Developing Measurement and Analysis System using MATLAB

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MathWorks Korea

Agenda

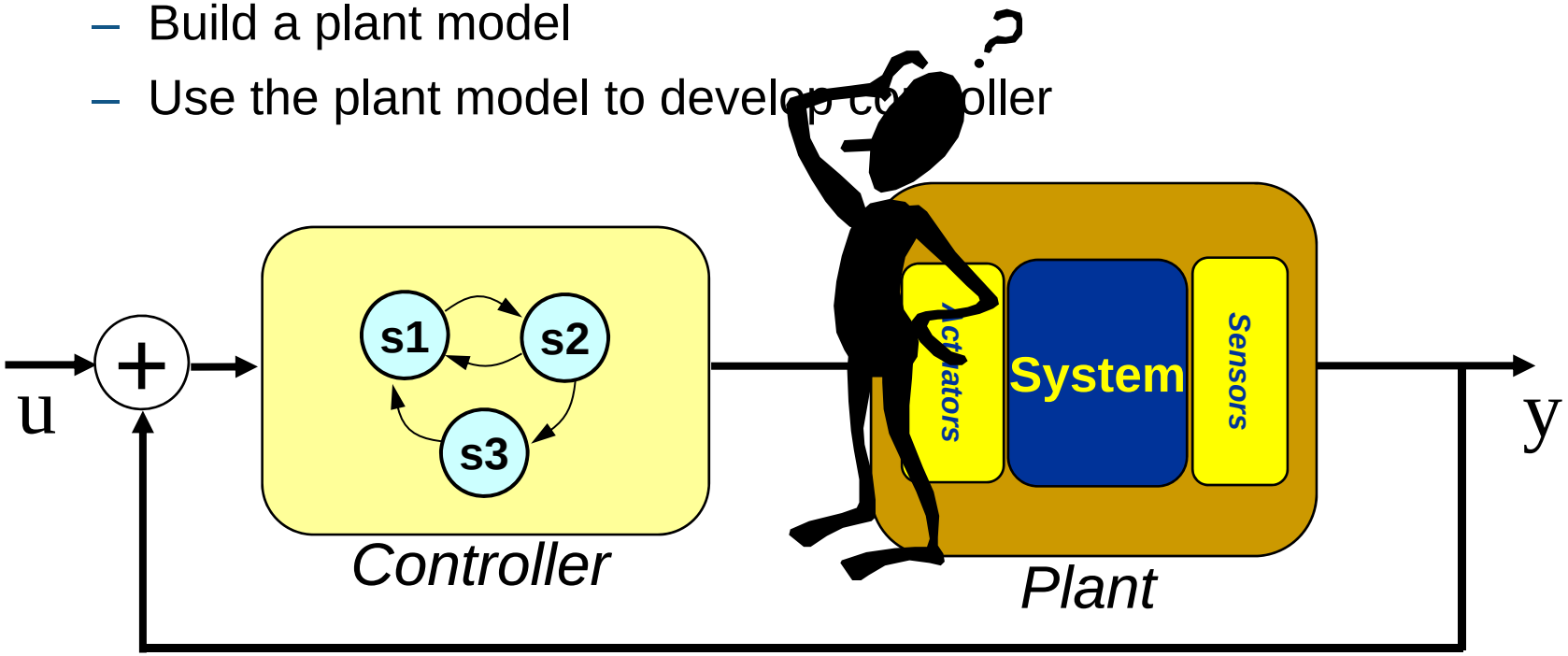
- Great Demo : Battery test demo
- Overview of data acquisition capabilities from MATLAB
- Simple examples
- Acquiring data from stand alone application
  - MATLAB Compiler
- Summary
- Q&A

Realistic Example of T&M System.

Battery Testing Demo

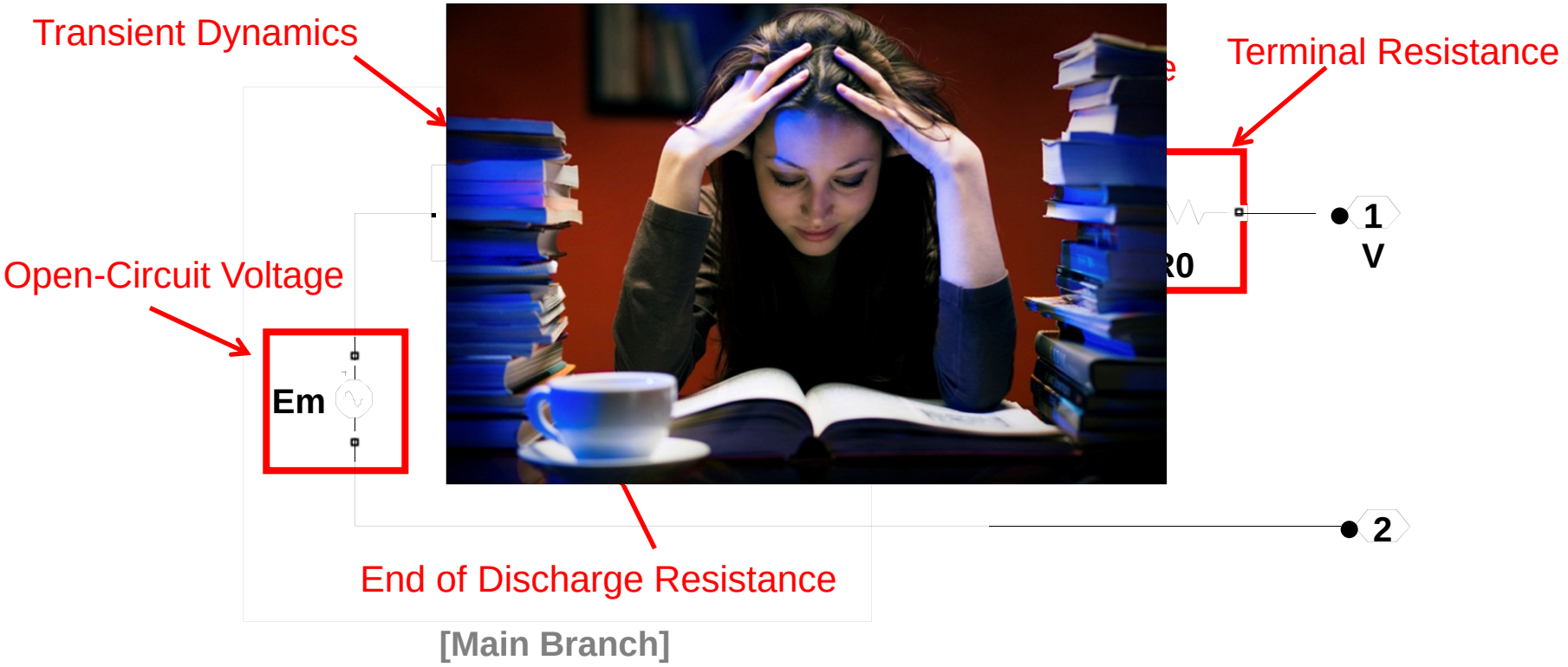
Control Algorithm Development

- What do I do first?
  - Understand the plant behavior.
- How can I do that?
  - Build a plant model
  - Use the plant model to develop controller

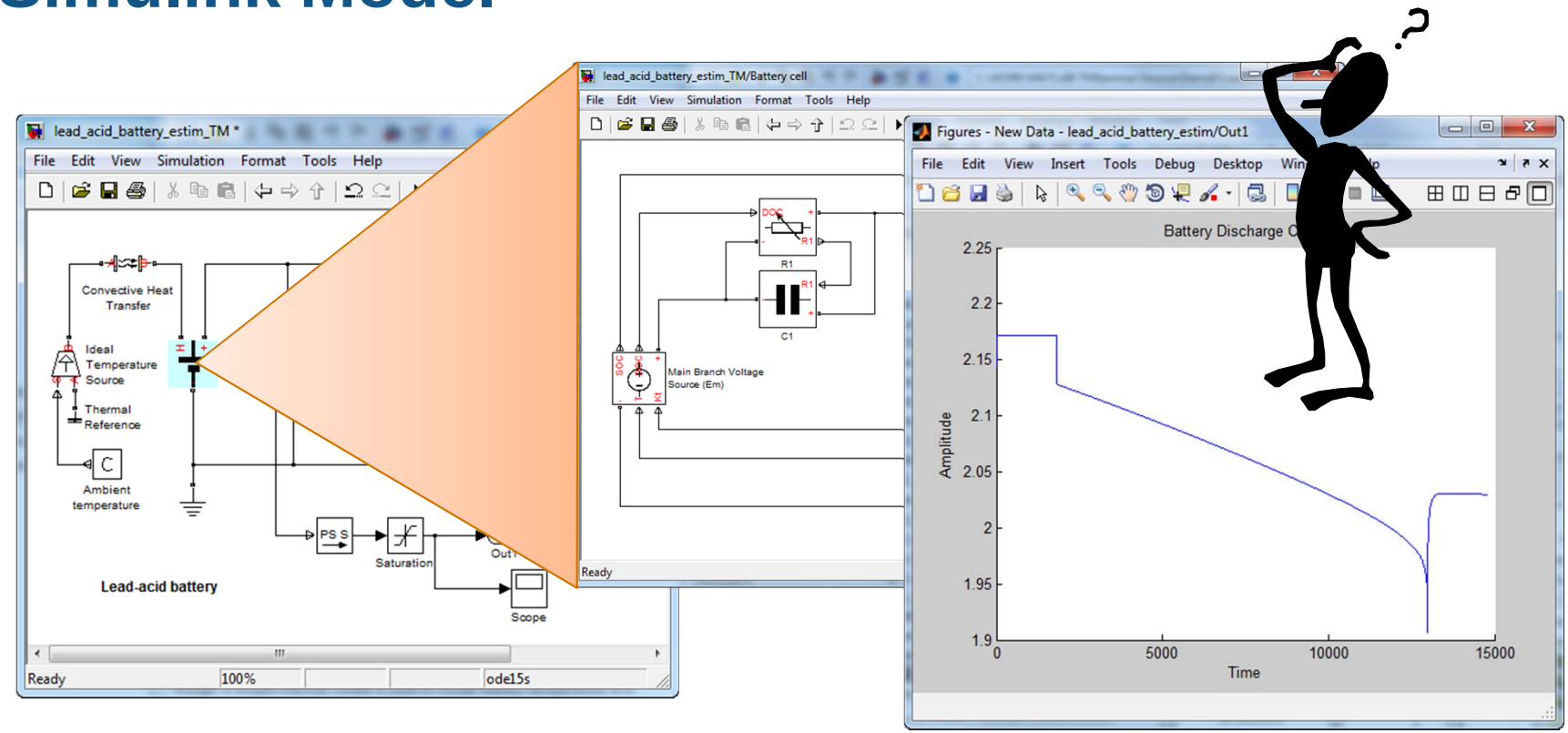


Battery Equivalent Circuit

$R_x = f(SOC, Current, Voltage, Temperature)$



Simulink Model



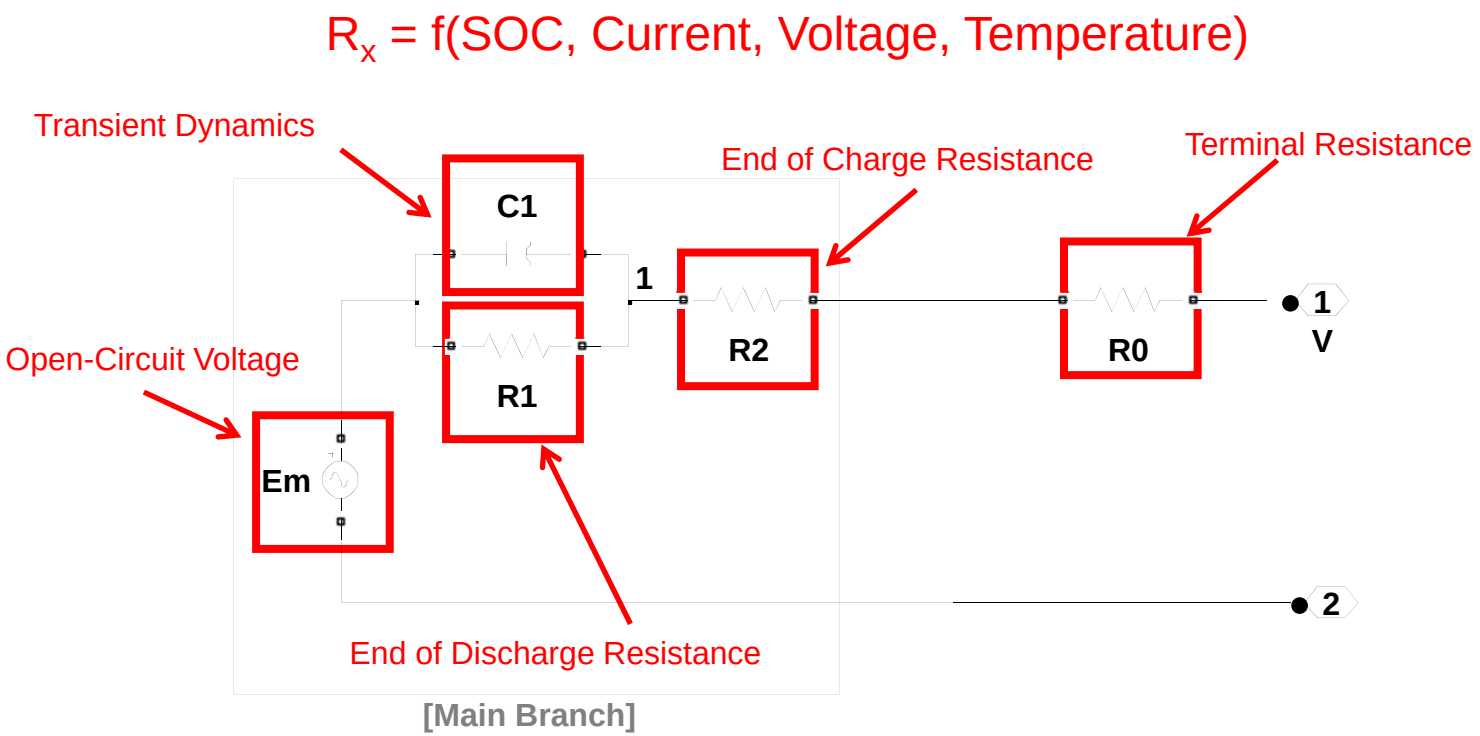
OR

OR

What did I just modeled?

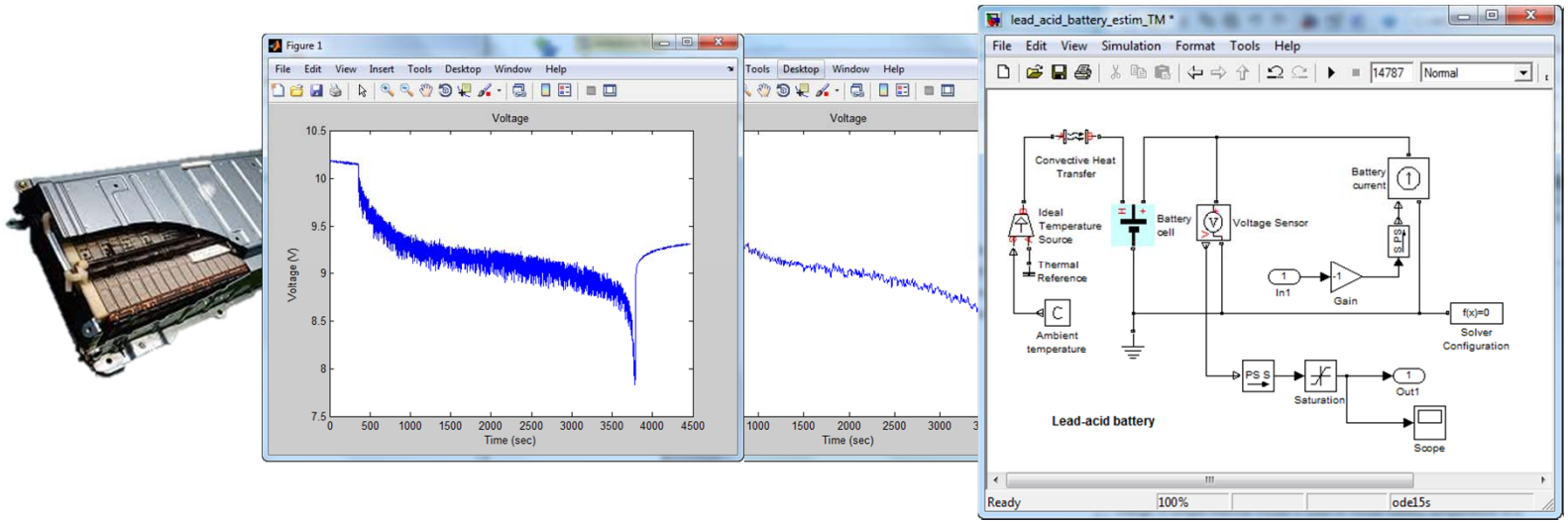
Model Correlation

- Every model needs to be correlated against real ***data***.

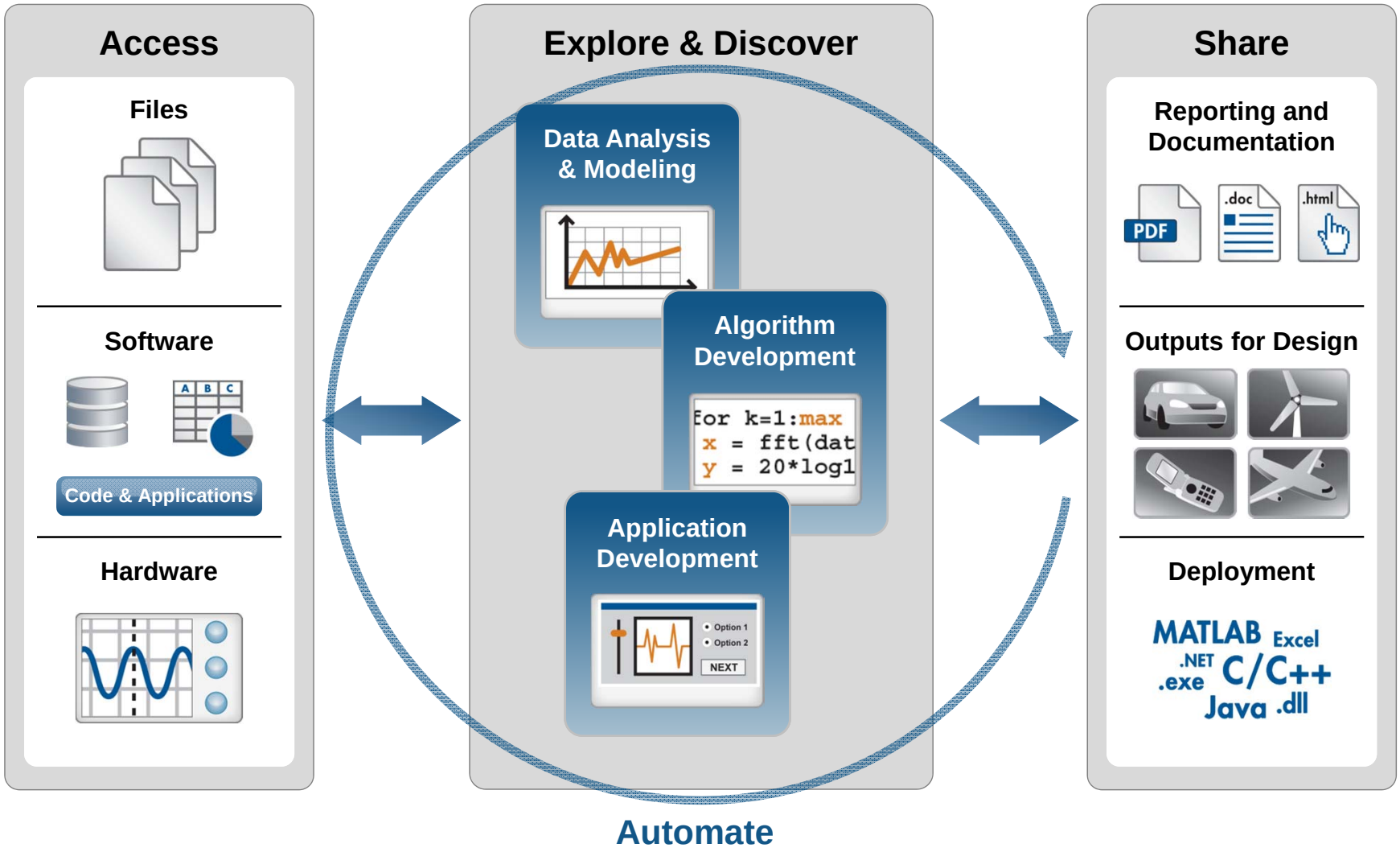


What is Model Correlation?

- A form of Data Analysis
  - Take raw data
  - Transform it into applicable form
  - Apply it to make engineering decision



Data Analysis Tasks



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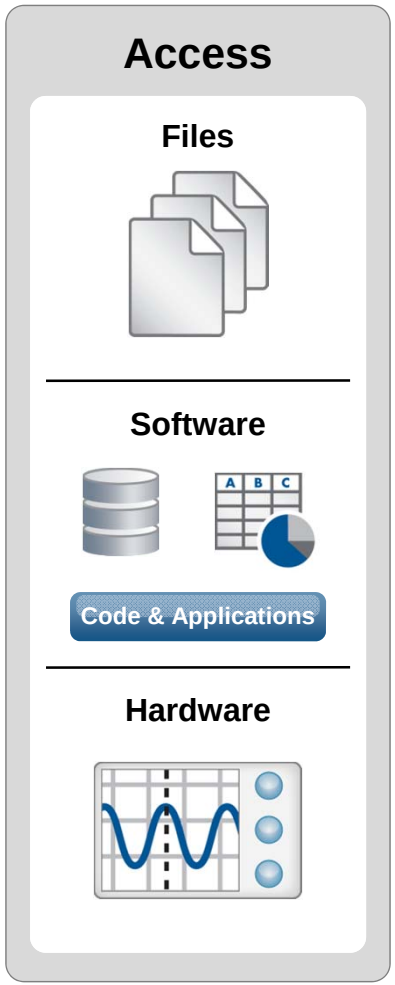
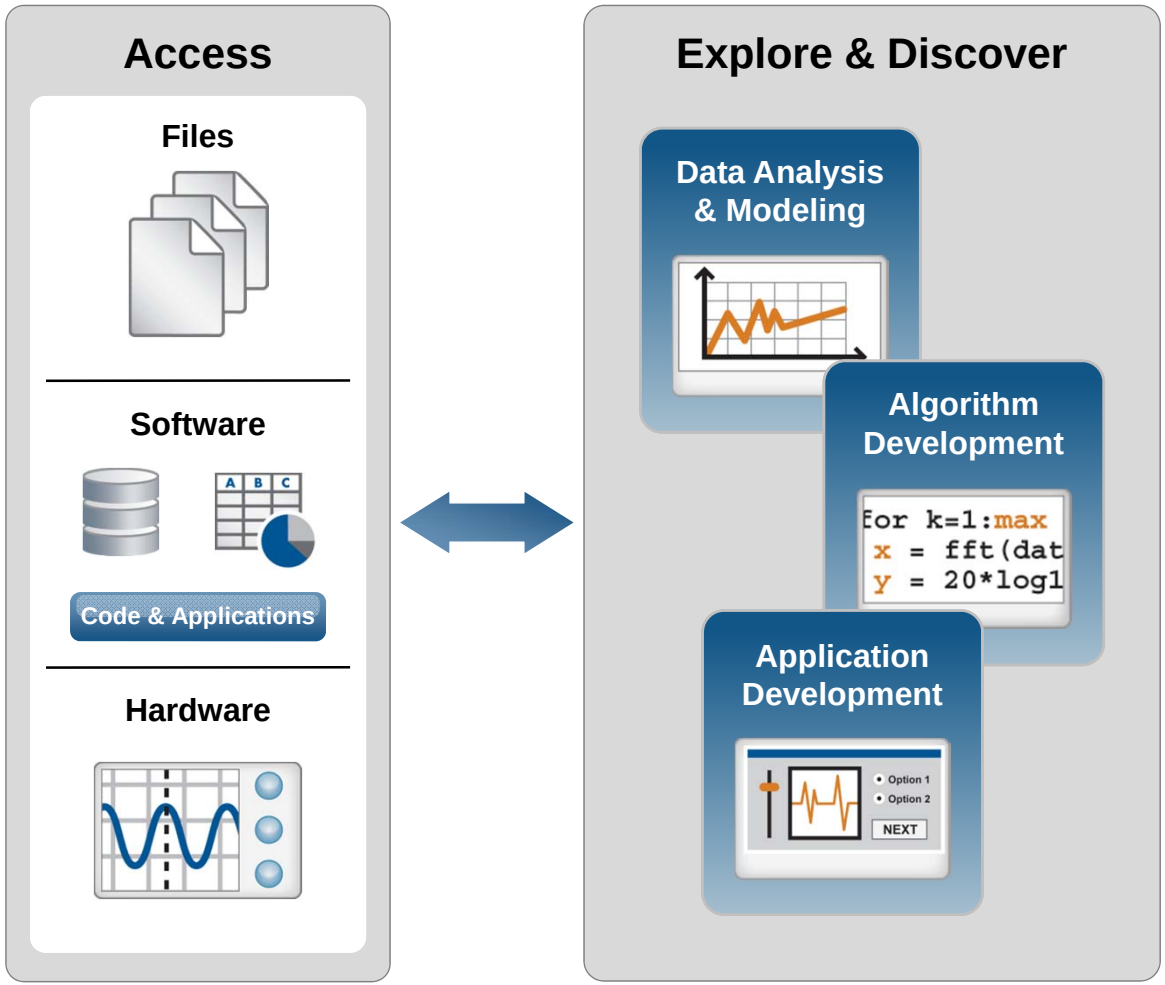


- Access
  - Bring data into MATLAB
    - Test and Measurement Toolbox
    - Vehicle Network Toolbox
  - Ensure data integrity ***during*** data collection
    - Voltage threshold
    - CAN dropout

Data Analysis Tasks



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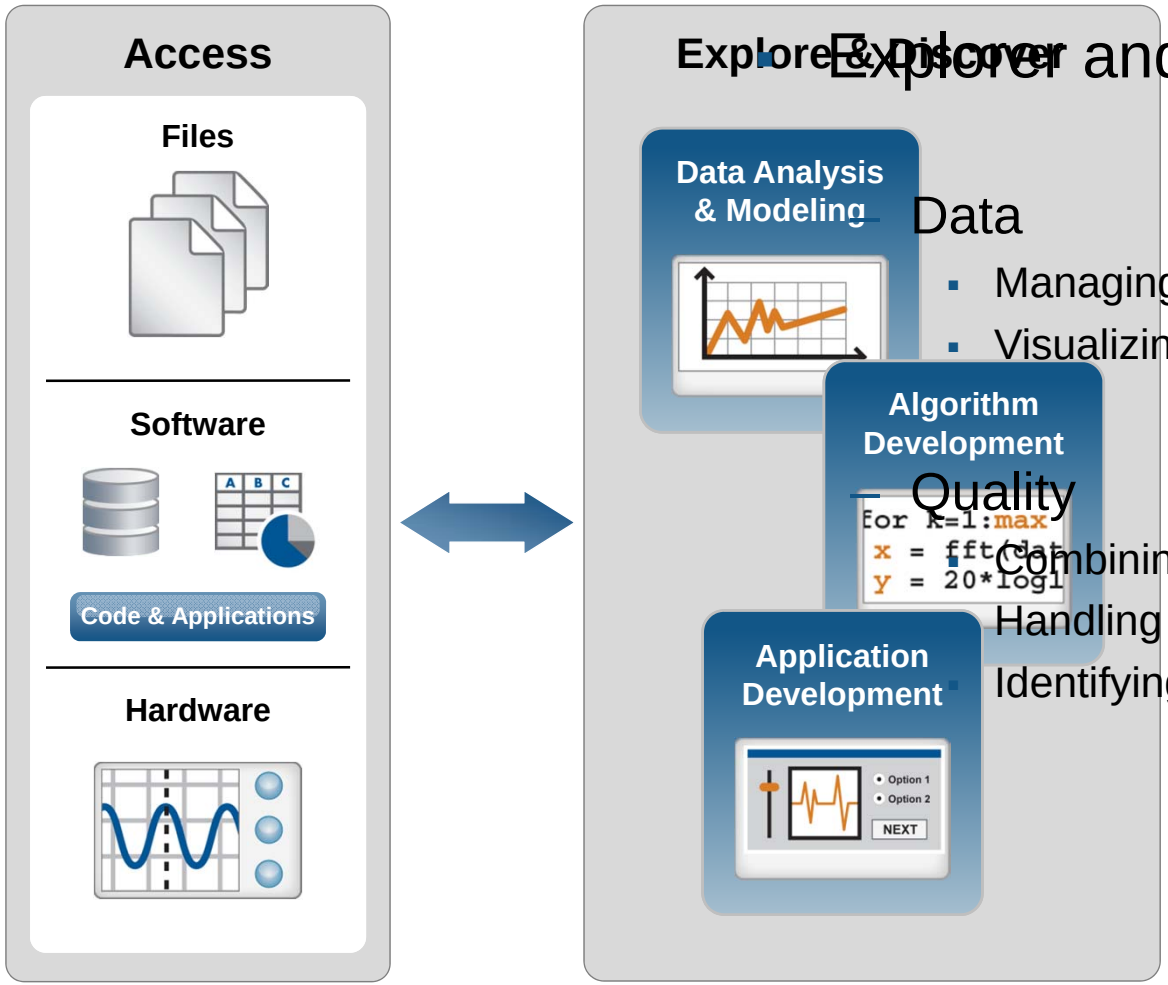


Explore and Discover

Data

- Managing heterogeneous data
- Visualizing

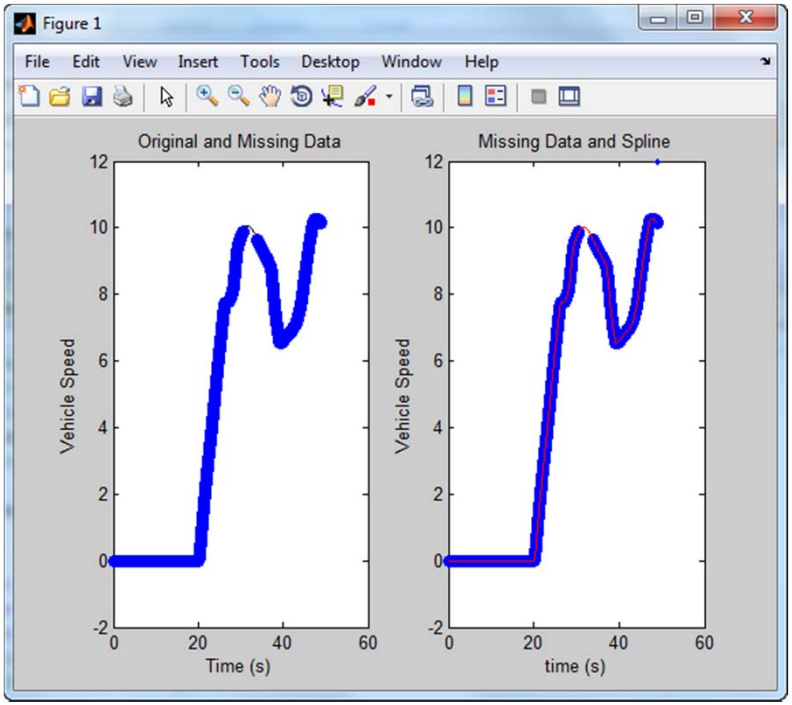
Quality

- Combining different sampling rates
- Handling missing data
- Identifying bad data (outliers)

Demo: Pre-Processing of Test Data

- Goal:
  - Prepare data for further analysis

- Approach:
  - Load data from files
  - Combine different sampling rates to unified time scale
  - Handle missing data
  - Identify outliers



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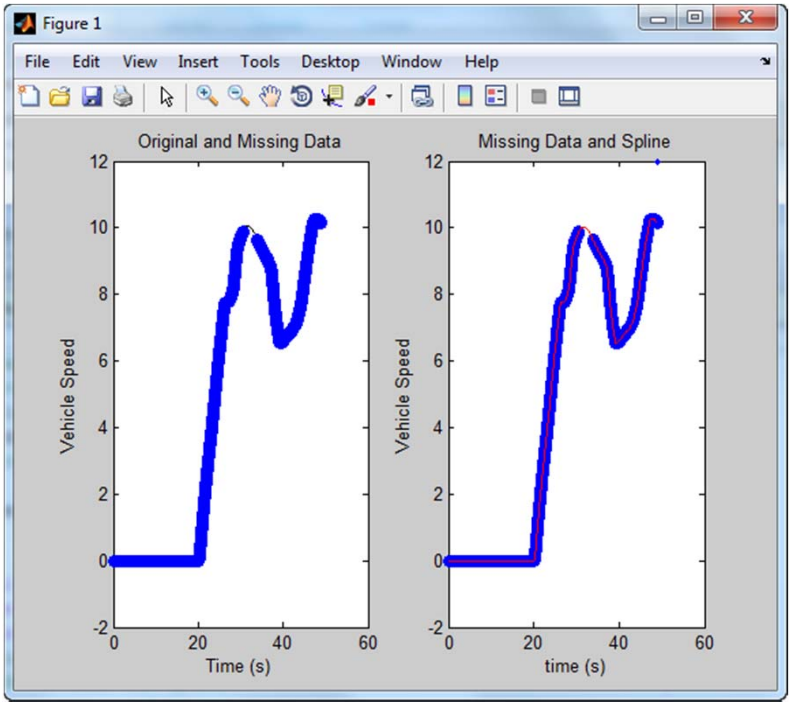
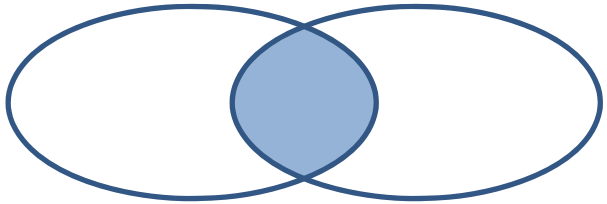
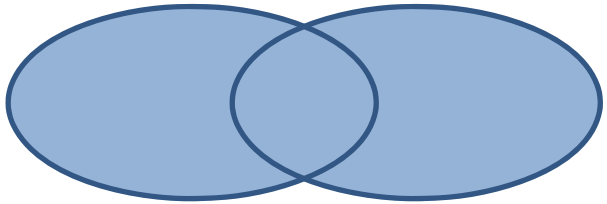


Joins for Datasets

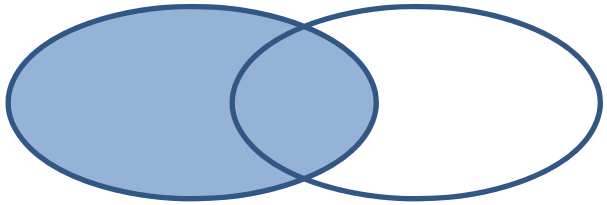
- Merge datasets together
- Popular Joins:
  - Inner
  - Full Outer
  - Left Outer
  - Right Outer



Inner Join

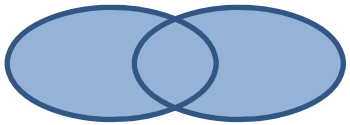


Full Outer Join



Left Outer Join

Full Outer Join



Key	B
1	1.1
4	1.4
7	1.7
9	1.9

First Data Set

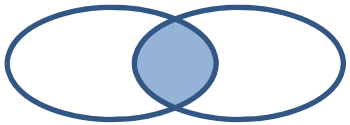
Key	Y	Z
1	0.1	0.2
3	0.3	0.4
5	0.5	0.6
7	0.7	0.8

Second Data Set

Key	B	Y	Z
1	1.1	0.1	0.2
3	NaN	0.3	0.4
4	1.4	NaN	NaN
5	NaN	0.5	0.6
7	1.7	0.7	0.8
9	1.9	NaN	NaN

Joined Data Set

Inner Join



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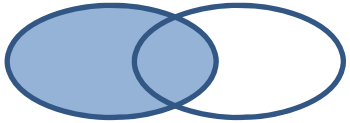

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Joined Data Set

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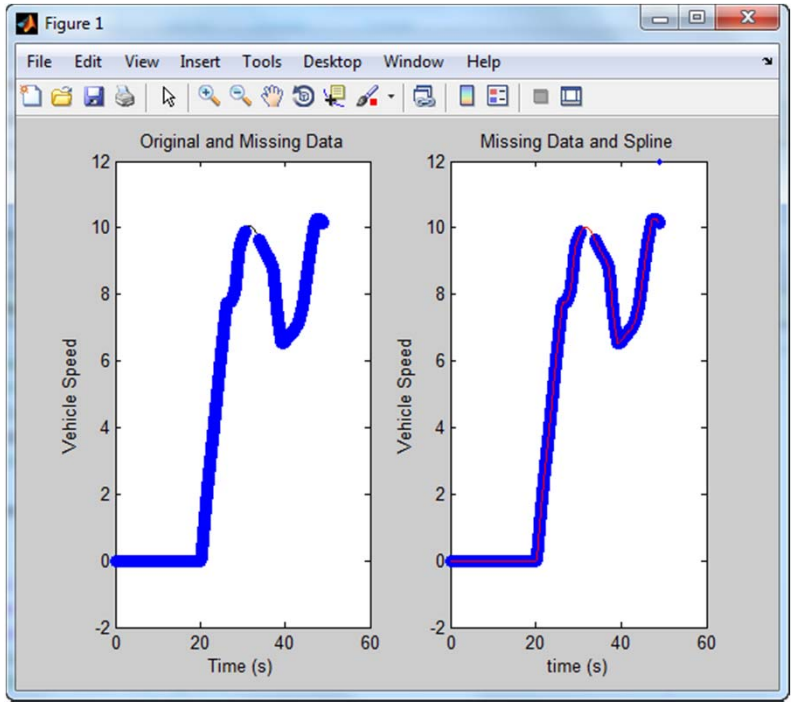
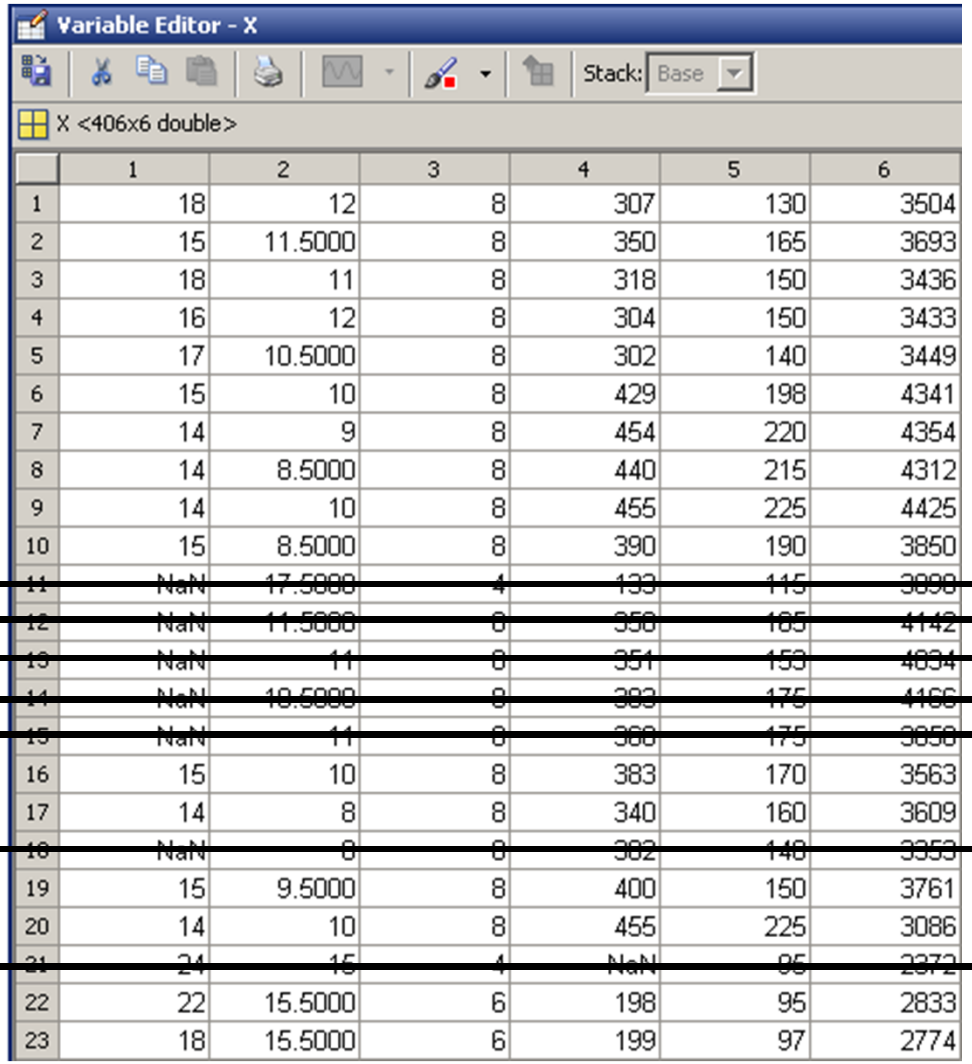
  - Handle missing data
  - Identify outliers



Techniques to Handle Missing Data

- List-wise deletion
  - Unbiased estimates (assuming that the data is MCAR)
  - Reduces sample size
  - Loss of power
- Implementation options
  - Listwise deletion is built in to many MATLAB functions
  - Manual filtering



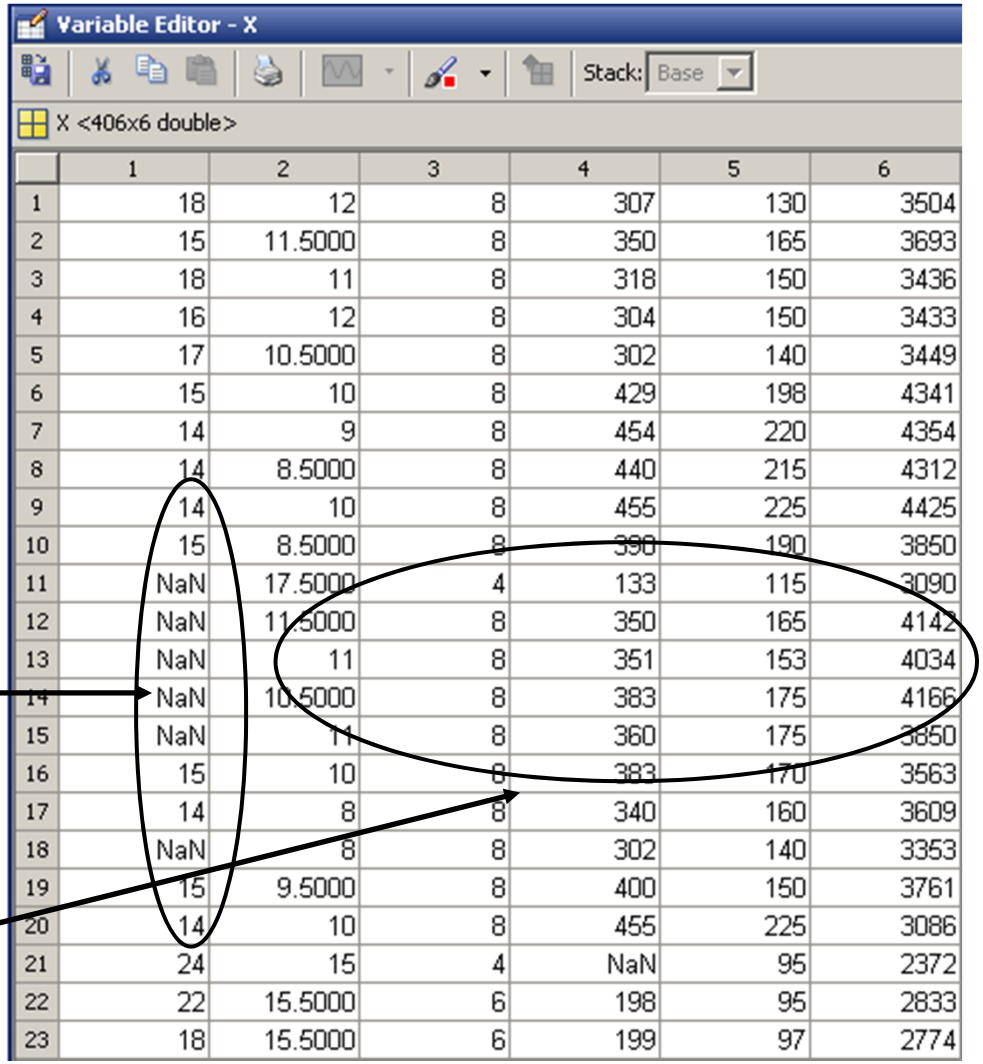
	1	2	3	4	5	6
1	18	12	8	307	130	3504
2	15	11.5000	8	350	165	3693
3	18	11	8	318	150	3436
4	16	12	8	304	150	3433
5	17	10.5000	8	302	140	3449
6	15	10	8	429	198	4341
7	14	9	8	454	220	4354
8	14	8.5000	8	440	215	4312
9	14	10	8	455	225	4425
10	15	8.5000	8	390	190	3850
11	NaN	17.5000	4	133	115	3090
12	NaN	11.5000	8	350	165	4142
13	NaN	11	8	351	153	4034
14	NaN	10.5000	8	383	175	4166
15	NaN	11	8	360	175	3850
16	15	10	8	383	170	3563
17	14	8	8	340	160	3609
18	NaN	8	8	302	140	3353
19	15	9.5000	8	400	150	3761
20	14	10	8	455	225	3086
21	24	15	4	NaN	95	2372
22	22	15.5000	6	198	95	2833
23	18	15.5000	6	199	97	2774

Techniques to Handle Missing Data

- Substitution - Replace missing data points with a reasonable approximation

Easy to model

Too important to exclude



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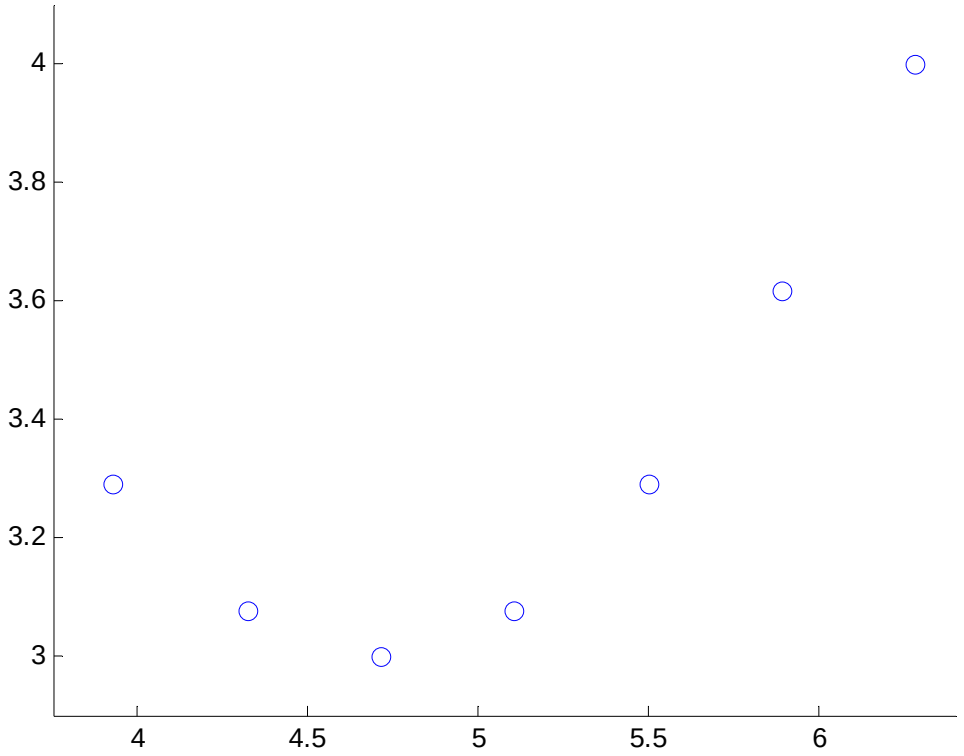
Techniques to handle missing data

- Substitution: Replace the missing data point with something reasonable
- Enables other types of analysis
- Error estimates will be biased



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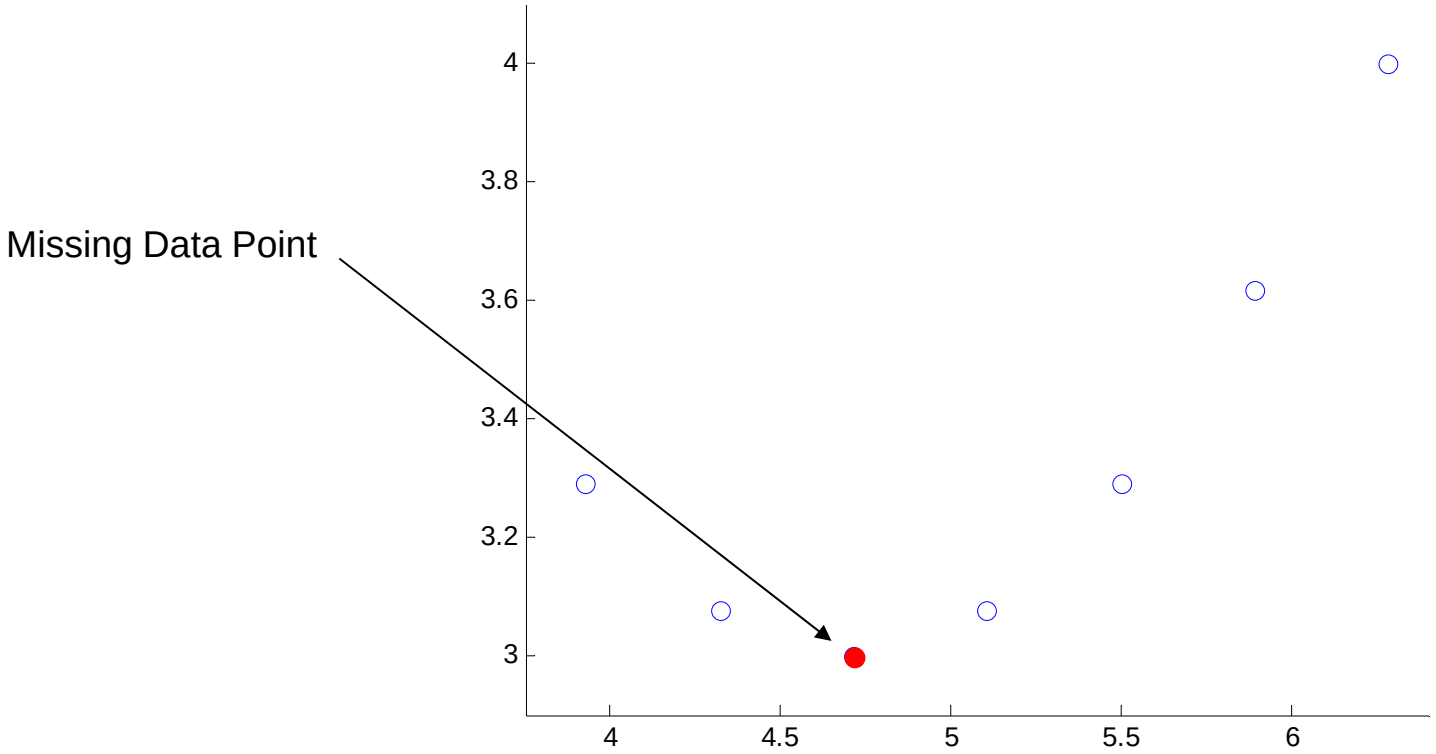

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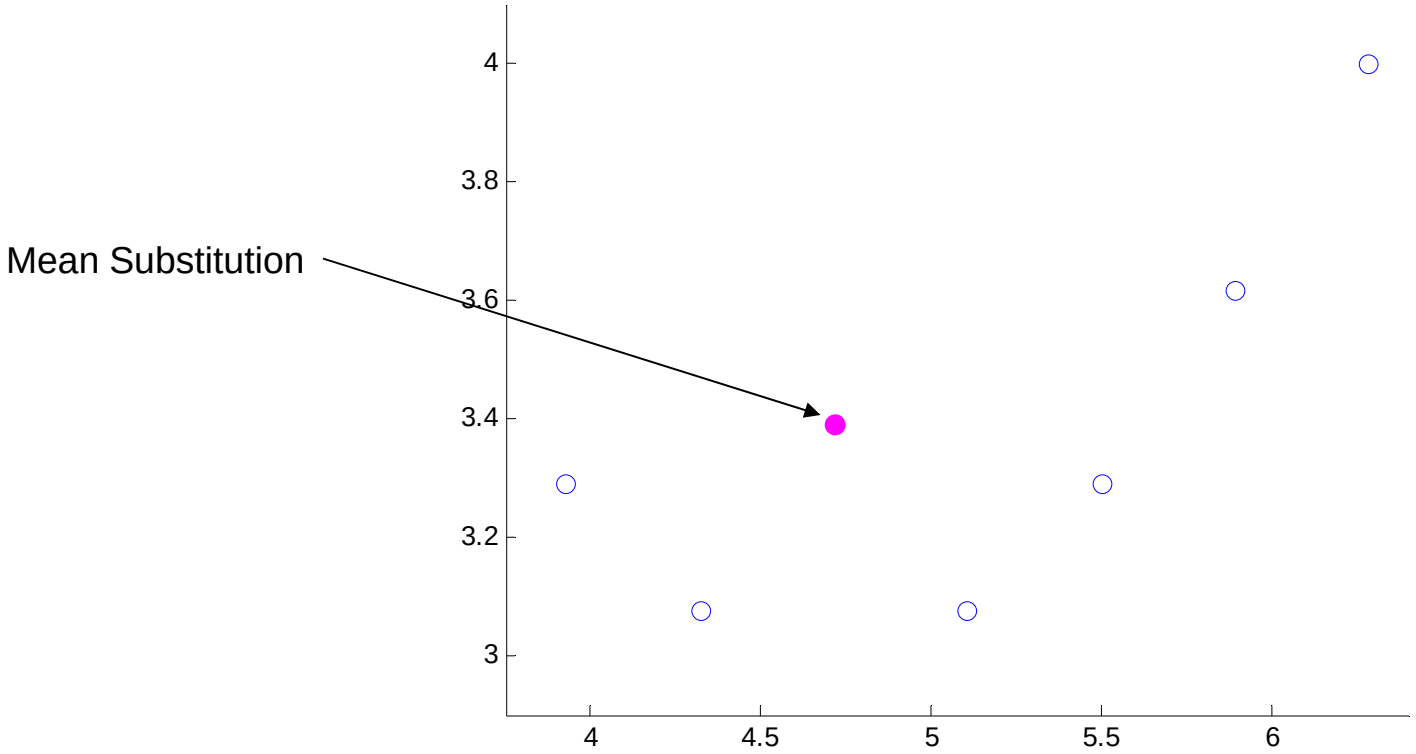

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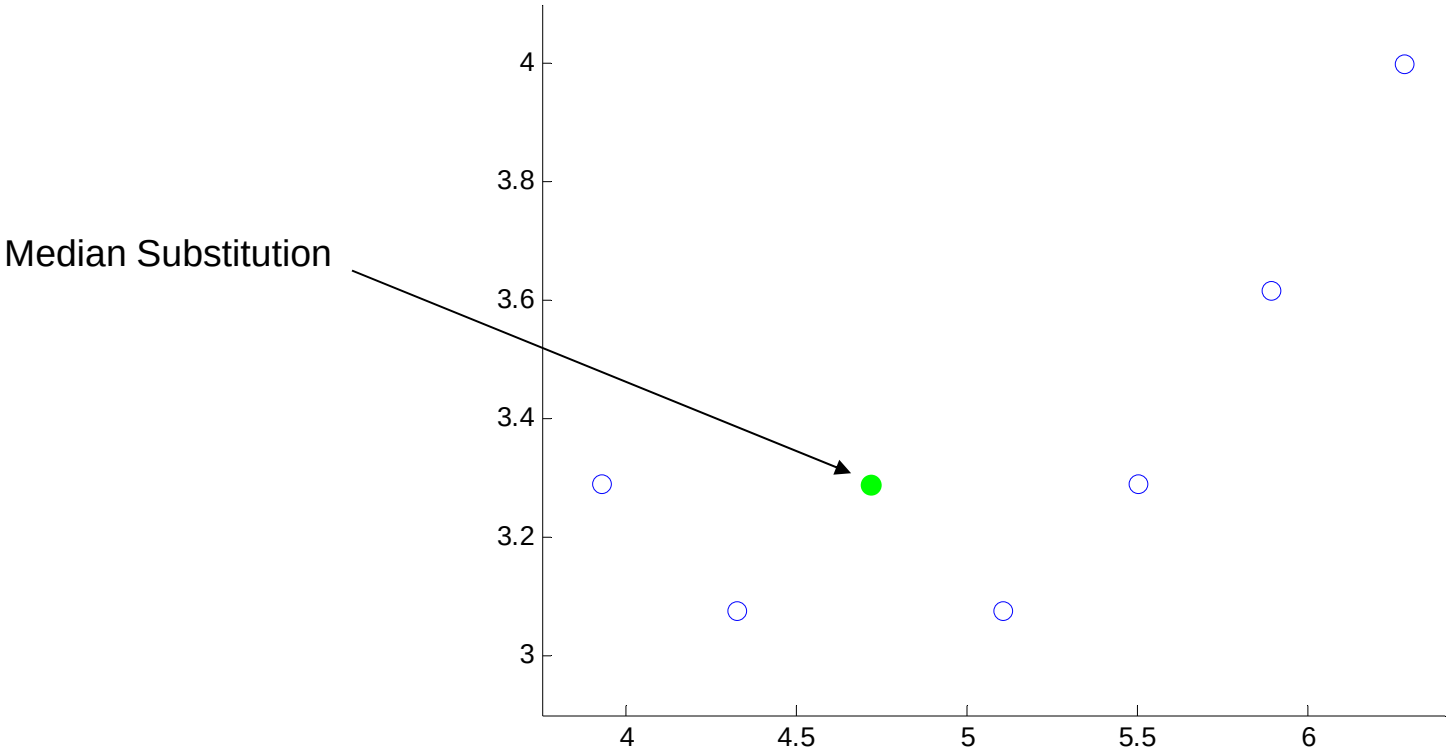

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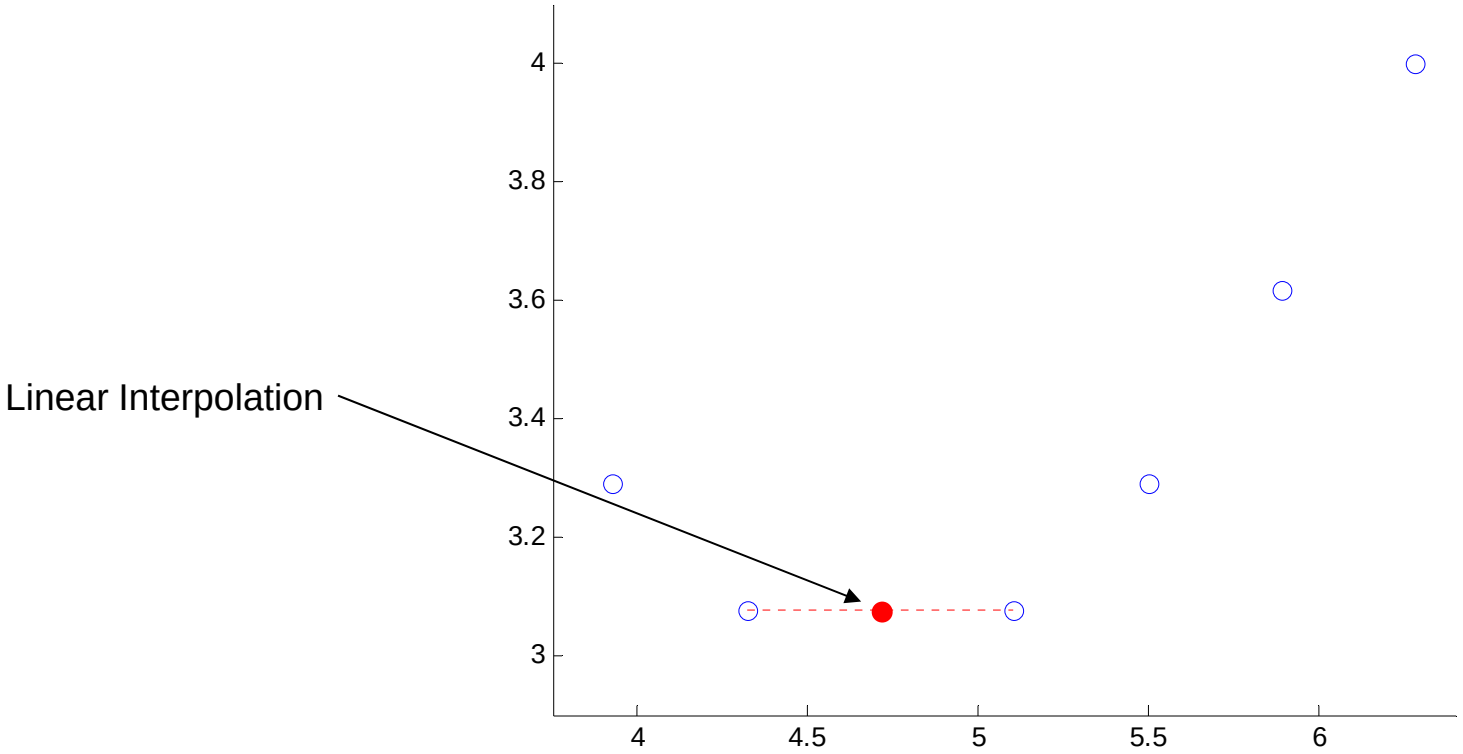

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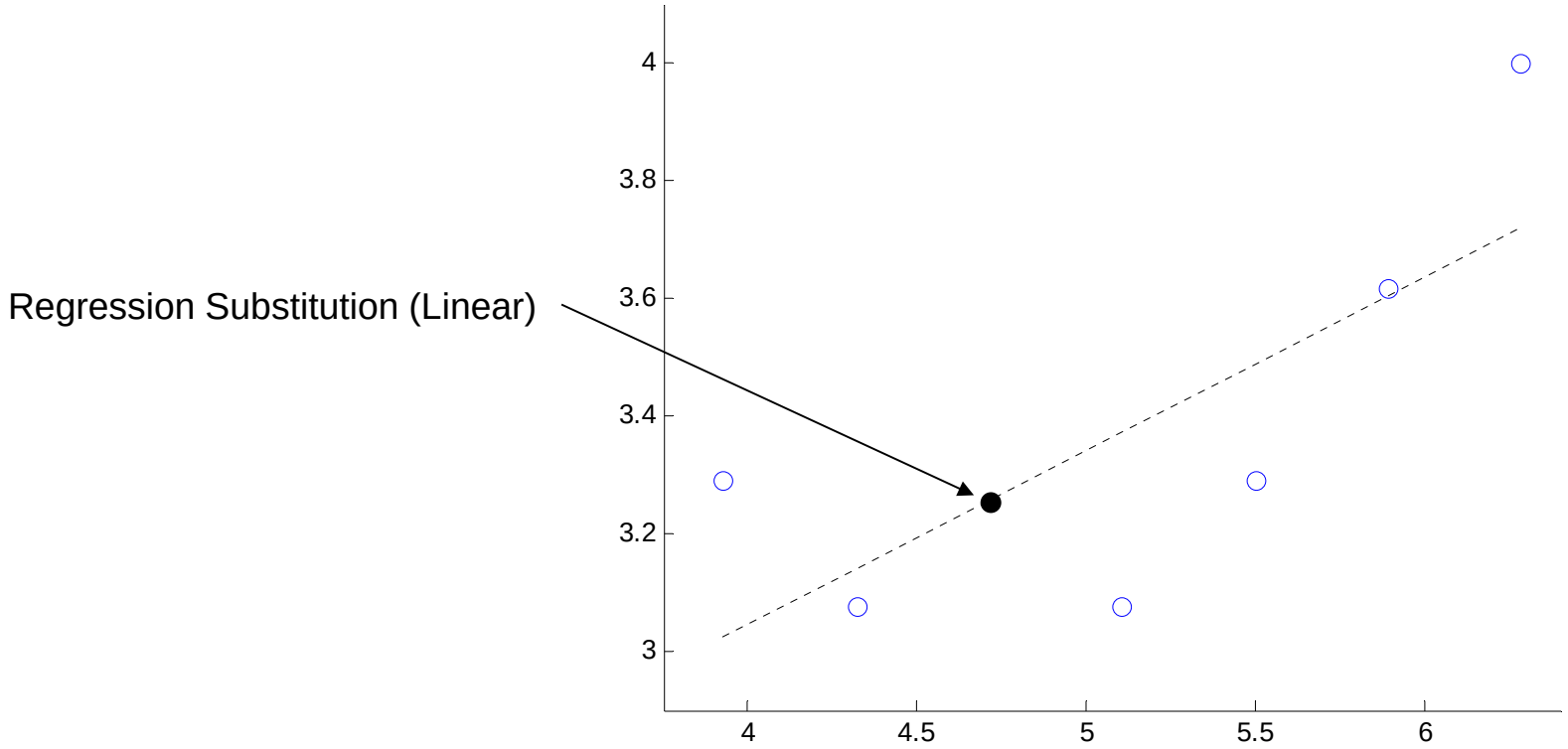
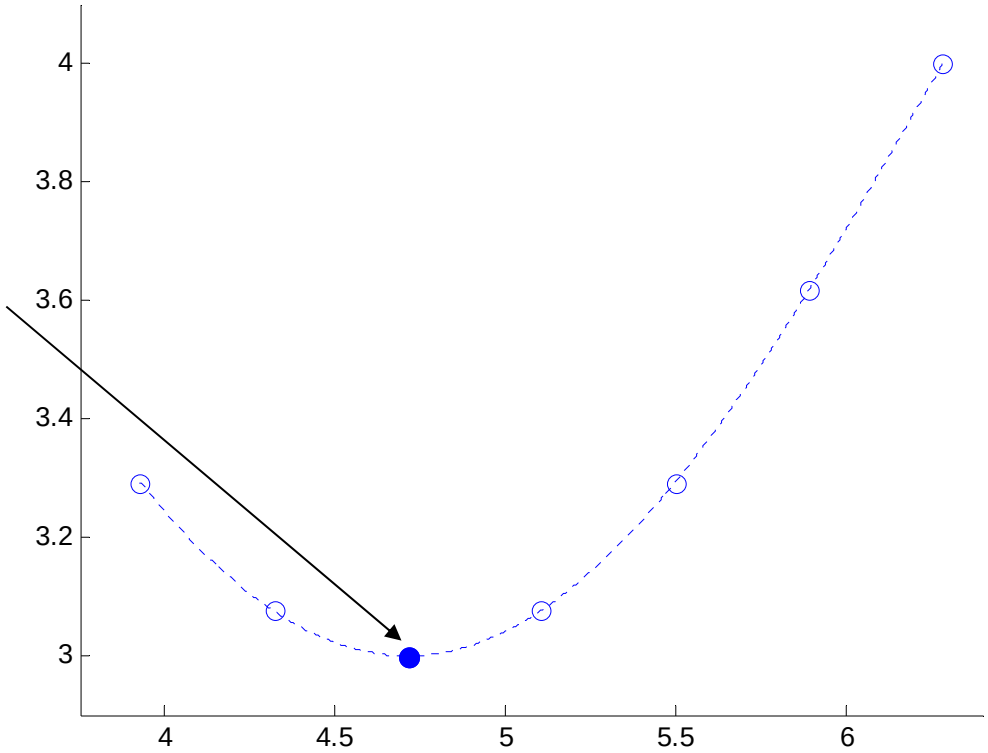


Techniques to handle missing data

- Substitution: Replace the missing data point with something reasonable

More complicated model
- Nonlinear regression
- Smoothing spline
- Localized regression
- …



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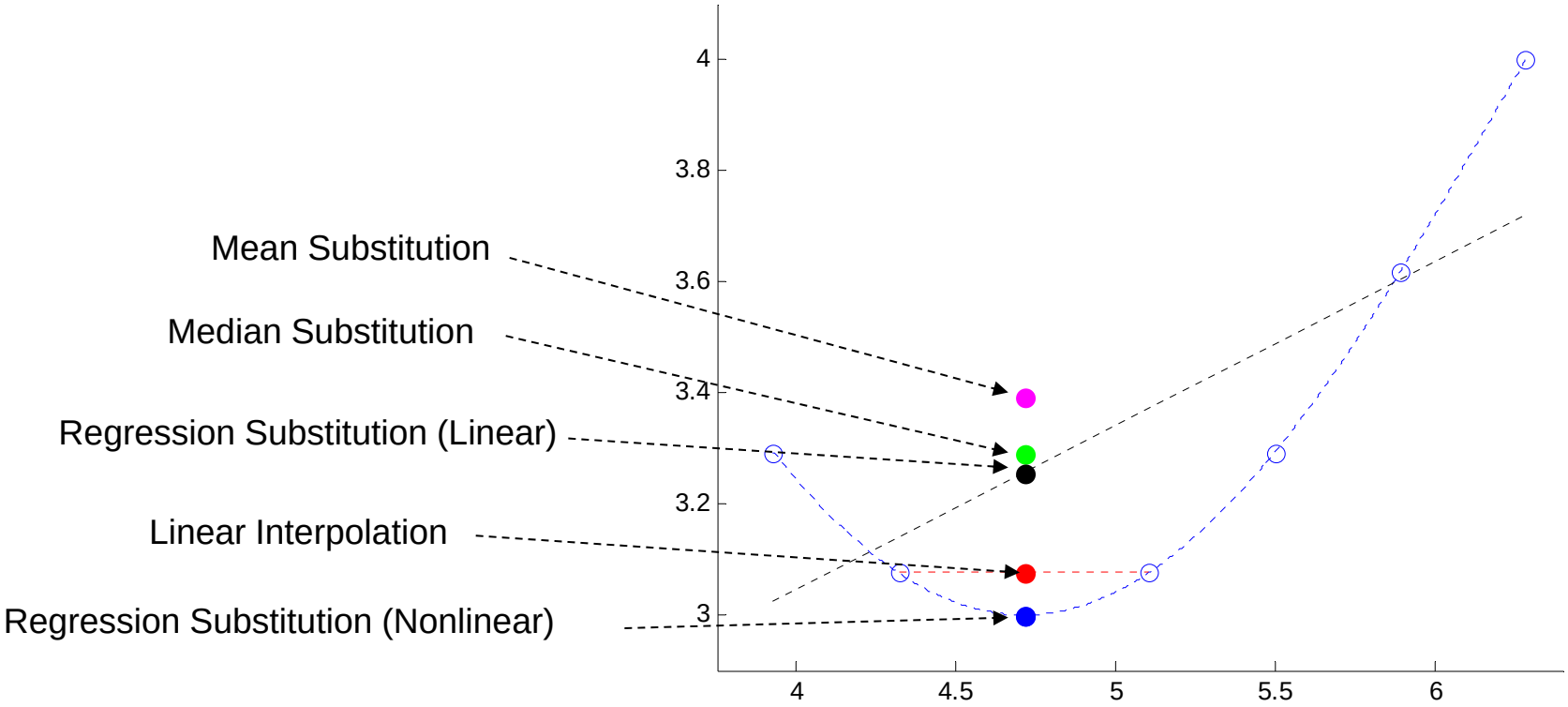

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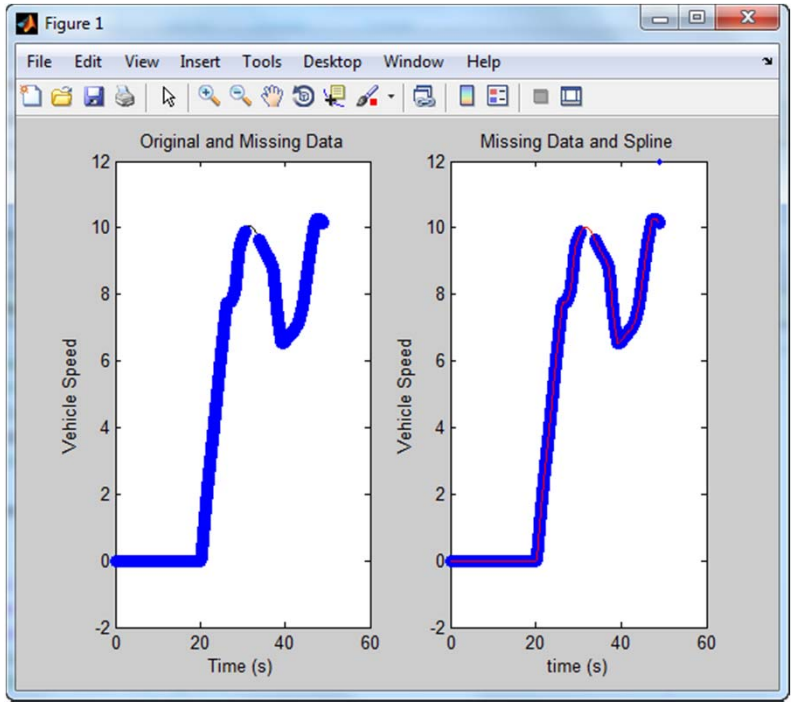
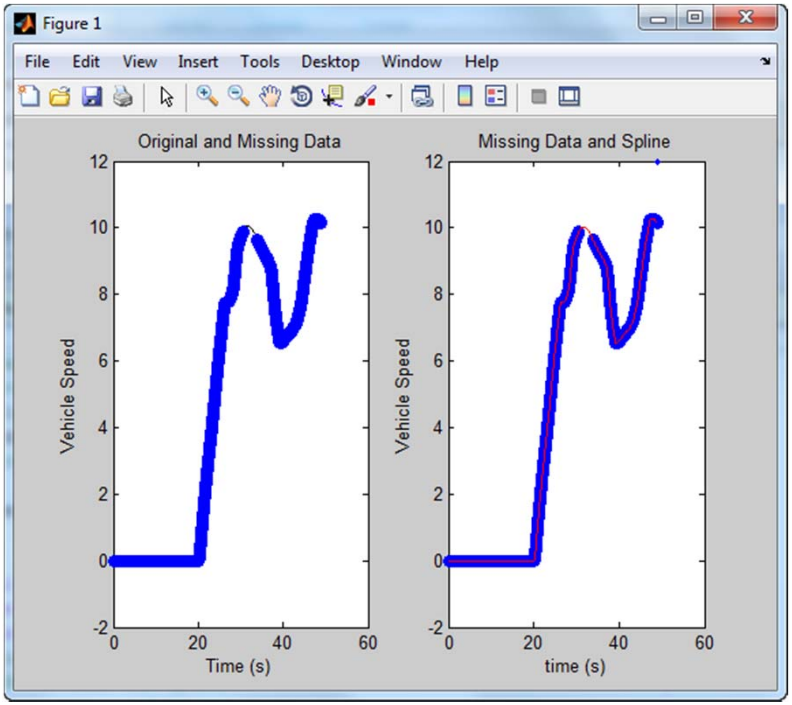
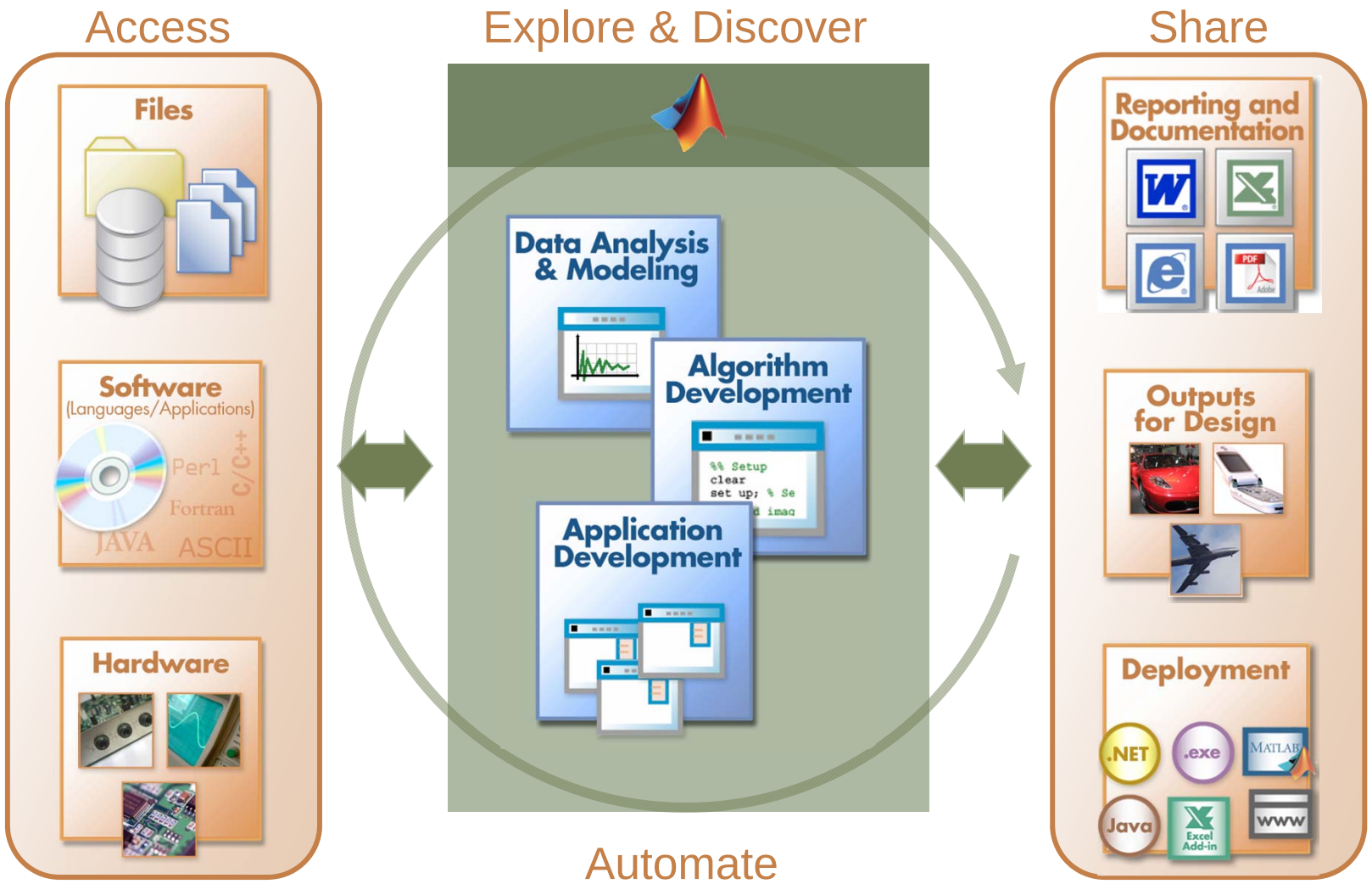


Demo: Pre-Processing of Test Data Summary

- Managed data with dataset array
- Merged dataset arrays with join
- Resampled data with fit objects and filled in missing values
- Identified outliers using statistical analysis



Technical Computing Workflow



MATLAB Connects to Your Hardware

Data Acquisition Toolbox
Plug in data acquisition boards and modules

Instrument Control Toolbox
Instruments and RS-232 devices

Image Acquisition Toolbox™
Image capture devices

Vehicle Network Toolbox
CAN bus interface devices

MATLAB
Interfaces for communicating with everything

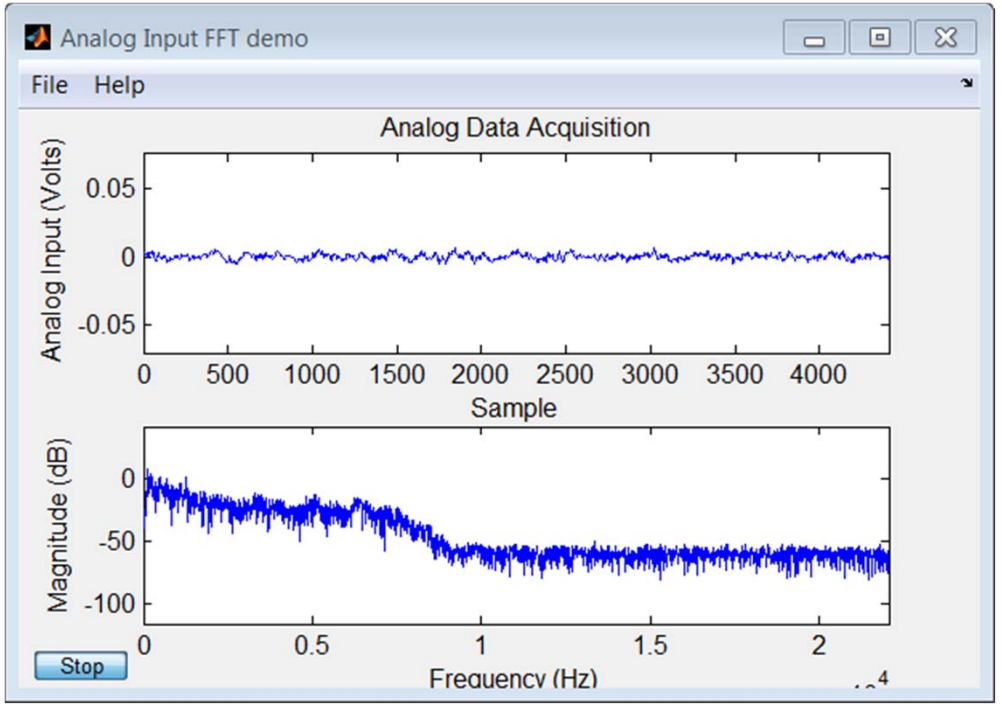
Data Acquisition Toolbox™: Supported Hardware

- Agilent Technologies
- Keithley
  - ISA, PCI, PCMCIA
- Measurement Computing Corporation
  - USB, PC/104, ISA, PCMCIA, Parallel port
- National Instruments
  - Hardware supported by NI-DAQ, NI-DAQmx drivers over AT, PCI, PCI Express, FireWire, PXI, SCXI, PCMCIA, parallel port, USB, CompactDAQ
- **Any Windows compatible sound cards (AI, AO)**
- IOtech
  - DaqBoard, DaqBook, DaqLab, DaqScan, Personal Daq/3000, and WaveBook Series
- Data Translation
  - All USB and PCI boards
- CONTEC
  - Various boards through CONTEC ML-DAQ adaptor
- Advantech

For a complete list, visit www.mathworks.com/products/daq/supportedio.html

Demo: Acquiring and analyzing data from sound cards

- Windows sound card
- Frequency Analysis
- Live Data
- Graphical User Interface



Analyzing sensor data from MATLAB

Physical Quantity

Sensor / Transducer

Voltage

Hardware

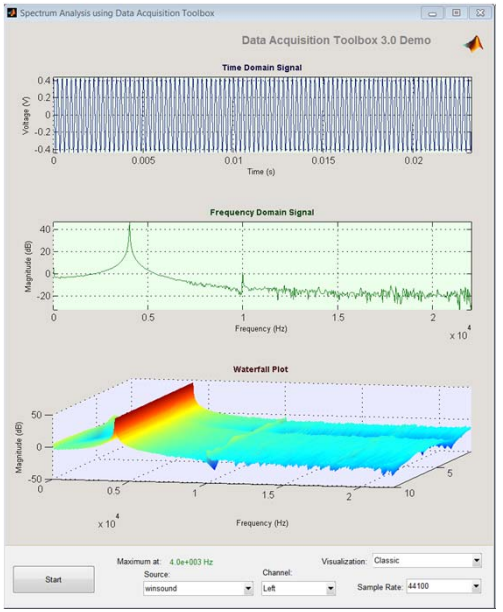
Data

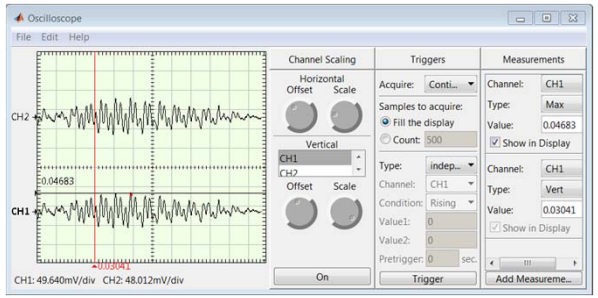
Computer

Measurement Types
- Temperature
- Pressure
- Flow
- Acceleration
- Rotation
- Strain
- …

Data Acquisition Toolbox

- What kind of hardware can I use?
  - Supports for a variety of data acquisition boards and USB modules
- Key Features
  - Support for analog input, analog output, counters, timers, and digital I/O
  - Direct access to voltage, current, IEPE accelerometer, and thermocouple measurements
  - Live acquisition of measured data directly into MATLAB or Simulink
  - Hardware and software triggers for control of data acquisition
  - Device-independent software interface





What's new in recent releases of Data Acquisition Toolbox?

- Two interfaces to connect to DAQ hardware
  - Legacy interface
  - Session-based interface (NI-only)
- Support the following on NI hardware
  - **IEPE accelerometer measurements**
  - **Bridge-based sensors measurements**
  - **Thermocouple and RTD measurements**
  - **Counter/Timer operations**
  - Analog Input, Analog Output, Digital I/O
  - Synchronization and Triggering functions

Session Interface vs. Legacy Interface

	Legacy	Session
Multi-vendor support	yes	No, NI only
Sound card support	yes	no
32-bit ML on 32 or 64-bit Windows OS	yes	yes
64-bit ML	no	yes
Analog Input	yes	yes
Analog Output	yes	yes
Digital I/O	yes	yes
Counter/Timer	no	yes
Voltage Measurements	yes	yes
Current	No*	yes
Thermocouple, RTD	No*	yes
IEPE accelerometer, Bridge	No*	yes
Advanced Synchronization capabilities (applies to NI)	yes	yes

**See supported hardware page for available interfaces for a specific NI device

Key Capabilities & Benefits (DAT)

Capabilities	Benefits
Connect to a wide variety of DAQ hardware using a common set of commands	**Freedom to choose the hardware that is right for the task** Easier to maintain code and leverage previously written code for new projects with different hardware
Access to hardware capable of specialized measurements such as IEPE accelerometer, thermocouple and Bridge	**Simplifies measurement test setup since the signal conditioning is in the hardware** Connect the sensor and acquire the data in the desired engineering units (g, degrees K etc.) without conversions or lookup tables
Access to counter/timer measurements	**Full access to the capability of the DAQ card** Simplifies applications involving counting, pulse width and frequency measurements
Advanced Synchronization	**Synchronize data collection from multiple devices** Auto synchronization capabilities, external event based triggering
Enables live analysis of acquired data	**Simplified background data acquisition** Analyze data as you collect it. Reduce collection of bad data

Instrument Control Toolbox

- What are the key features of Instrument Control Toolbox?
  - IVI, VXIplug&play, and native MATLAB instrument driver support
  - GPIB and VISA (GPIB, GPIB-VXI, VXI, USB, TCP/IP, and serial) support
  - TCP/IP, UDP, and Bluetooth serial protocol support
  - Interactive tool for identifying, configuring, and communicating with instruments
  - Simulink® blocks for sending and receiving live data between instruments and Simulink models
  - Functions for reading and writing binary and ASCII data to and from instruments
  - Synchronous and asynchronous (blocking and nonblocking) read-and-write operations

Instrument Control Toolbox: Supported Hardware

- Instruments from Agilent, Anritsu, LeCroy, Rohde & Schwarz, Tabor, Tektronix, and others

- Instruments and devices supporting common communication protocols (GPIB, VISA, TCP/IP, UDP, and serial, Bluetooth)

- Serial devices – Any device with a RS-232, RS-422, or RS-485 interface (EEGs, gas chronometers, mass spectrometers, etc.)

- Instruments using industry-standard instrument drivers (IVI, VXI*plug&play*, LXI)



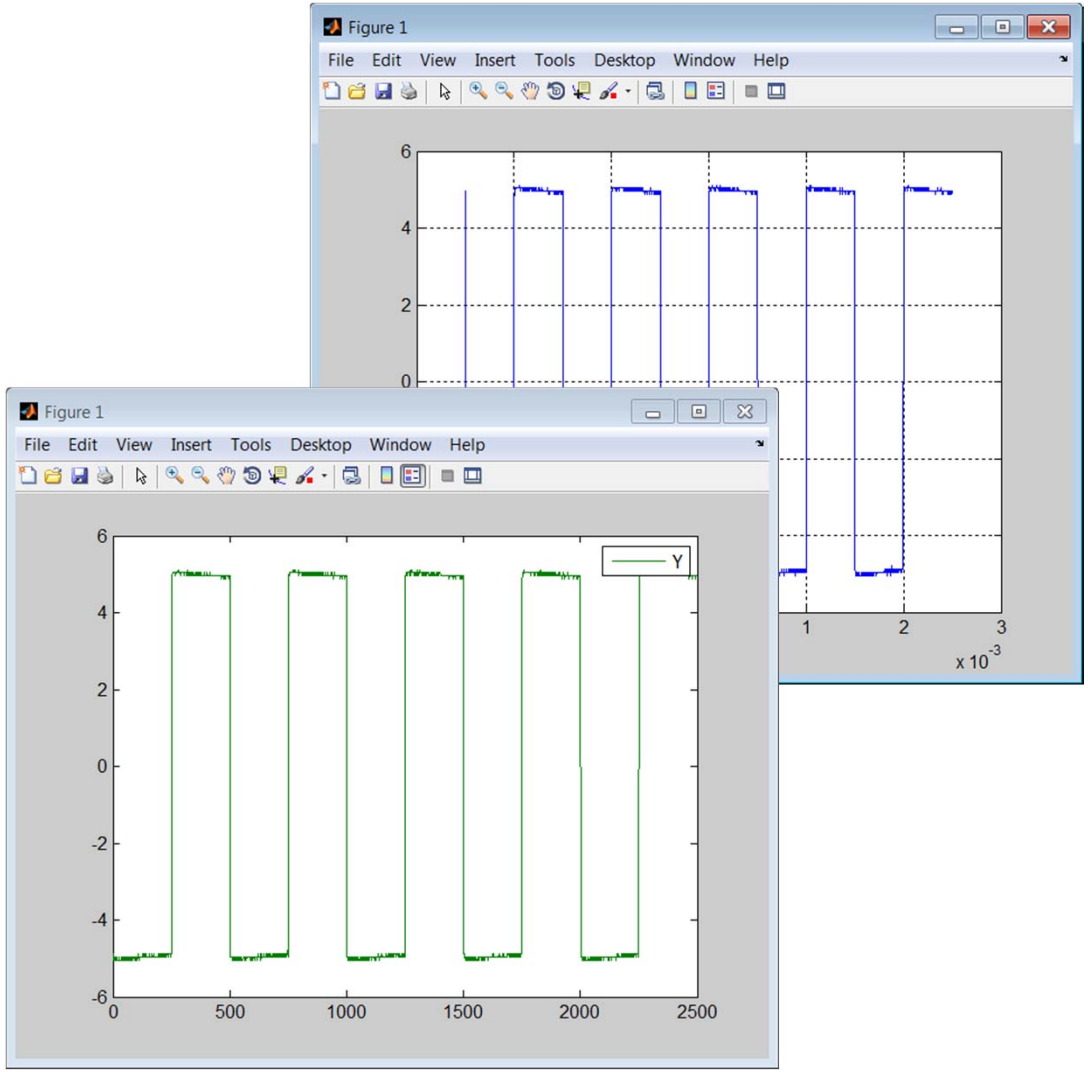
For a complete list, visit http://www.mathworks.com/products/instrument/hardware/index.html

Acquiring Data Using the Test and Measurement Tool

Features:

Export directly to Figure Window

Export to MATLAB workspace



Test and Measurement Tool Features

Features:

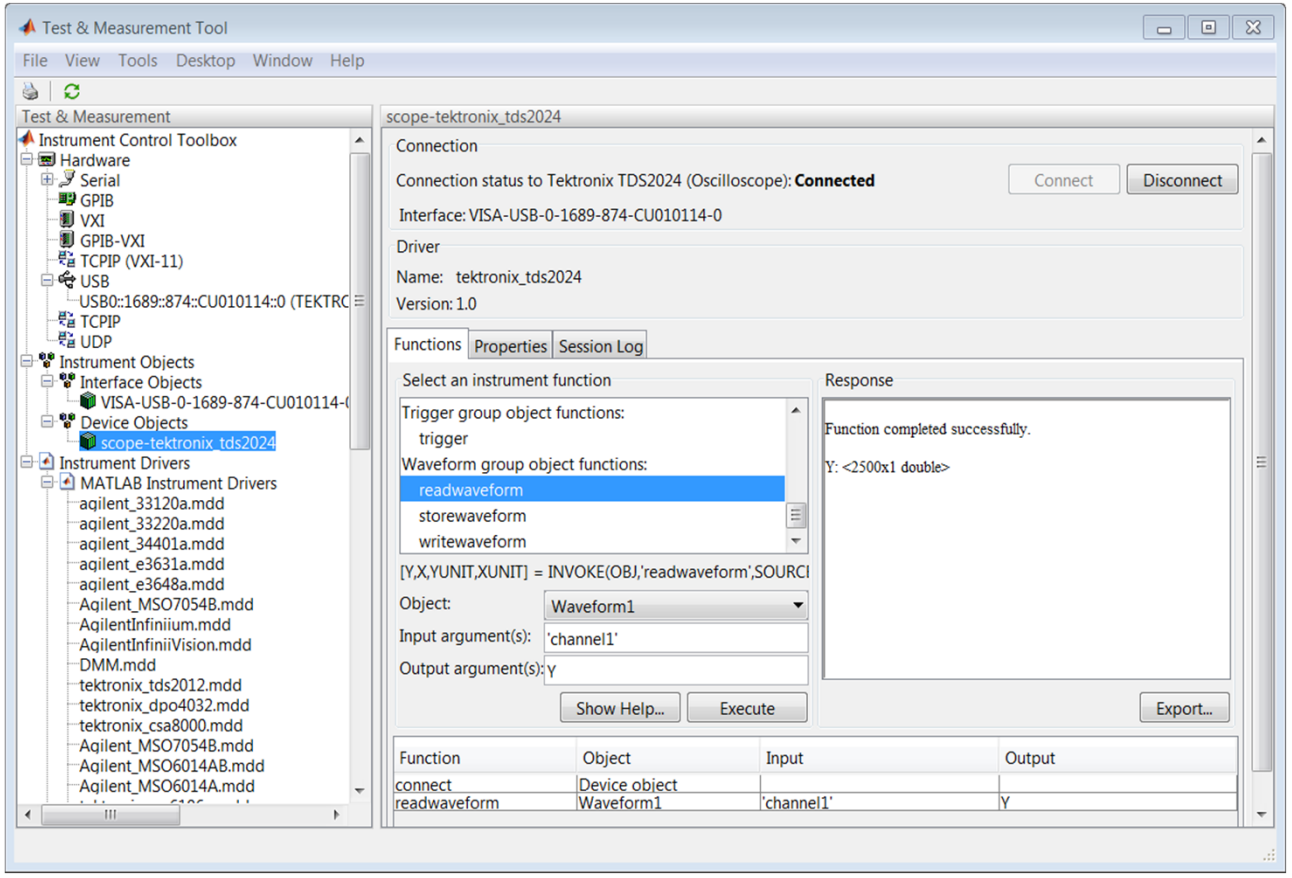
View driver properties

View driver functions

Create device objects

Create interface objects

View connected hardware



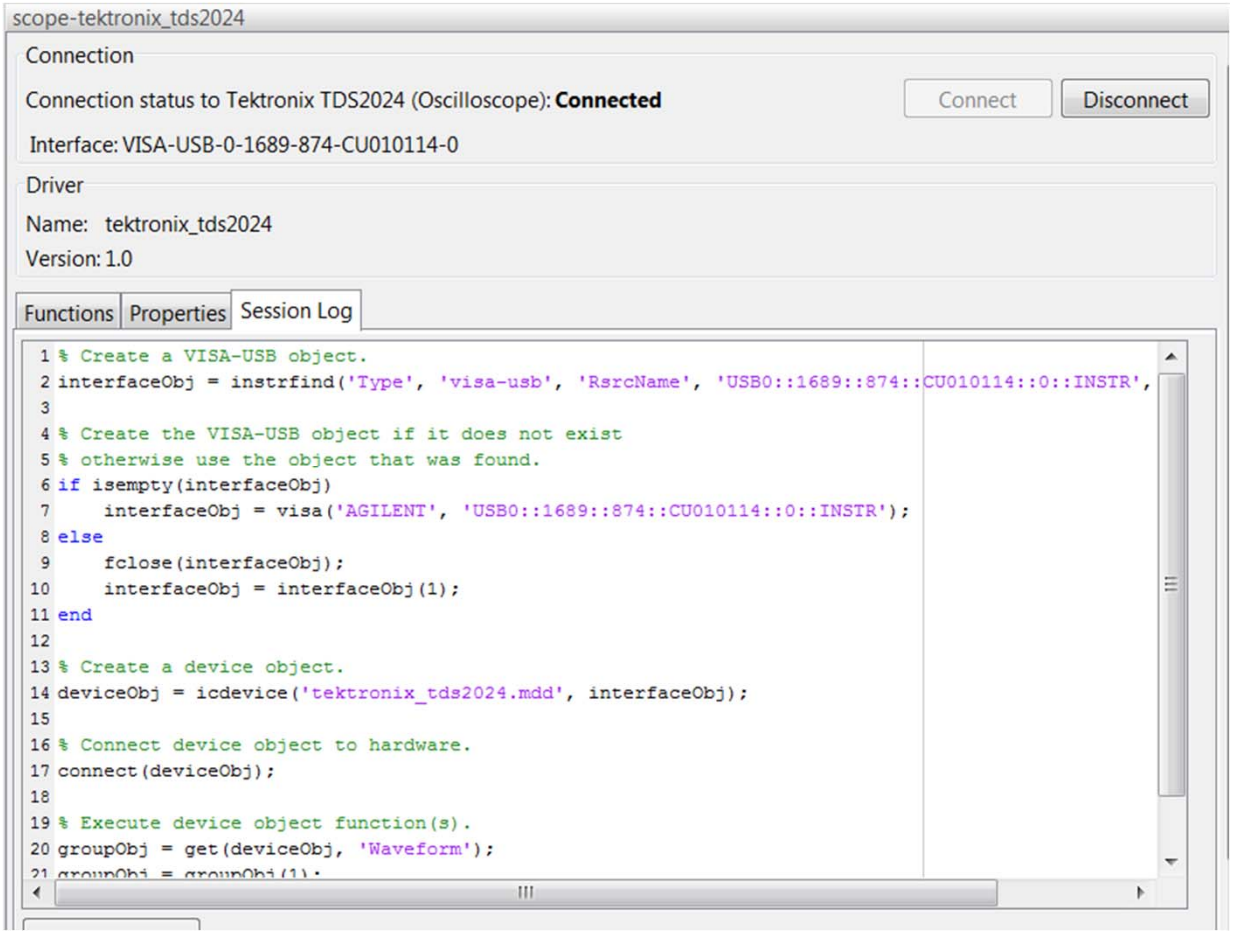
Session Log

Features:

Automatically creates MATLAB code from activity within the tool

Comments the code

Can be saved for use in application



What's new in recent releases of Instrument Control Toolbox

- Bluetooth support
  - Serial Port Profile (SPP)
- I2C support
- Quick Control Instruments
  - Quick Control Oscilloscope
  - Quick Control Function Generator

```
sc = oscilloscope();
sc.Resource = 'myScope';
sc.connect()
data = getWaveform(sc);
plot(data)
```

```
myfgen=fgen();
myfgen.Resource= 'USB0::2391::1031::my43000277::0::INSTR';
myfgen.connect
myfgen.Waveform='sine'
myfgen.Frequency=5000;
enableOutput(myfgen);
```

Key Capabilities & Benefits (ICT)

Capabilities	Benefits
Control and acquire data from instruments using IVI, VXIplug&play and MATLAB instrument drivers	**Verify designs and build test systems** Instrument Control Toolbox and MATLAB as a platform for design verification. Develop models in MATLAB or Simulink and test them with data generated or collected from test equipment. Verify that prototypes meets specs and build larger test systems.
Connect to instruments and devices over GPIB, TCP/IP, VISA, USB and Serial and Bluetooth and I2C	**Easily connect to hardware without leaving MATLAB** Analyzing data, visualizing data and developing custom measurements all in the single environment saves time.
Quick Control Instruments	**Connect to instruments without knowing SCPI or driver commands** Connect to oscilloscopes and function generators with only a few lines of MATLAB code
Connect to remote software applications using TCP/IP or UDP	**Enables analysis of data collected from a remote source**

Summary

- Acquire Data from sensors and Instruments
  - Data Acquisition Toolbox
  - Instrument Control Toolbox
  - Image Acquisition Toolbox
  - Vehicle Network Toolbox
- Without leaving MATLAB you can acquire, analyze and visualize your data
- Acquiring and analyzing data from the same environment saves time and enables live analysis of data

Resources

- Data sheets, user stories, demos, technical literature, documentation
  - **www.mathworks.com/products**
- View this and other archived webinars
  - **www.mathworks.com/products/daq**
- View more data acquisition demos
  - **http://www.mathworks.com/products/daq/demos.html**
- View more instrument control demos
  - **http://www.mathworks.com/products/instrument/demos.html**
- View supported hardware
  - Data Acquisition Toolbox
  - Instrument Control Toolbox
  - Image Acquisition Toolbox
  - Vehicle Network Toolbox