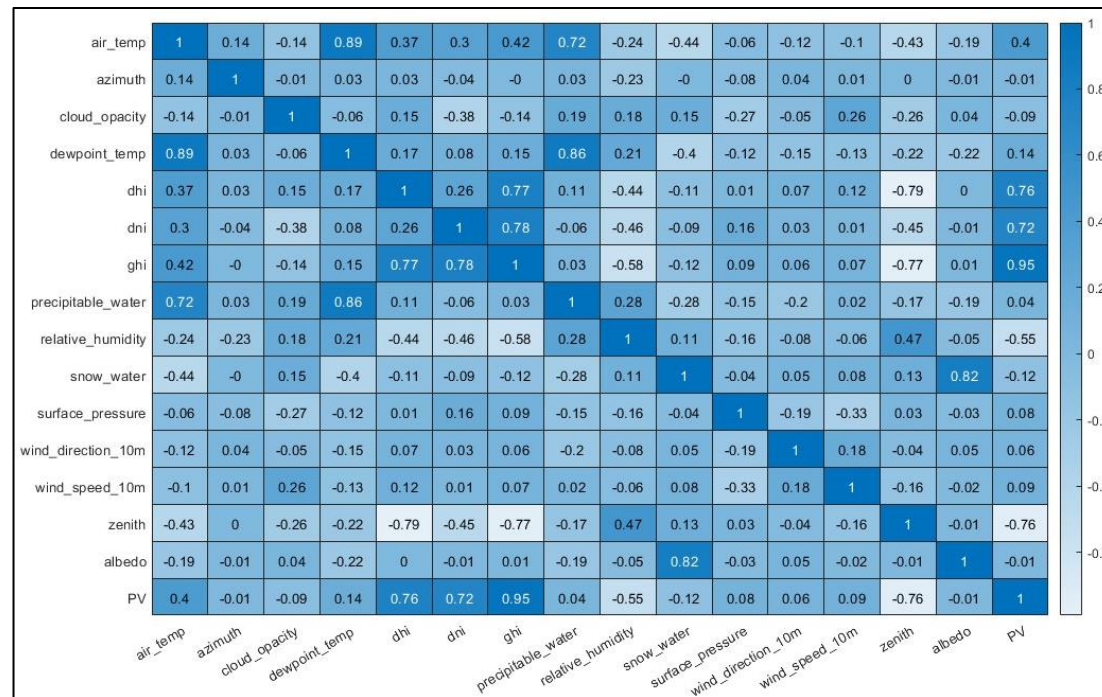
## Feature Engineering

Correlation matrix of the feature

High correlation between two features suggests redundancy.

Why to remove redundant features?

- Redundant features can cause the model to learn noise instead of the actual patterns
- Removing redundant features can simplify the model
- Fewer features mean less computational resources

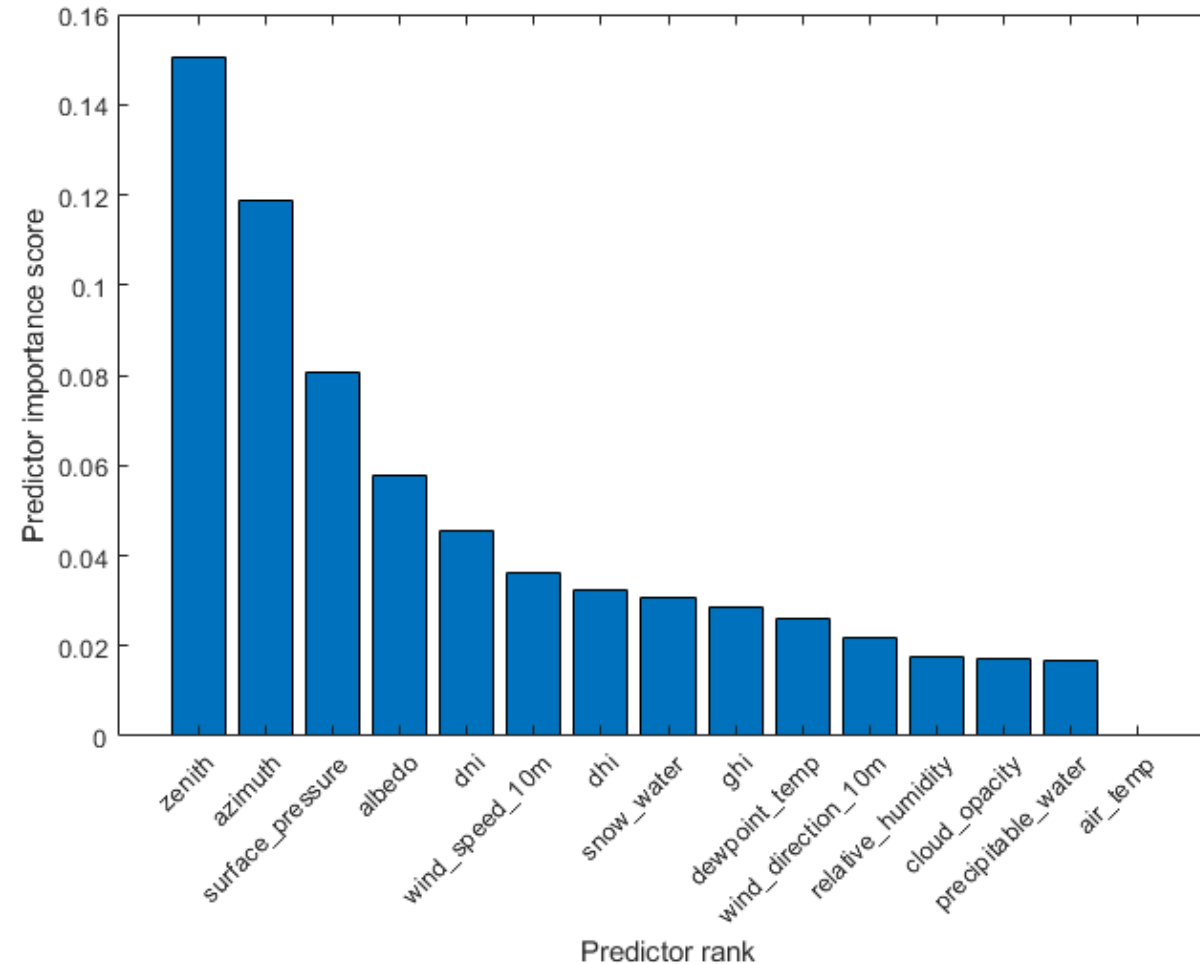


# Feature Engineering

Relevance check



Feature  
Engineering

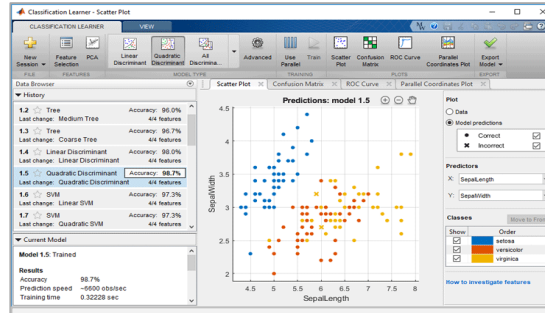


**fscmrmr function** : Rank features using minimum redundancy maximum relevance (MRMR) algorithm

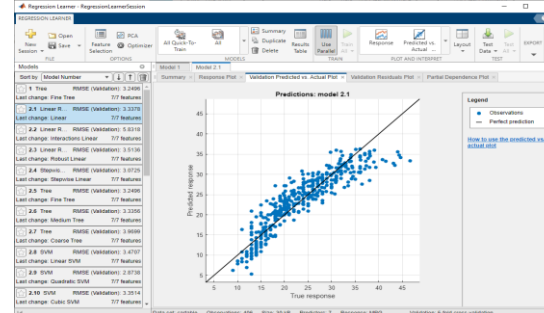
# Model Training

```
for k=1:max
    x = fft(da
    y = 20*log
```

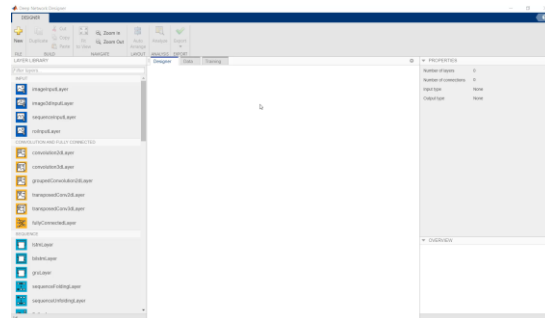
Train Model



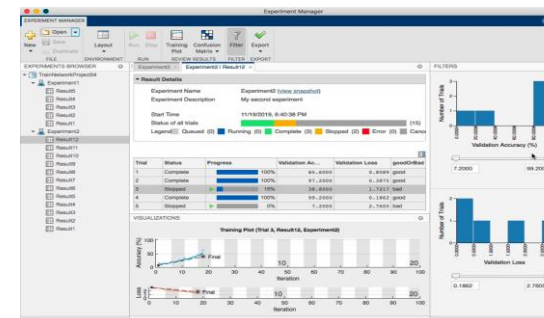
**Classification Learner** app to try different classifiers and find the best fit for data sets.



**Regression Learner** app to try different regressions and find the best fit for data sets.



**Deep Network Designer** app to build, visualize, and edit deep learning networks.



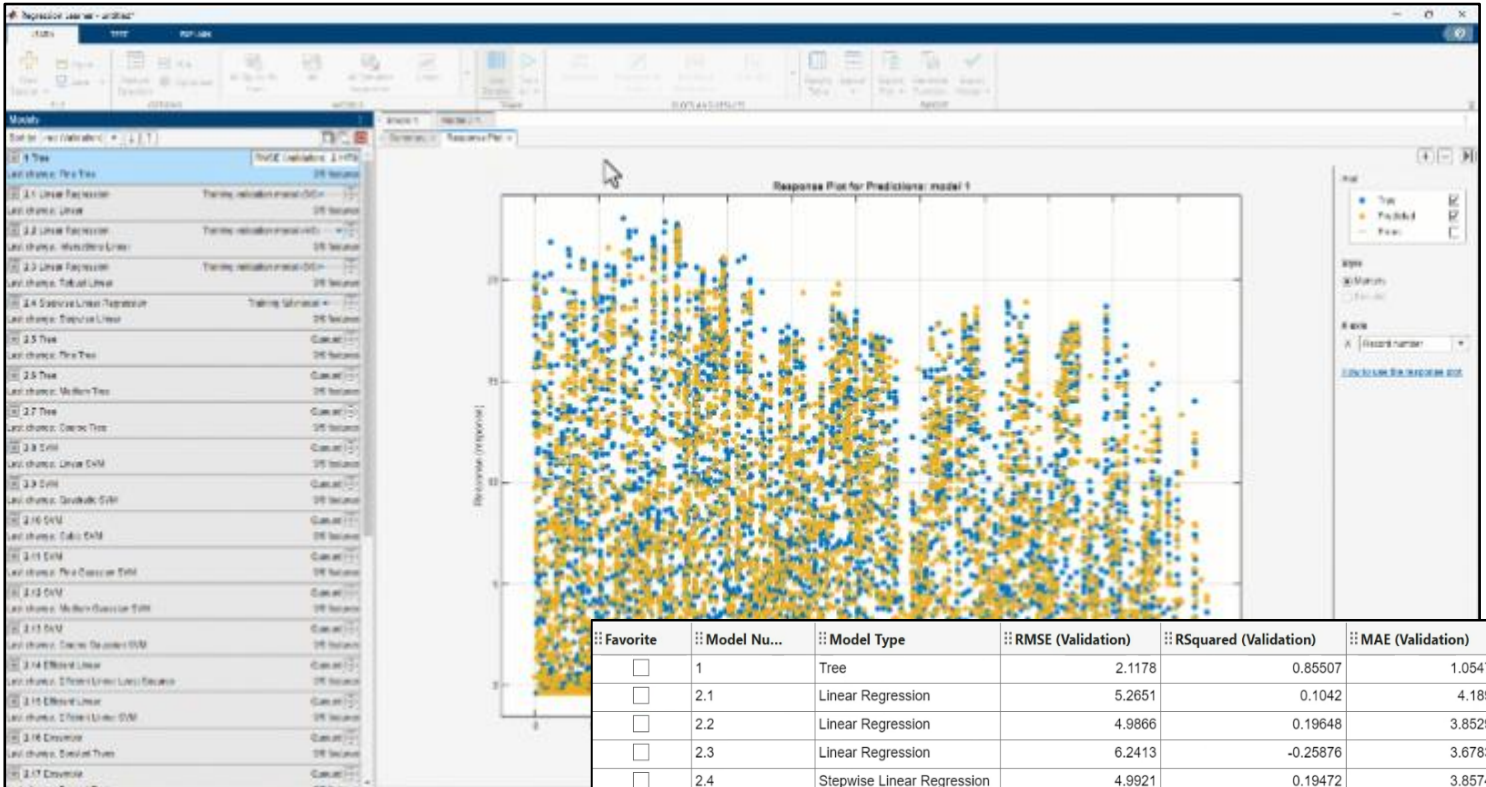
**Experiment Manager** app to run deep learning experiments to train networks and compare results

The data is divided into training (70%) and testing dataset (30%)

# Model Training

```
for k=1:max
    x = fft(da
    y = 20*log
```

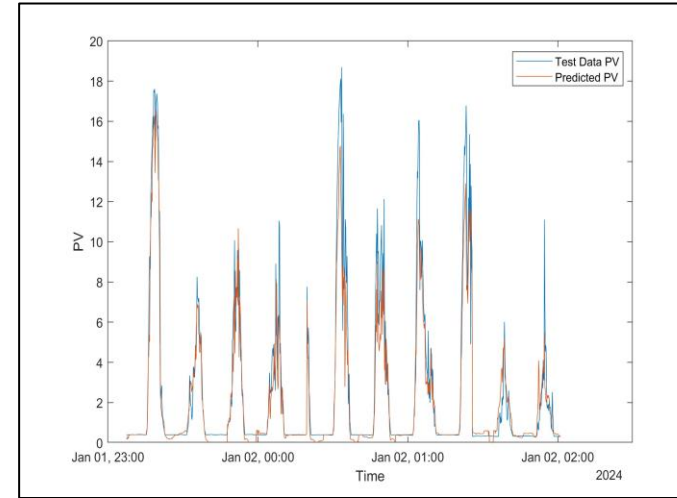
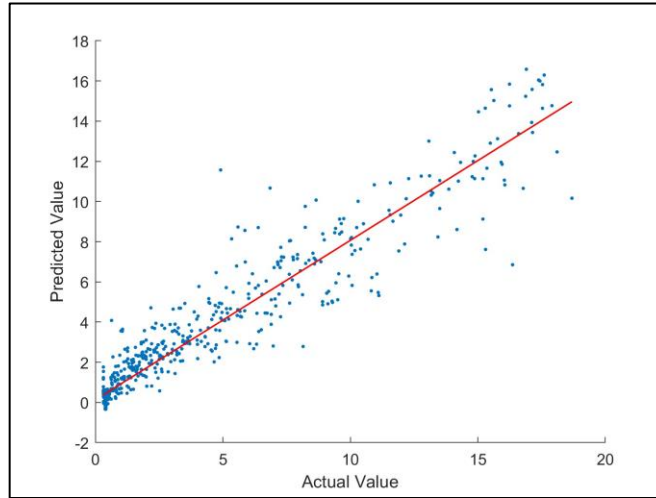
Train Model



| Favorite                 | Model Nu... | Model Type                 | RMSE (Validation) | RSquared (Validation) | MAE (Validation) | Prediction Speed (obs/sec) | Model Size (bytes) |
|--------------------------|-------------|----------------------------|-------------------|-----------------------|------------------|----------------------------|--------------------|
| <input type="checkbox"/> | 1           | Tree                       | 2.1178            | 0.85507               | 1.0547           | 63279                      | 273273             |
| <input type="checkbox"/> | 2.1         | Linear Regression          | 5.2651            | 0.1042                | 4.189            | 63869                      | 11618              |
| <input type="checkbox"/> | 2.2         | Linear Regression          | 4.9866            | 0.19648               | 3.8529           | 51703                      | 55406              |
| <input type="checkbox"/> | 2.3         | Linear Regression          | 6.2413            | -0.25876              | 3.6783           | 65337                      | 12162              |
| <input type="checkbox"/> | 2.4         | Stepwise Linear Regression | 4.9921            | 0.19472               | 3.8574           | 52925                      | 33310              |
| <input type="checkbox"/> | 2.5         | Tree                       | 2.1178            | 0.85507               | 1.0547           | 62818                      | 273273             |
| <input type="checkbox"/> | 2.6         | Tree                       | 2.1263            | 0.8539                | 1.13             | 3.5908e+05                 | 126197             |
| <input type="checkbox"/> | 2.7         | Tree                       | 2.2772            | 0.83243               | 1.2796           | 3.6472e+05                 | 51697              |
| <input type="checkbox"/> | 2.8         | SVM                        | 5.9607            | -0.14812              | 3.6555           | 38043                      | 693386             |
| <input type="checkbox"/> | 2.9         | SVM                        | 3.3907            | 0.6285                | 2.318            | 27124                      | 693562             |
| <input type="checkbox"/> | 2.10        | SVM                        | 2.6905            | 0.76609               | 1.8381           | 39205                      | 659242             |
| <input type="checkbox"/> | 2.11        | SVM                        | 1.7744            | 0.89826               | 0.97148          | 21485                      | 376838             |
| <input type="checkbox"/> | 2.12        | SVM                        | 2.5654            | 0.78733               | 1.7274           | 13602                      | 618998             |
| <input type="checkbox"/> | 2.13        | SVM                        | 4.872             | 0.23298               | 2.9219           | 21289                      | 657478             |
| <input type="checkbox"/> | 2.14        | Efficient Linear           | 5.5583            | 0.0016586             | 4.5562           | 2.6244e+05                 | 11685              |
| <input type="checkbox"/> | 2.15        | Efficient Linear           | 6.3259            | -0.29311              | 3.8295           | 2.2653e+05                 | 11725              |
| <input type="checkbox"/> | 2.16        | Ensemble                   | 2.2429            | 0.83744               | 1.4399           | 83118                      | 179082             |

# Model Evaluation

```
for k=1:max
    x = fft(da
    y = 20*log
```



Train Model

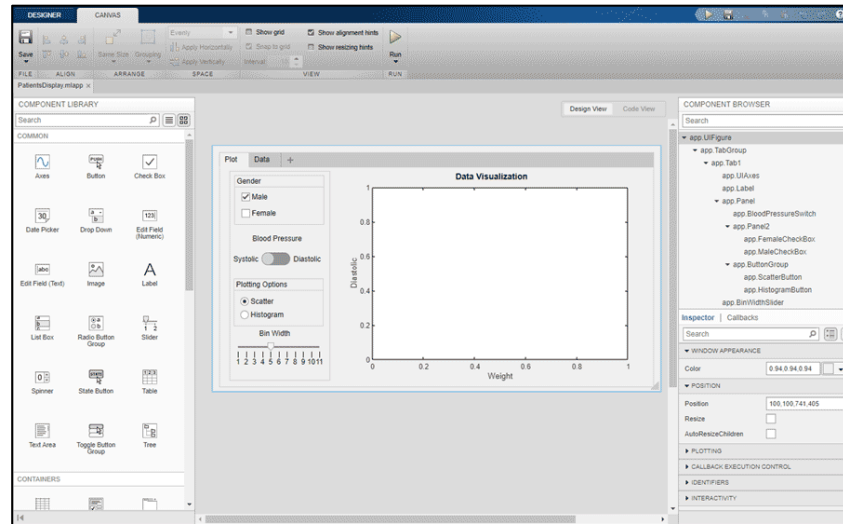
| Matrices  | Wide NN | Shallow NN | SVM    | GPR    | Bagged Tree | Boosted Trees | LSTM   | CNN    |
|-----------|---------|------------|--------|--------|-------------|---------------|--------|--------|
| RMSE      | 3.94    | 1.20       | 5.01   | 2.09   | 1.28        | 1.41          | 2.19   | 2.36   |
| R-Squared | 0.00    | 0.91       | -0.62  | 0.72   | 0.90        | 0.87          | 0.69   | 0.64   |
| MBE       | -1.64   | 0.16       | 3.14   | 0.06   | -0.36       | -0.51         | 0.52   | 1.39   |
| MDAE      | 1.93    | 0.61       | 5.29   | 0.94   | 0.21        | 0.23          | 1.58   | 1.20   |
| MDAPE     | 332.40  | 91.50      | 544.54 | 185.05 | 40.69       | 39.70         | 187.01 | 129.18 |
| SMAPE     | 132.17  | 67.74      | 134.25 | 95.48  | 45.00       | 42.15         | 97.29  | 74.24  |
| MAE       | 2.79    | 0.84       | 4.66   | 1.46   | 0.65        | 0.70          | 1.72   | 1.71   |
| MAPE      | 332.04  | 98.74      | 894.03 | 188.51 | 41.54       | 35.98         | 274.98 | 217.97 |

# App Designer

Building modern, full-featured applications using the rich set of components and custom interactions available in App Designer.



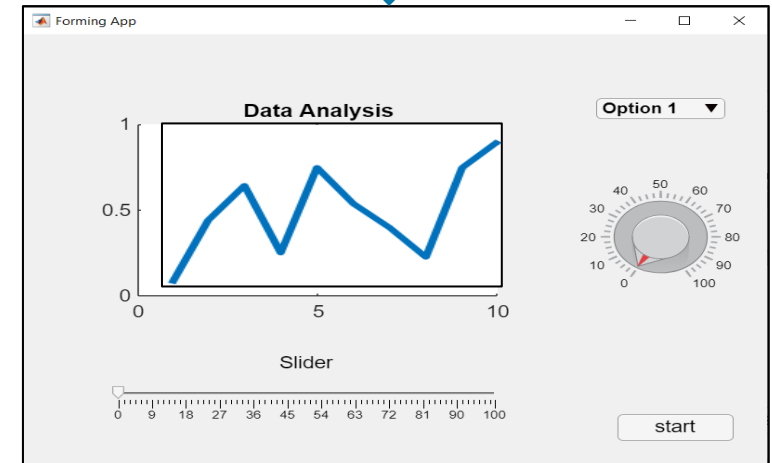
Develop UI  
App



MATLAB Compiler



Create → Package → Share





# PV Analytics Methodology

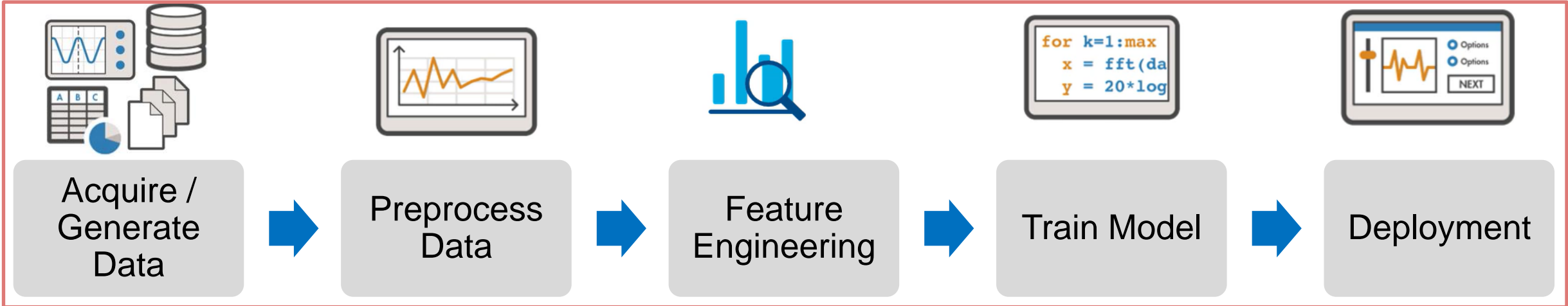


Develop UI App



# Conclusion

GUI



**MATLAB Analytics** work with **business and engineering data**

**MATLAB enables domain experts to do Data Science**

**MATLAB Analytics run anywhere**

**Supports end-to-end Workflow**

## Benefits and opportunities

Faster Time To Market

Ease in Development

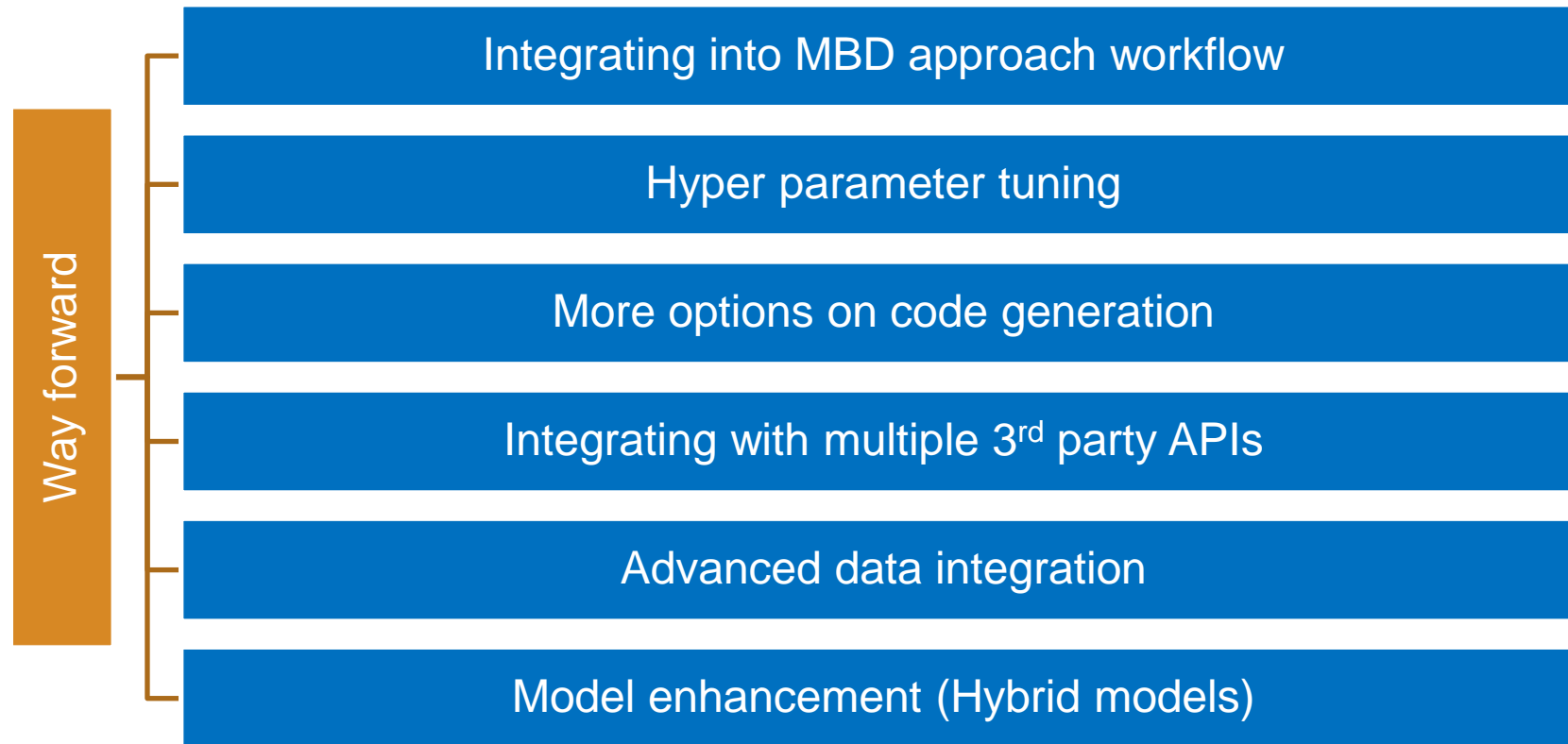
Ease in Deployment

Streamlined Documentation

Adherence to Standards / Compliance

Continuous Verification

# Way forward



# Q&A



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Share the EXPO experience

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# MATLAB EXPO



Get the code



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# MATLAB EXPO



Get the code