

MATLAB EXPO

Low Code Data Analysis in MATLAB

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(he/him)

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(she/her)



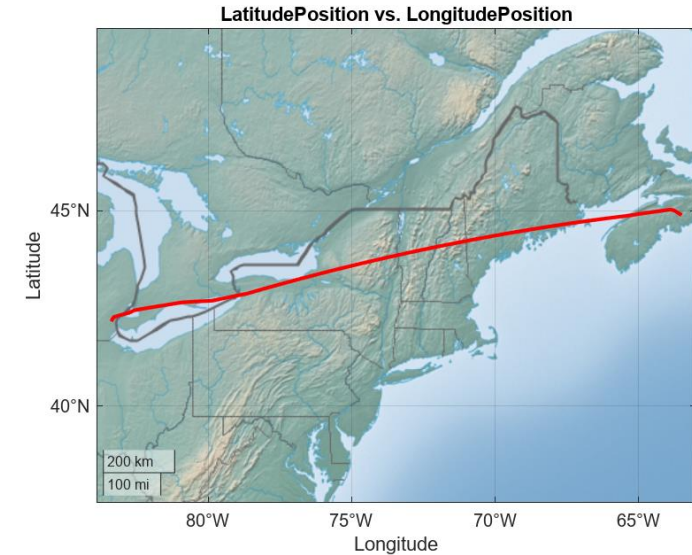
Case Study: Get Flight Sensor Data ready for Modeling

- **Objective:**
 - Explore, analyze and prepare flight sensor data for modeling

- **Inputs:**
 - Excel file with raw flight sensor data

- **Output:**
 - Cleaned sensor data that can be trained to predict Air Speed
 - Reusable code

- **Source:**
 - [NASA Dash Link: Sample Flight Data](#)



	A	B	C	D	E	F	G	H	I	J	K	L	M
1	Time	FuelQuantity	Latitude	Longitude	OilPressure	OilTemperature	FlightPhaseFromACMS	WeightOnWheels	Altitude	ExhaustGasTemperature	FuelFlow	TrueAirSpeed	WindDirection
2	6/2/2001 5:41	8048	44.8915135	-63.519183	0	23.67477417	Planning		0	419	17.5	0	0
3	6/2/2001 5:41	8048	44.8915135	-63.519183	0	23.67477417	Planning		0	419	17.5	0	0
4	6/2/2001 5:41	8048	44.8915135	-63.519183	0	23.67477417	Planning		0	420	17.5	0	0
5	6/2/2001 5:41	8048	44.8915135	-63.519183	0	23.67477417	Planning		0	419	17.5	0	0
6	6/2/2001 5:41	8048	44.8915135	-63.519183	0	23.67477417	Planning		0	419	17.5	0	0
7	6/2/2001 5:41	8048	44.8915135	-63.519183	0	23.67477417	Planning		0	420	17.5	0	0
8	6/2/2001 5:41	8048	44.8915135	-63.519183	0	23.67477417	Planning		0	419	17.5	0	0
9	6/2/2001 5:41	8048	44.8915135	-63.519183	0	23.67477417	Planning		0	419	17.5	0	0
10	6/2/2001 5:41	8048	44.8915135	-63.518992	0	23.67477417	Planning		0	419	17.5	0	0
11	6/2/2001 5:41	8048	44.8915135	-63.518992	0	23.67477417	Planning		0	418	17.5	0	0
12	6/2/2001 5:41	8048	44.8915135	-63.518992	0	23.67477417	Planning		0	420	17.5	0	0
13	6/2/2001 5:41	8048	44.8915135	-63.518992	0	23.67477417	Planning		0	419	17.5	0	0
14	6/2/2001 5:41	8040	44.8915135	-63.518992	0	23.67477417	Planning		0	419	17	0	0
15	6/2/2001 5:41	8040	44.8915135	-63.518992	0	23.67477417	Planning		0	419	17	0	0
16	6/2/2001 5:41	8040	44.8915135	-63.518992	0	23.67477417	Planning		0	418	17	0	0
17	6/2/2001 5:41	8040	44.8915135	-63.518992	0	23.67477417	Planning		0	419	17	0	0
18	6/2/2001 5:41	8032	44.8915135	-63.518992	0	25.0178833	Planning		0	418	17	0	0
19	6/2/2001 5:41	8032	44.8915135	-63.518992	0	25.0178833	Planning		0	418	17	0	0

What are “low code” tools?

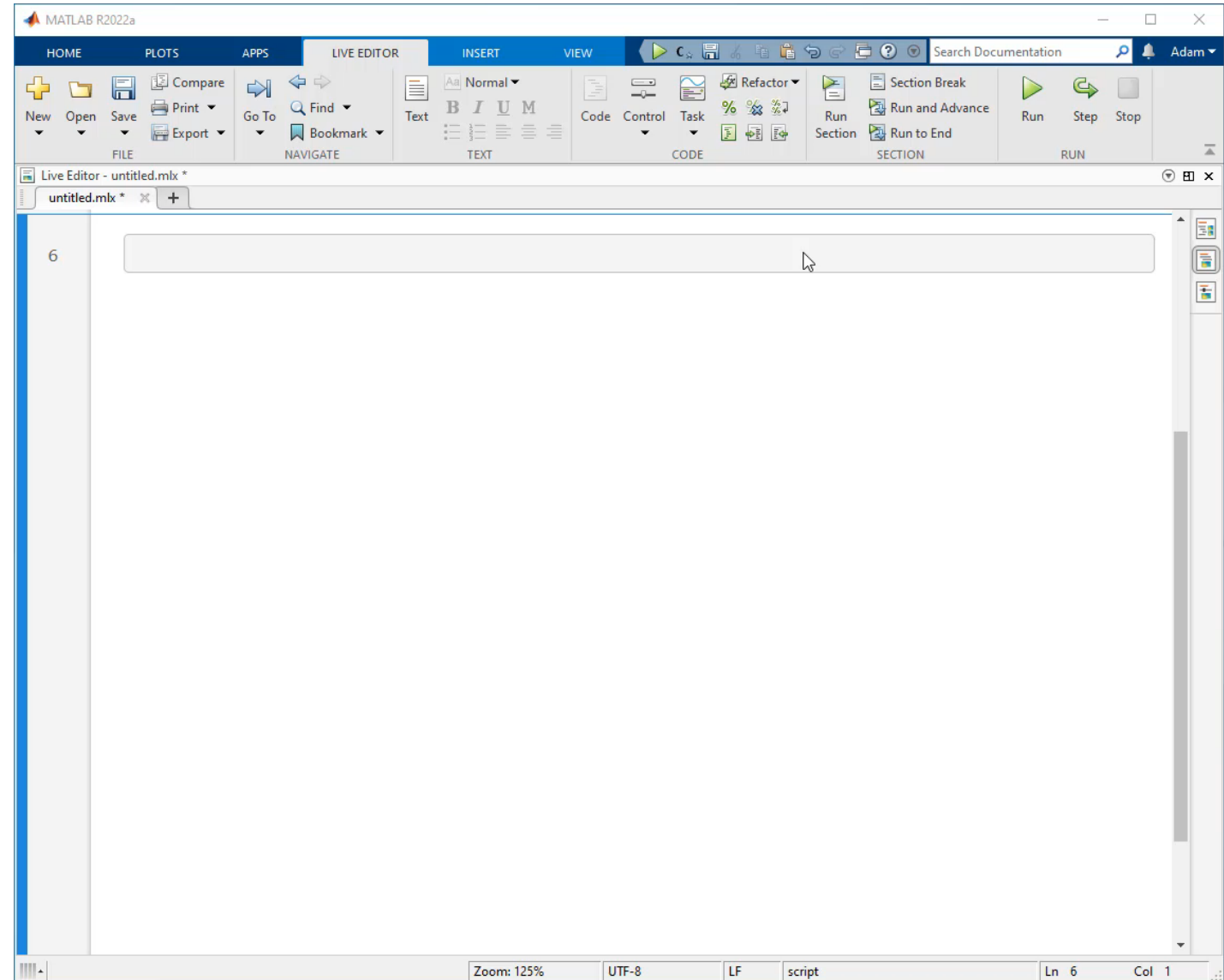
Low code tools enable:

- rapid software development
- minimal manual coding

Benefits of low code tools:

- Shallow learning curve
- Teach *how* to code
- Solve task first, code later

Not just for beginners



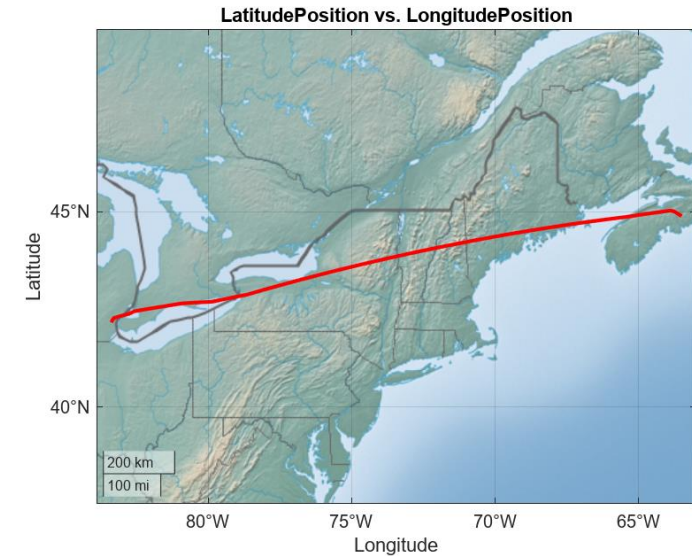
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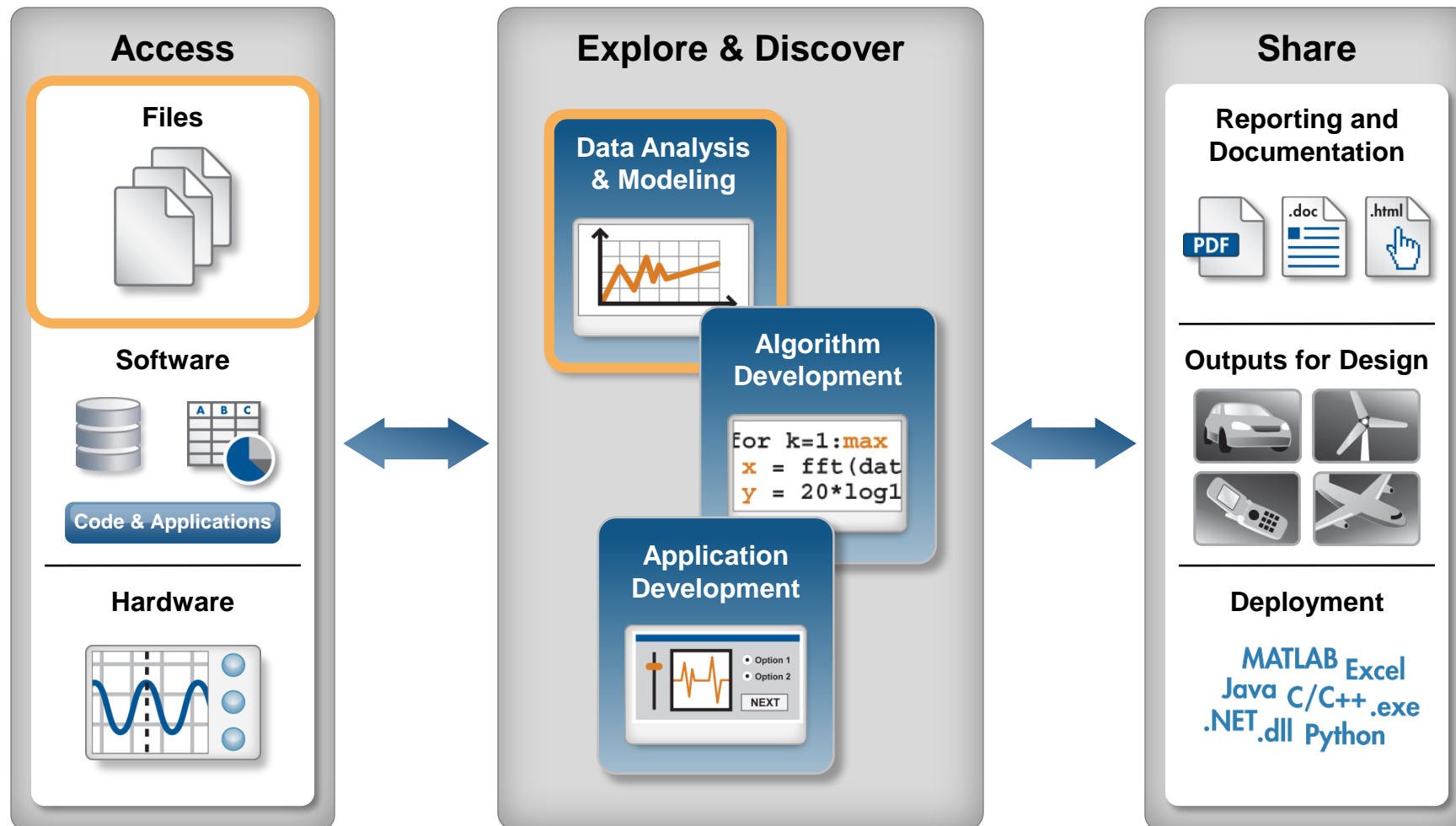
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14	6/2/2001 5:41	8040	44.8915135	-63.518992	0	23.67477417	Planning		0	419	17	0	0
15	6/2/2001 5:41	8040	44.8915135	-63.518992	0	23.67477417	Planning		0	419	17	0	0
16	6/2/2001 5:41	8040	44.8915135	-63.518992	0	23.67477417	Planning		0	418	17	0	0
17	6/2/2001 5:41	8040	44.8915135	-63.518992	0	23.67477417	Planning		0	419	17	0	0
18	6/2/2001 5:41	8032	44.8915135	-63.518992	0	25.0178833	Planning		0	418	17	0	0
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MATLAB simplifies the data analysis workflow with low code tools



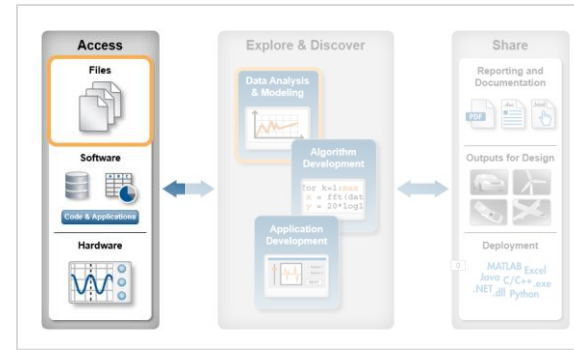
Use low code tools for easy access to files, databases, and hardware

- Import Tool and Import Live Task
 - Text, CSV, and Excel files

- Database Explorer (*Database Toolbox*)
 - ODBC & JDBC SQL Databases

- Measurement hardware and industrial data

- Data acquisition hardware (*Data Acquisition Toolbox*)
- Stand-alone instruments and hardware (*Instrument Control Toolbox*)
- OPC UA and Aveva PI Server, Modbus devices (*Industrial Communication Toolbox*)
- CAN, J1939, and XCP (*Vehicle Network Toolbox*)



Database Explorer

Time	FuelQuantity	OilPressure	OilTemperature	LatitudePos	LongitudePos	Altitude	ExhaustTe...	FuelFlow	FuelSpeed	TrueAirSpe...	WindDirect...	WindSpeed	WeightOn...
02-Jun-200...	8048	0	23.6748	44.8915	-63.5182	174	17.5000	0					
03-Jun-200...	8048	0	23.6748	44.8915	-63.5182	174	17.5000	0					
04-Jun-200...	8048	0	23.6748	44.8915	-63.5182	174	17.5000	0					
05-Jun-200...	8048	0	23.6748	44.8915	-63.5182	175	17.5000	0					
06-Jun-200...	8048	0	23.6748	44.8915	-63.5182	173	17.5000	0					
07-Jun-200...	8048	0	23.6748	44.8915	-63.5191	174	17.5000	0					
08-Jun-200...	8048	0	23.6748	44.8915	-63.5191	174	17.5000	0					
09-Jun-200...	8048	0	23.6748	44.8915	-63.5190	174	17.5000	0					
10-Jun-200...	8048	0	23.6748	44.8915	-63.5190	174	17.5000	0					
11-Jun-200...	8047e+03	0	23.6748	44.8915	-63.5190	174	17.5000	0					
12-Jun-200...	8045	0	23.6748	44.8915	-63.5190	173	17.5000	0					
13-Jun-200...	8.0424e+03	0	23.6748	44.8915	-63.5190	174	17.5000	0					
14-Jun-200...	8040	0	23.6748	44.8915	-63.5190	174	17	0					
15-Jun-200...	8.0379e+03	0	23.6846	44.8915	-63.5190	173	17	0					
16-Jun-200...	8.0333e+03	0	24.3463	44.8915	-63.5190	173	17	0					
17-Jun-200...	8.0333e+03	0	24.8080	44.8915	-63.5190	173	17	0					
18-Jun-200...	8032	0	25.0179	44.8915	-63.5190	174	17	0					
19-Jun-200...	8.0302e+03	0	24.8080	44.8915	-63.5190	172	17	0					
20-Jun-200...	8.0398e+03	0	24.3463	44.8915	-63.5190	173	17	0					
21-Jun-200...	8.0455e+03	0	23.8846	44.8915	-63.5190	174	17	0					
22-Jun-200...	8048	0	23.6748	44.8915	-63.5190	174	17	0					
23-Jun-200...	8.0468e+03	0	23.6748	44.8915	-63.5190	173	17	0					
24-Jun-200...	8.0439e+03	0	23.6748	44.8915	-63.5190	173	17	0					
25-Jun-200...	8.0412e+03	0	23.6748	44.8915	-63.5190	173	17	0					
26-Jun-200...	8040	0	23.6748	44.8915	-63.5190	173	17	0					
27-Jun-200...	8040	0	23.6748	44.8915	-63.5190	174	17	0					
28-Jun-200...	8040	0	23.6748	44.8915	-63.5190	173	17	0					
29-Jun-200...	8040	0	23.6748	44.8915	-63.5190	173	17	0					
30-Jun-200...	8040	0	23.6748	44.8915	-63.5190	173	17	0					
01-Jun-200...	8040	0	23.6748	44.8915	-63.5190	173	17	0					
02-Jun-200...	8040	0	23.6748	44.8915	-63.5190	173	17	0					

SQL Query

```
SELECT inventorytable.productnumber,
inventorytable.quantity,
inventorytable.price,
inventorytable.inventorydate
FROM ( inventorytable
INNER JOIN producttable
ON inventorytable.productnumber = producttable.productnumber)
```

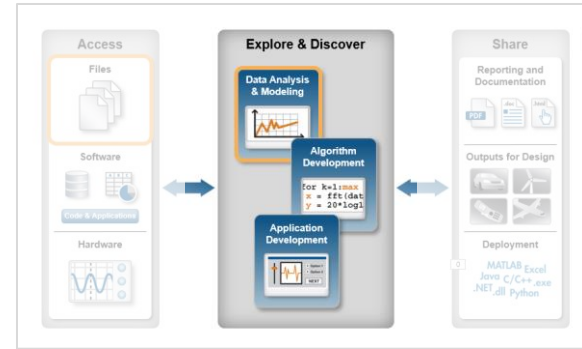
Data Preview (First 10 Rows)

productnumber	quantity	price	inventorydate
9	2339	13	2011-02-09 12:50:59
8	8350	5	2011-06-18 11:45:35
7	6034	16	2014-08-06 08:38:00
2	1200	9	2014-07-08 22:50:45
4	2580	21	2013-06-08 14:24:33
1	1700	14.5000	2014-09-23 09:38:34
5	9000	3	2012-08-14 15:00:25
6	4540	8	2013-12-25 19:45:00
3	356	17	2014-05-14 07:14:28
10	723	24	2012-03-14 13:13:09

Over 100 low code tools for data analysis, engineering, and AI

- Data Analysis

- Visualize, manipulate, and preprocess
- Math, statistics, and optimization



Optimize

Minimize a function with or without constraints

Specify problem type

Objective

Linear

Quadratic

Least squares

Nonlinear

Nonsmooth

Select an objective type to see example functions

Unconstrained

Lower bounds

Upper bounds

Linear inequality

Constraints

Linear equality

Second-order cone

Nonlinear

Integer

Select constraint types to see example formulas

Solver fminsearch - Unconstrained derivative-free nonlinear minimization (recommended) ?

Select problem data

Objective function From file Browse... New... ?

Initial point (x0) select ▼

Specify solver options

Display progress

Text display Final output ▼

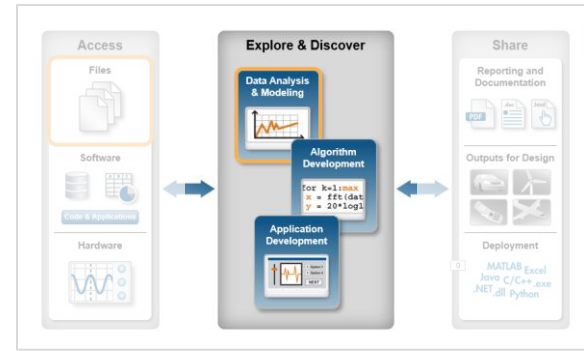
Plot Current point Evaluation count Objective value

Optimize Live Task (Optimization Toolbox)

Over 100 low code tools for data analysis, engineering, and AI

- Data Analysis
 - Visualize, manipulate, and preprocess
 - Math, statistics, and optimization

- Engineering
 - Control system design and analysis
 - Signal processing and communications
 - Image processing and computer vision



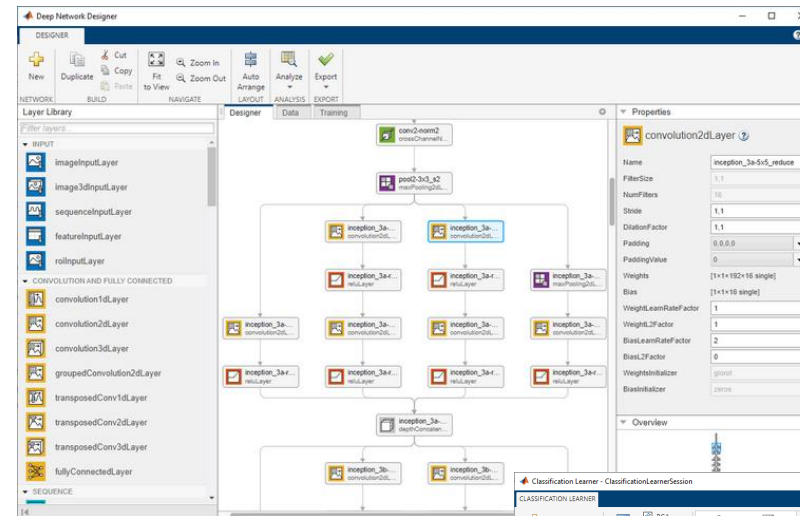
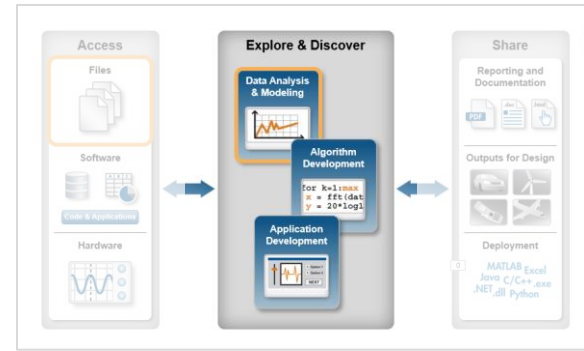
Signal Analyzer (Signal Processing Toolbox)

Over 100 low code tools for data analysis, engineering, and AI

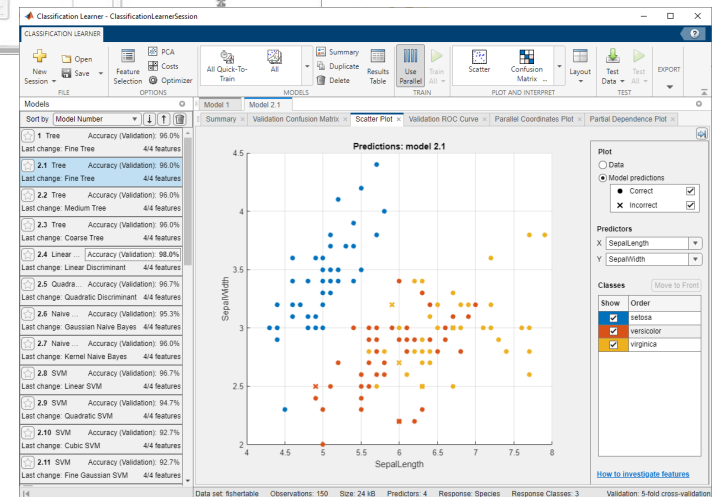
- Data Analysis
 - Visualize, manipulate, and preprocess
 - Math, statistics, and optimization

- Engineering
 - Control system design and analysis
 - Signal processing and communications
 - Image processing and computer vision

- Artificial Intelligence
 - Ground truth labeling
 - Network design, training, and validation
 - Quantization and deployment



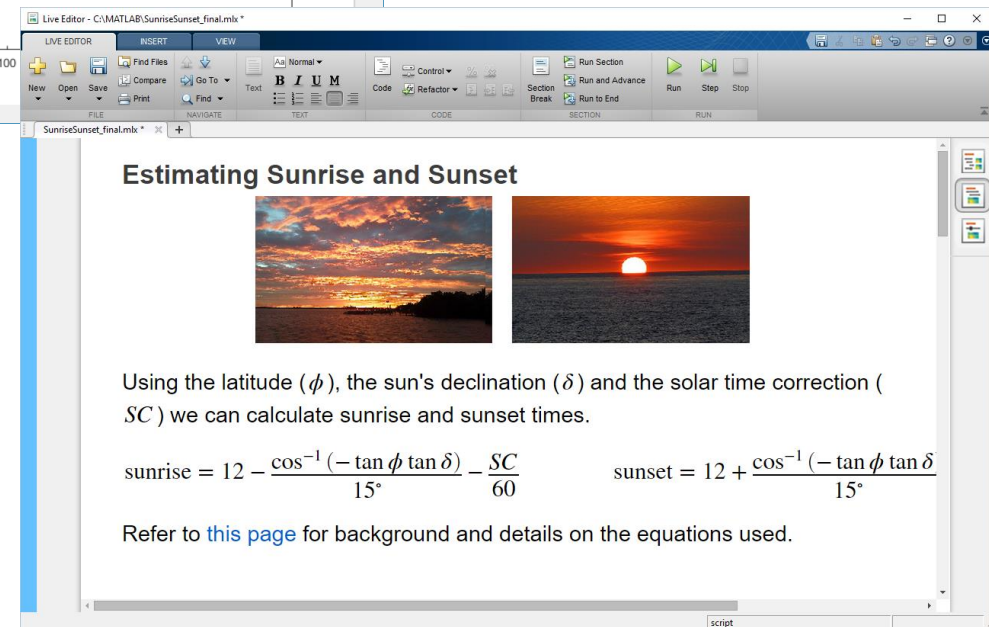
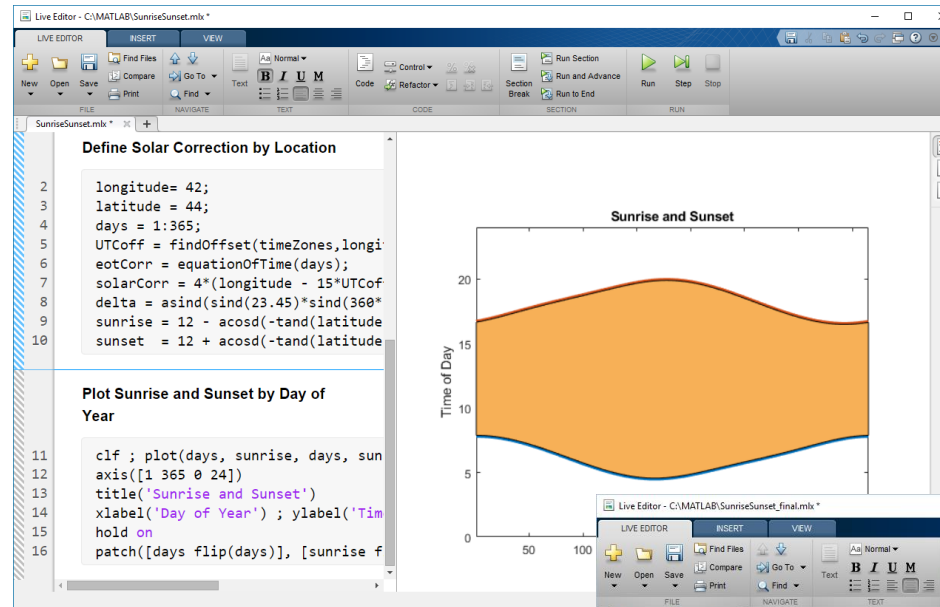
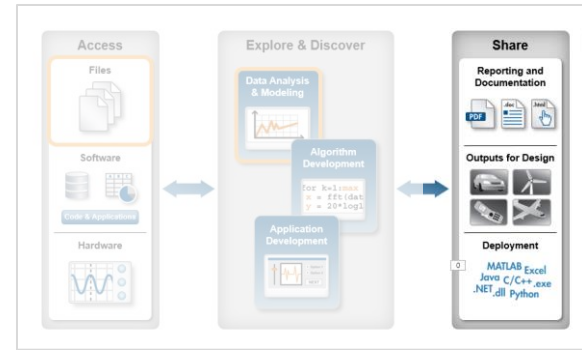
Deep Network Designer (Deep Learning Toolbox)



Classification Learner (Statistics and Machine Learning Toolbox)

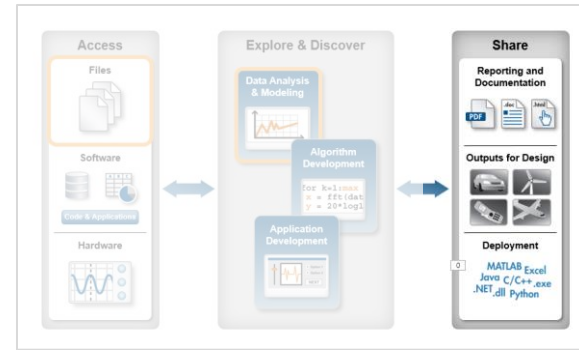
Document as you go – *your script is your report*

- Divide code into sections
- Embed outputs next to the code
- Add rich text formatting, equations, images, and hyperlinks
- Save directly to PDF, HTML, Word, and LaTeX



Deploy and integrate MATLAB code

- Package and deploy MATLAB programs
- Generate code (C, Mex, GPU, HDL)



MATLAB Coder

The MATLAB Coder workflow generates standalone C and C++ code from MATLAB code. To begin, select your entry-point function(s).

Generate code for function:

Finish Workflow

✔ **Source Code Generated Successfully**
You can now use the C code in your applications. [Learn more](#)

Project Summary

Functions: kalmanfilter.m
Project Type: MATLAB Coder
Project File: kalmanfilter.prj

Generated Output

C Code: C:\Work\coderdemodemo_kalman_filter\codegen\lib\kalmanfilter
Example main Files: C:\Work\coderdemodemo_kalman_filter\codegen\lib\kalmanfilter\examples
Reports: Code Generation Report

Start with low code ... and switch to code easily when needed



```
FlightData = sortrows(FlightData, "FuelQuantity", "descend");
FlightData = FlightData(FlightData.FuelQuantity >= 3863,:)
```

Update Code Copy

County General Ho...
 County General Hospital
 VA Hospital
 St. Mary's Medical Center

filename = C:\Work\data1.mat

50 -100 100

2

Interactive Controls

DATA IMPORT

Import Data
Import data from a file

GRAPHICS

Create Plot
Interactively create and explore visualizations

PREPROCESSING DATA

Clean Missing Data
Find, fill, or remove missing data

Clean Outlier Data
Find, fill, or remove outliers

Compute by Group
Summarize, transform, or filter by group

```
% Create plot of FlightData.Time and FlightData.FuelFlow
h2 = plot(FlightData.Time, FlightData.FuelFlow, "DisplayName", "FuelFlow");

% Add xlabel, ylabel, title, and legend
xlabel("Time")
ylabel("FuelFlow")
title("FuelFlow vs. Time")
legend
```

Center and scale data

Preprocess Text Data
Preprocess and clean up text data

Smooth Data
Smooth noisy data

TABLES AND TIMETABLES

Join Tables
Combine two tables using key variables

Retime Timetable
Resample or aggregate timetable

Stack Table Variables
Combine values from multiple tables

Synchronize Timetables
Retime and combine timetables

Unstack Table Variables
Distribute values from one table

Live Tasks

untitled2*

```
function [trainedClassifier, validationAccuracy] = trainClassifier(trainingData, responseData)
% [trainedClassifier, validationAccuracy] = trainClassifier(trainingData,
% responseData)
% Returns a trained classifier and its accuracy. This code recreates the
% classification model trained in Classification Learner app. Use the
% generated code to automate training the same model with new data, or to
% learn how to programmatically train models.
%
% Input:
% trainingData: A matrix with the same number of columns and data type
% as the matrix imported into the app.
%
% responseData: A vector with the same data type as the vector
% imported into the app. The length of responseData and the number of
% rows of trainingData must be equal.
%
% Output:
% trainedClassifier: A struct containing the trained classifier. The
% struct contains various fields with information about the trained
% classifier.
%
% trainedClassifier.predictFcn: A function to make predictions on new
% data.
%
% validationAccuracy: A double representing the validation accuracy as
% a percentage. In the app, the Models pane displays the validation
% accuracy for each model.
%
% Auto-generated by MATLAB

% Extract predictors and response
inputTable = array2table(trainingData, 'VariableNames', {'column_1', 'column_2', 'column_3', 'column_4', 'column_5'});

predictorNames = {'column_1', 'column_2', 'column_3', 'column_4', 'column_5'};
predictors = inputTable(:, predictorNames);
response = responseData;
isCategoricalPredictor = [false, false, false, false, false];
classNames = {'Female'; 'Male'};

% Train a classifier
% This code specifies all the classifier options and trains the classifier.
classificationTree = fitctree(...
predictors, ...
response, ...
'splitCriterion', 'gdi', ...
'MaxNumSplits', 100, ...
'Surrogate', 'off', ...
'classNames', classNames);

% Create the result struct with predict function
predictorExtFunction = @(x) array2table(x, ...);
```

Apps

MATLAB EXPO

Thank you



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