Q&A

Please fill the session-related questions into the Q&A sheet in your registration kit and hand over the sheet to our promoters

MATLAB EXPO 2019

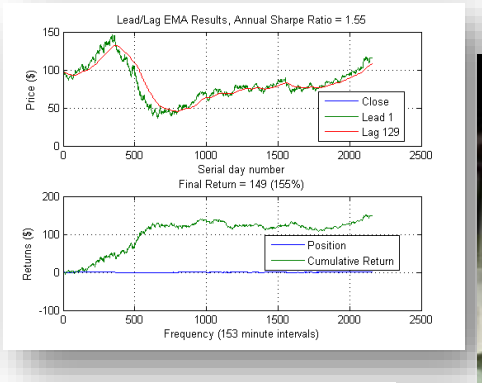
Developing and Deploying Machine Learning Solutions for Embedded Applications

Nitin Rai – Application Engineer

Machine Learning Solutions for Embedded Applications

Application examples

- Fitness Trackers
- Structural health monitoring (SHM)
- Fault and event detection
- Advanced surveillance
- Medical Devices
- Face detection
- .....



Machine Learning Solutions for Embedded Applications
Challenges

- Data access from multiple sensors on embedded devices
- Iterative feature extraction and model development
- Tuning model for embedded deployment
- Implementing and deploying models on embedded devices

BMW Uses Machine Learning to Detect Oversteering

Challenge

Develop automated software for detecting oversteering, an unsafe condition in which rear tires lose their grip during a turn

Solution

Use MATLAB to develop, train, and evaluate a variety of supervised machine learning classifier types, including KNN, SVM, and decision trees

Results

- Oversteering identified with greater than 98% accuracy
- Multiple machine learning classifiers trained automatically
- Code generated and deployed to an ECU for real-time, in-vehicle testing

A BMW M4 oversteering on a test track.

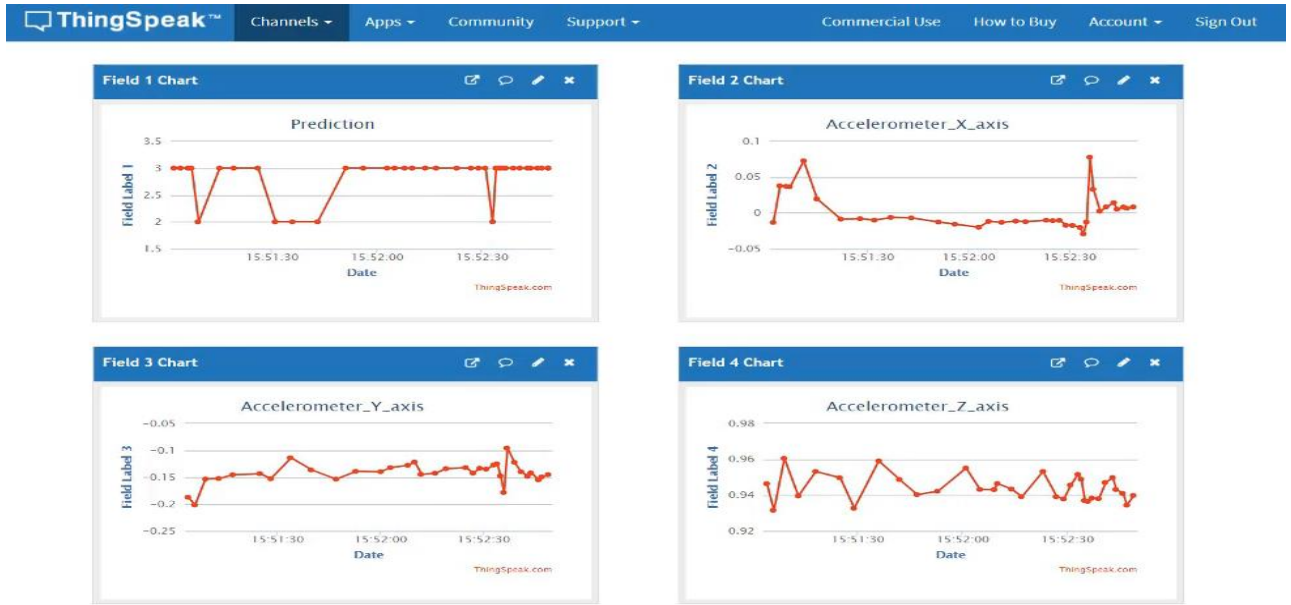
"Working in MATLAB, we developed a supervised machine learning model as a proof of concept. Despite having little previous experience with machine learning, in just three weeks we completed a working ECU prototype capable of detecting oversteering with over 98% accuracy."

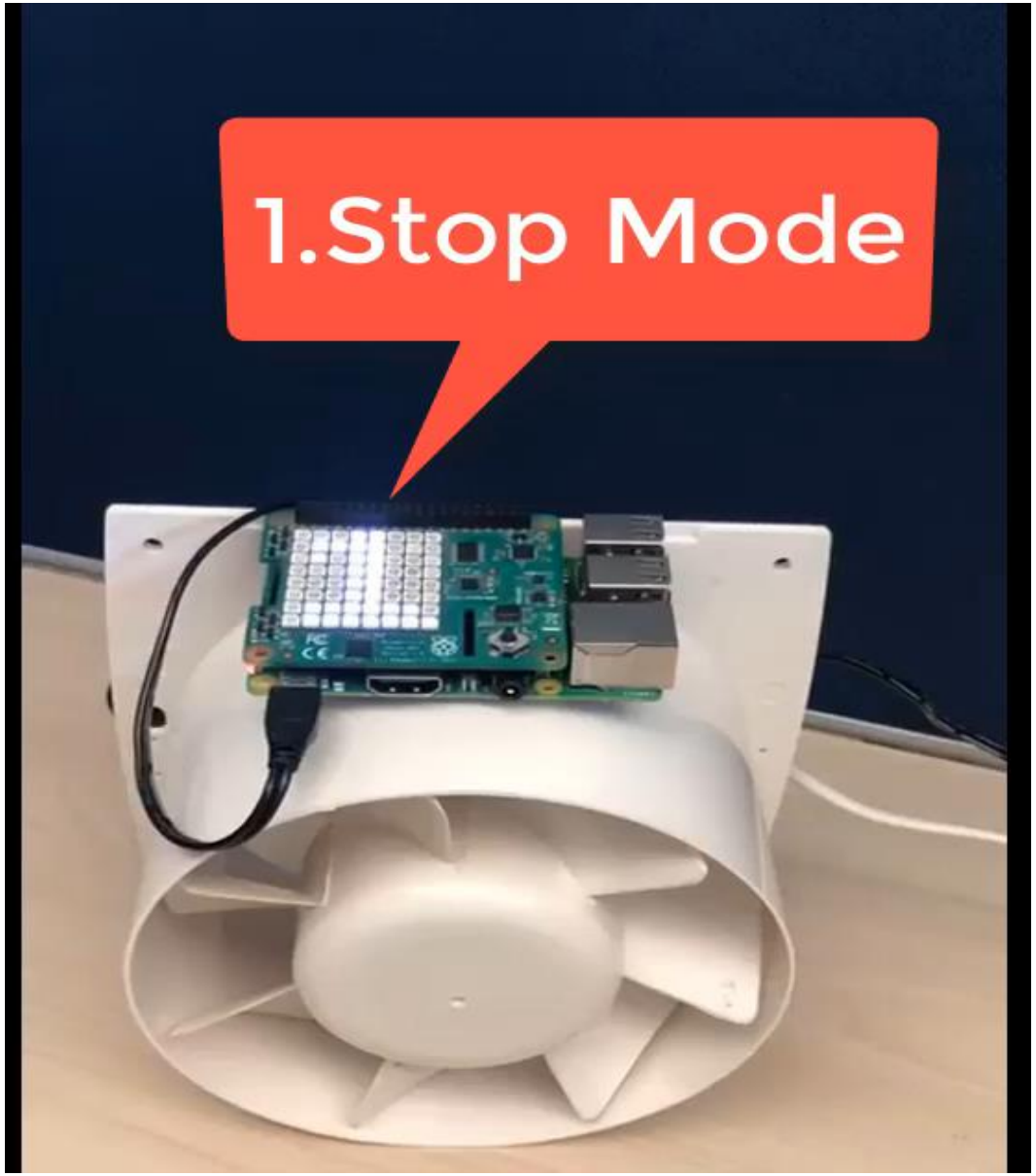
- Tobias Freudling, BMW Group

Link to article

Online Health Monitoring Using Vibration Data

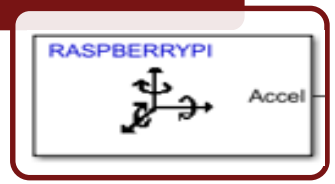
Platform	Raspberry Pi
Data	Vibration Data
Sensor	Sense HAT : Accelerometer along x, y, and z axes
Prediction	Stopped Normal Blocked Imbalanced
Output	On ThingSpeak





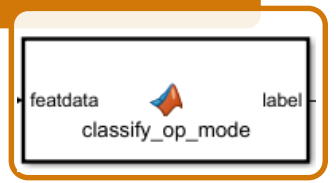
Developing and Deploying Machine Learning Workflow

Sensor Data Acquisition

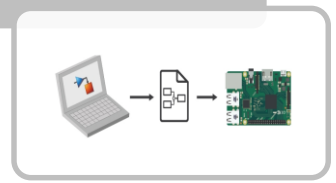


Feature Extraction

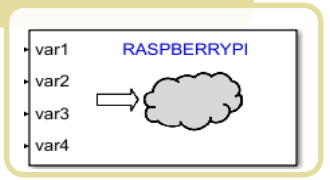
Develop Predictive Model

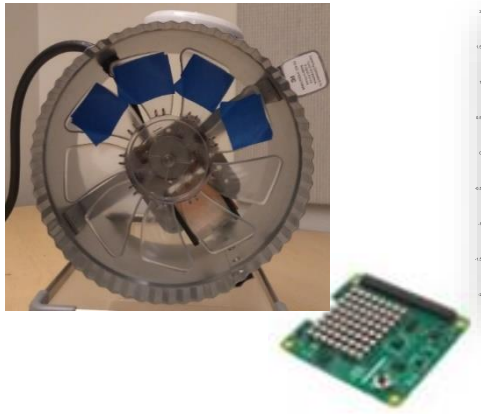


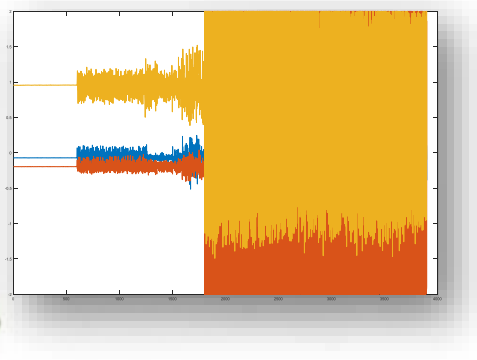
Embedded Implementation

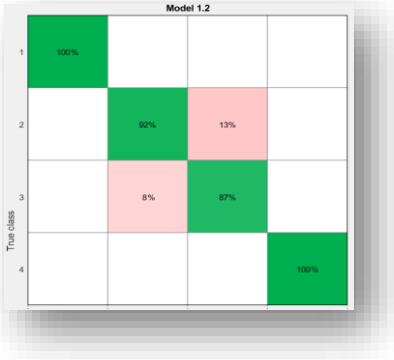


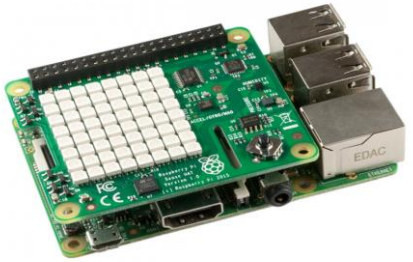
Cloud based Communication

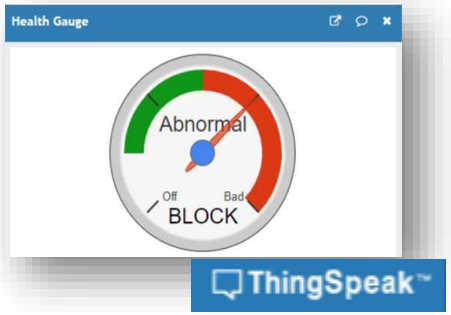










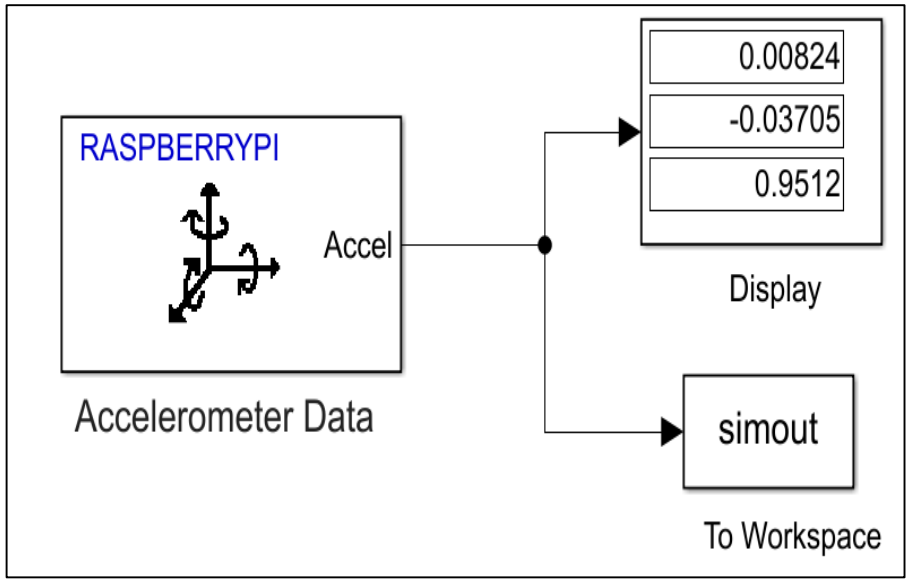


Access and Explore Sensor Data

- Raspberry Pi support package lets you Acquire sensor and image data from your connected Raspberry Pi into MATLAB and SIMULINK

https://www.mathworks.com/hardware-support/raspberry-pi-matlab.html

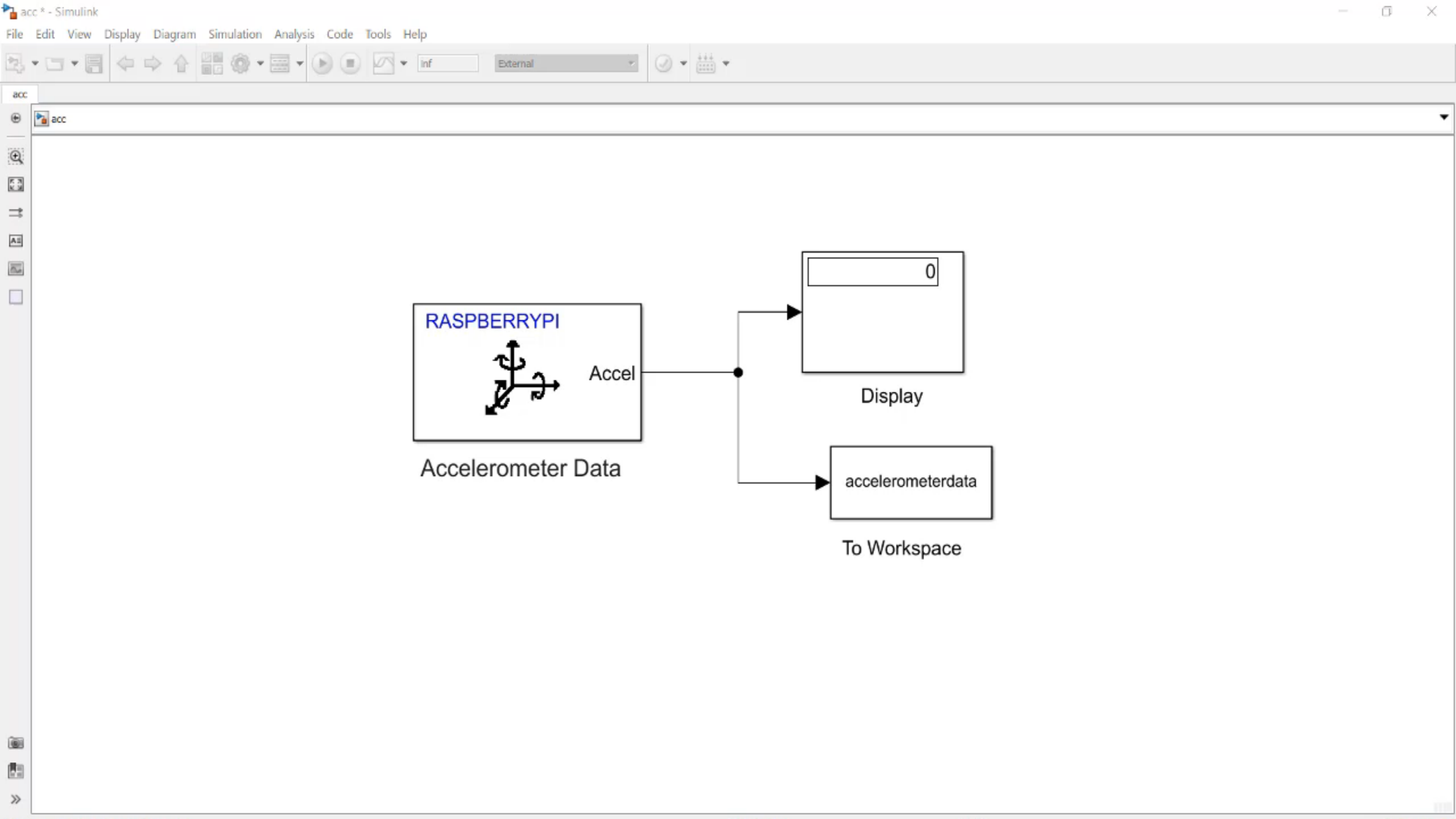
SIMULINK



MATLAB

```
mysh = sensehat(mypi)

acceleration =
readAcceleration(mysh)
```


acc * - Simulink
File Edit View Display Diagram Simulation Analysis Code Tools Help
inf
External
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acc
RASPBERRYPI
Accel
Accelerometer Data
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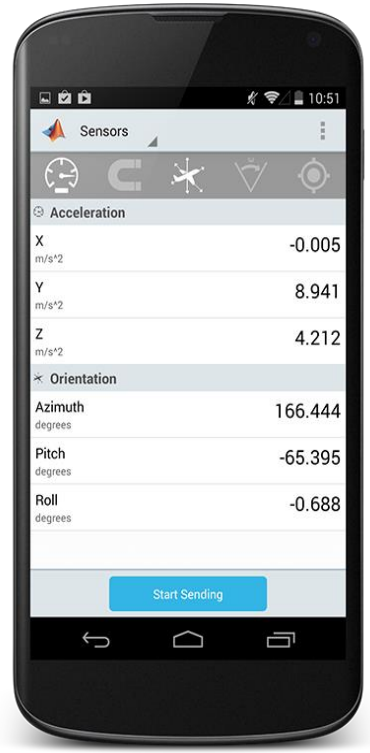
Display
accelerometerdata
To Workspace

Access and Explore Sensor Data

- MATLAB Support Packages for Apple iOS Sensors and Android Sensors
- MATLAB Support Package for Arduino Hardware
- Data Acquisition Toolbox - Connect to data acquisition cards, devices, and modules



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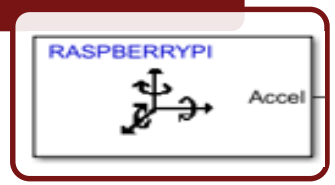

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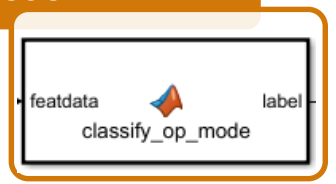

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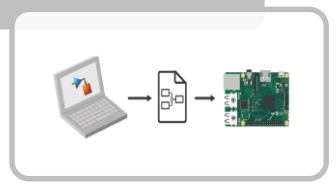

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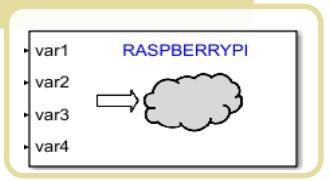
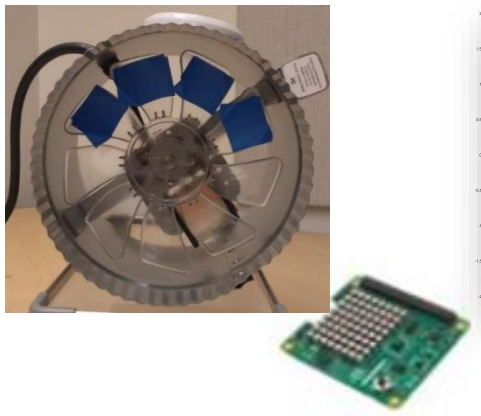
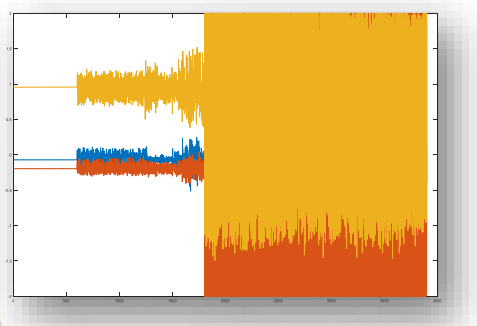
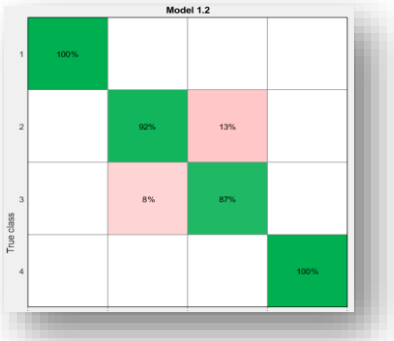
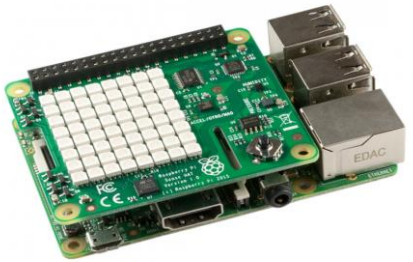
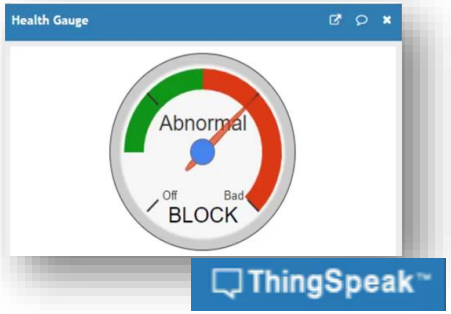












Block: healthcheck/MATLAB Function*

EDITOR VIEW

hdl_setup2 hdl setup

New Open Save Find Files Compare Print — FILE
Go To Find — NAVIGATE
Insert Comment Indent — EDIT
Breakpoints — BREAKPOINTS
Run Model Stop Model Build Model — RUN
Go To Diagram Edit Data Simulation Target View Report Help — SIMULINK

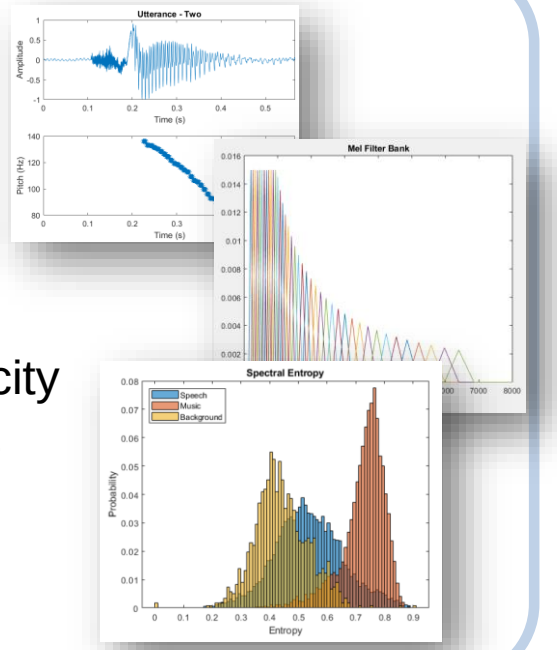
```
function [featmat,feature1,feature2,feature3] = extractfeat(accx_mat,accy_mat,accz_mat)
%%  *Feature Extraction*

    featmat = zeros(1,33);
    fs = 10.0;

    %% Mean
    feature1 = mean(accx_mat,1);
    %feature1 = feature1(:);
    featmat(1) = feature1;

    %%
    feature2 = mean(accy_mat,1);
    %feature2 = feature2(:);
    featmat(2) = feature2;

    %%
    feature3 = mean(accz_mat,1);
    %feature3 = feature3(:);
    featmat(3) = feature3;

    %% Root Mean Square
    feature4 = rms(accx_mat,1);
    %feature4 = feature4(:);
    featmat(4) = feature4;

    %%
```

extractfeat Ln 5 Col 15

Domain-Specific Features and Transformations – Examples

Speech and Audio

- MFCC
- GTCC
- MDCT
- Pitch, harmonicity
- Spectral shape descriptors
- ...



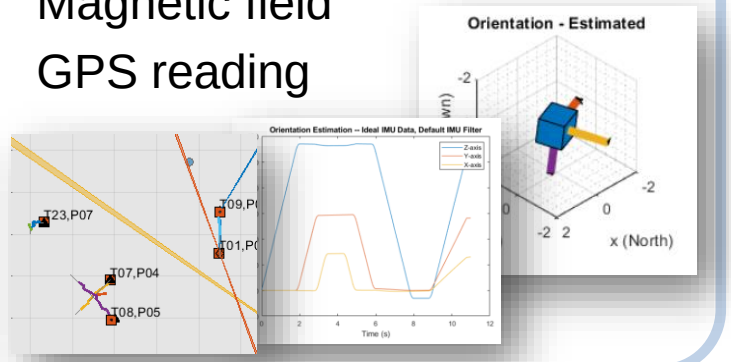
Navigation and Sensor Fusion

- Orientation
- Height
- Position

from

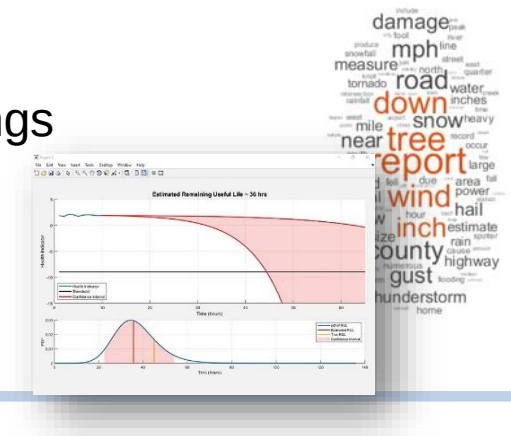
- Acceleration, angular velocity
- Magnetic field
- GPS reading

- Multi-object tracking
- ...



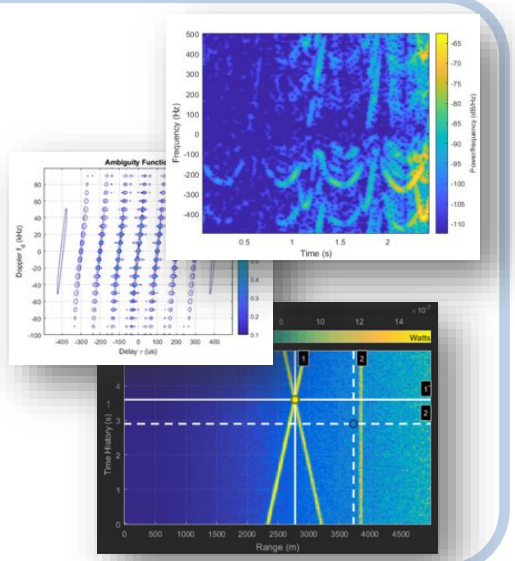
Text Analytics

- Train Word Embeddings
- Word2Vec
- Topic Modeling
- ...



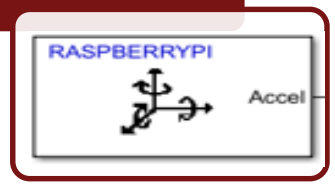
Radar

- Micro-Doppler analysis
- Range-Doppler processing
- Synthetic aperture imaging
- Spectral analysis
- Waveform ambiguity
- ...



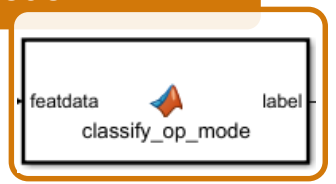
Developing and Deploying Machine Learning Workflow

Sensor Data Acquisition

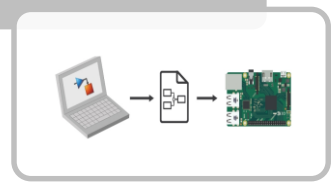


Feature Extraction

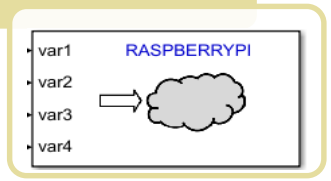
Develop Predictive Model

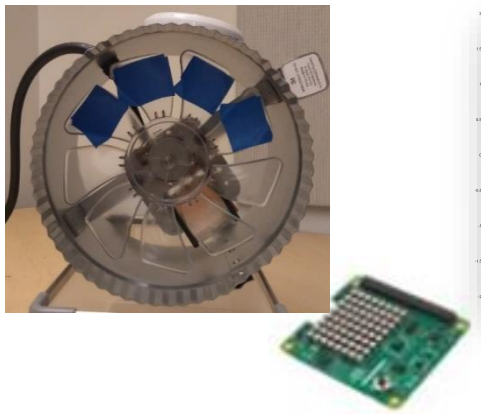


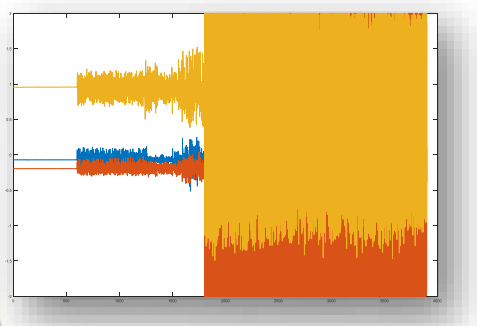
Embedded Implementation

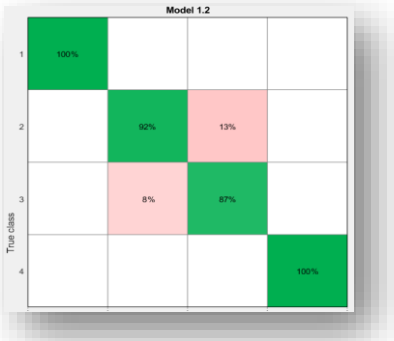


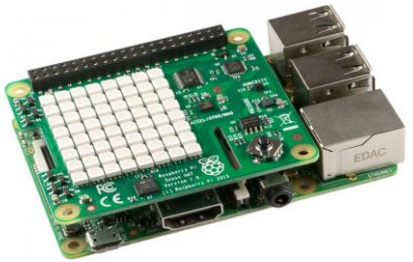
Cloud based Communication

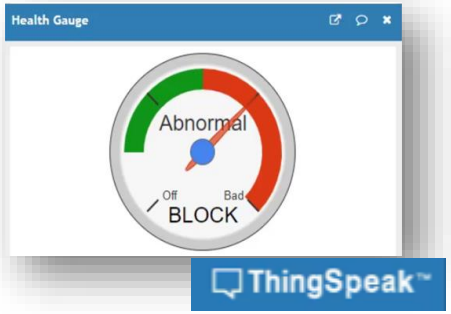












MATLAB R2018b

HOME | PLOTS | APPS

hdl_setup2 | hdl setup | Search Documentation | Nitin

Get More Apps | Install App | Package App | Curve Fitting | Optimization | PID Tuner | Analog Input Recorder | System Identification | Wireless Waveform Ge... | Signal Analyzer | Image Acquisition | Instrument Control | SimBiology | MATLAB Coder | Application Compiler

FILE | APPS

C: ▸ NITIN ▸ expo2019 ▸

Current Folder

Name

- **Folder**
  - healthcheck_ert_rtw
  - slprj
- **ELF File**
  - healthcheck.elf
- **JPG File**
  - four.jpg
  - one.jpg
  - three.jpg
  - two.jpg
- **Function**
  - spectralPowerFeatures.m

Details

Workspace

Name	Value	Class
fullfeattable	283x34 tab...	table
trainedModel	1x1 struct	struct

Command Window

New to MATLAB? See resources for Getting Started.

```
>> classificationLearner
```

Classification Learner - Scatter Plot

CLASSIFICATION LEARNER | VIEW

hdl_setup2 | hdl setup

New Session | Feature Selection | PCA | All Quick-To-T... | All | All Linear | Fine Tree | Advanced | Use Parallel | Train | Scatter Plot | Confusion Matrix | ROC Curve | Parallel Coordinates Plot | Export Model

FILE | FEATURES | MODEL TYPE | TRAINING | PLOTS | EXPORT

Data Browser

History

1 Tree [Draft]
Last change: Disabled PCA 33/33 features

Current Model

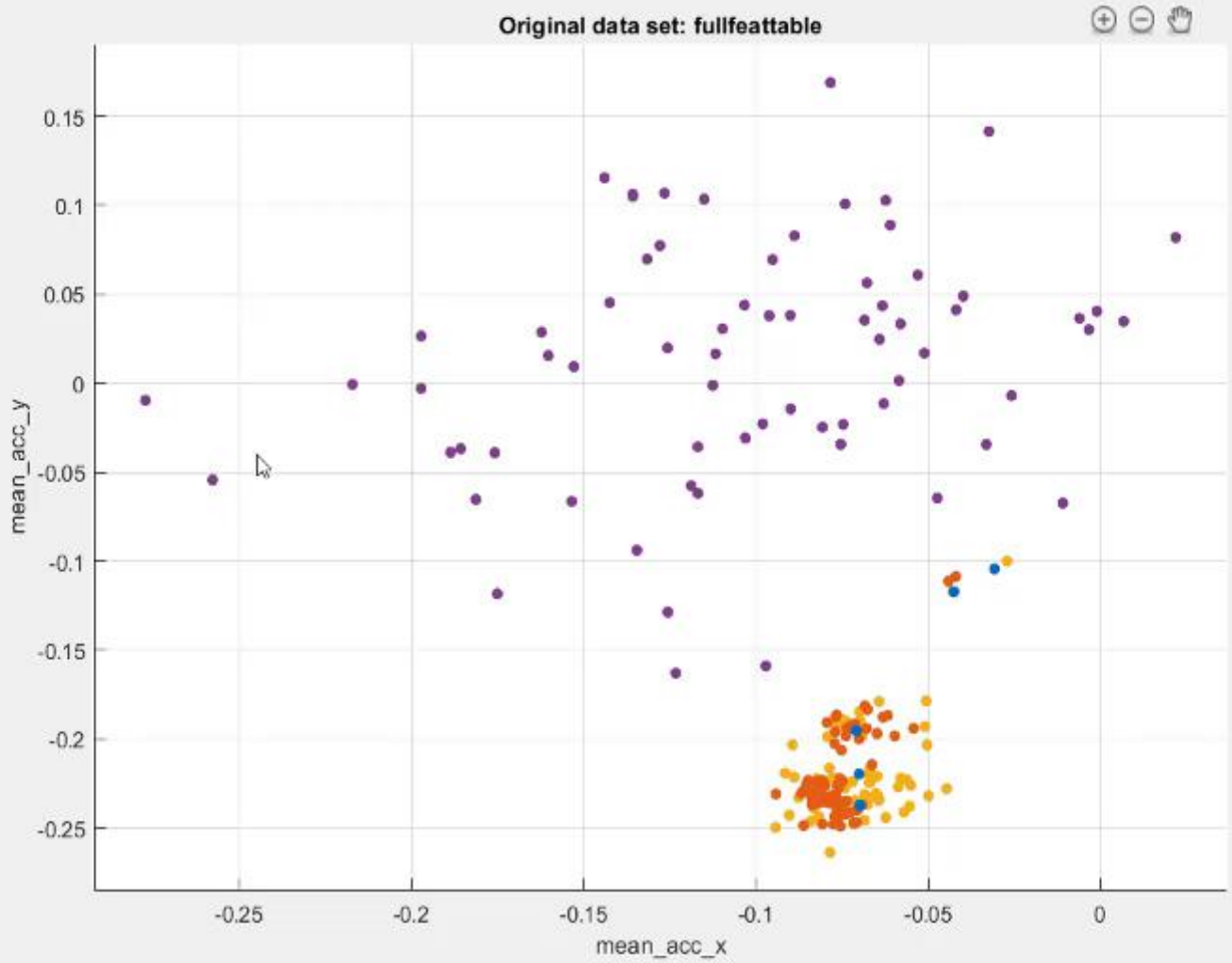
Model 1: Draft

Model Type
Preset: Fine Tree
Maximum number of splits: 100
Split criterion: Gini's diversity index
Surrogate decision splits: Off

Feature Selection
All features used in the model, before PCA

PCA
PCA disabled

Scatter Plot



Plot
Data
Model predictions

Predictors
X: mean_acc_x
Y: mean_acc_y

Classes
Move to Front

Show	Order
☑	stop_mode
☑	normal_op_mode
☑	blockage_mode
☑	rotor_imbal_mode

How to investigate features

Data set: **fullfeattable** Observations: **283** Size: **83 kB** Predictors: **33** Response: **mode** Response Classes: **4**

Validation: **Holdout Validation with 20% held out**

Classification Learner - Scatter Plot

CLASSIFICATION LEARNER | VIEW

hdl_setup2 | hdl setup

New Session | Feature Selection | PCA | All Quick-To-T... | All | All Linear | Fine Tree | Advanced | Use Parallel | Train | Scatter Plot | Confusion Matrix | ROC Curve | Parallel Coordinates Plot | Export Model

FILE | FEATURES | MODEL TYPE | TRAINING | PLOTS | EXPORT

Data Browser

History

1 Multiple [Draft]
Last change: All 33/33 features

Current Model

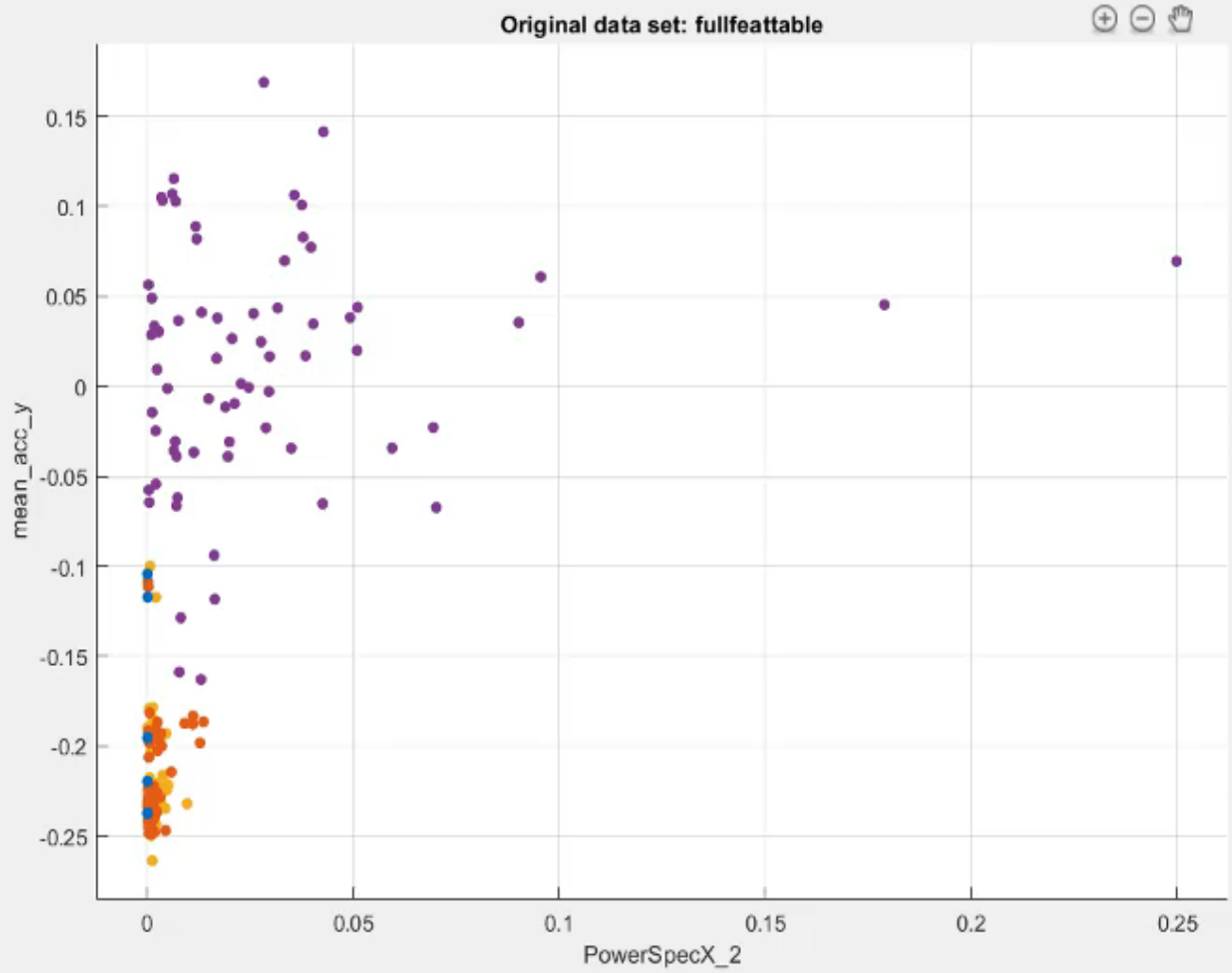
Model 1: Draft

Model Type
Preset: All

Feature Selection
All features used in the model, before PCA

PCA
PCA disabled

Scatter Plot | Parallel Coordinates Plot



Plot
- Data
- Model predictions

Predictors
X: PowerSpecX_2
Y: mean_acc_y

Classes | Move to Front

Show	Order
☑	stop_mode
☑	normal_op_mode
☑	blockage_mode
☑	rotor_imbal_mode

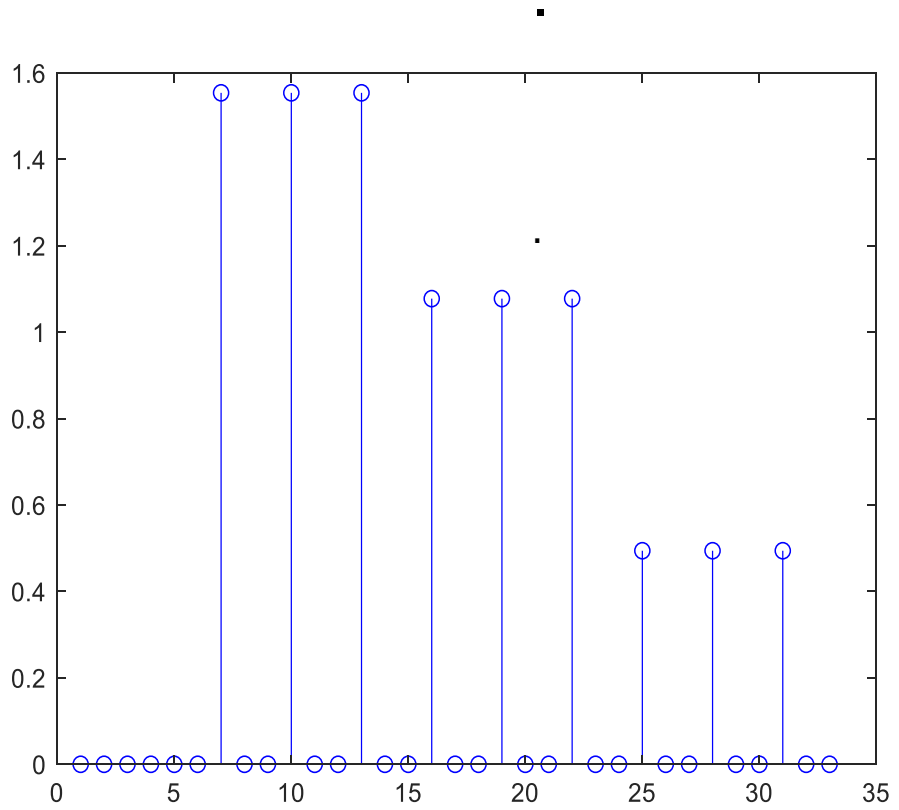
How to investigate features

Data set: **fullfeattable** Observations: **283** Size: **83 kB** Predictors: **33** Response: **mode** Response Classes: **4**

Validation: **Holdout Validation with 20% held out**

Perform feature selection using Neighborhood Component Analysis

fscnca(X,Y) performs feature selection for classification using the predictors in X and responses in Y.



Principal component analysis

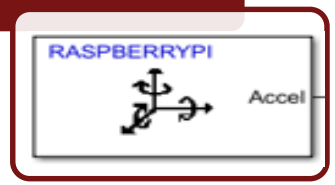
- To emphasize variation and bring out strong patterns in a dataset

Bayesian Optimization

- Tune hyperparameters of machine learning algorithms automatically

Developing and Deploying Machine Learning Workflow

Sensor Data Acquisition



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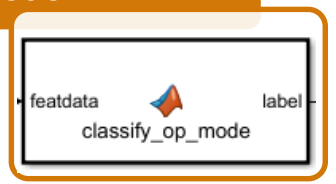

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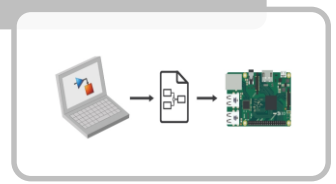
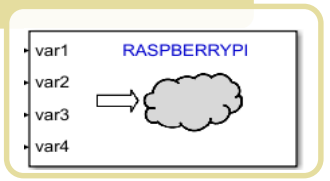
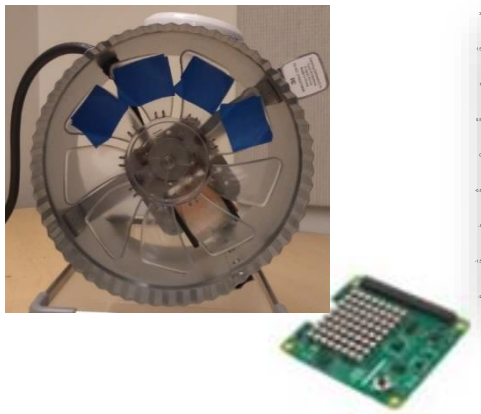
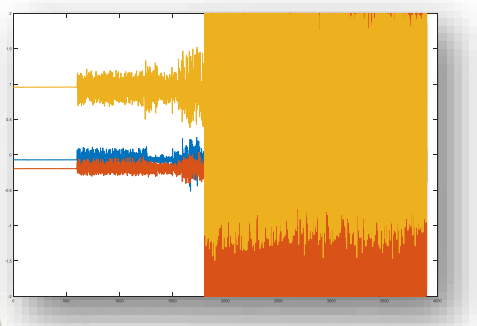
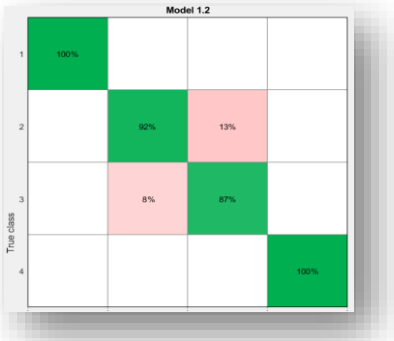


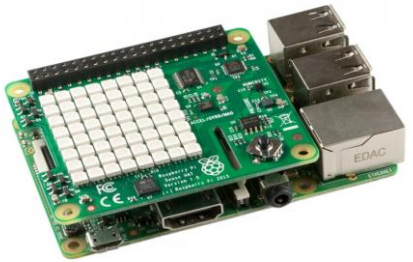
Cloud based Communication

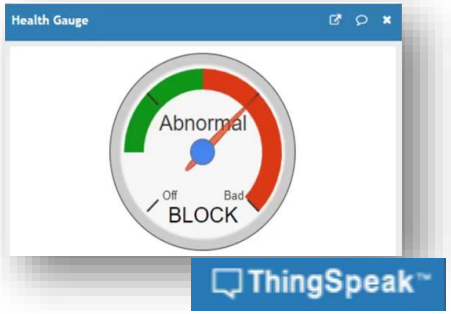












Embedded Implementation

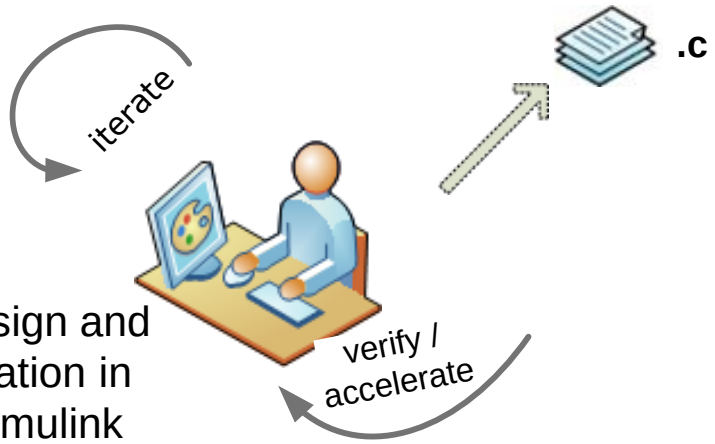
SIMULINK MATLAB

Embedded Coder

C, C++

DSP / MCU

Why Automatic Code Generation?



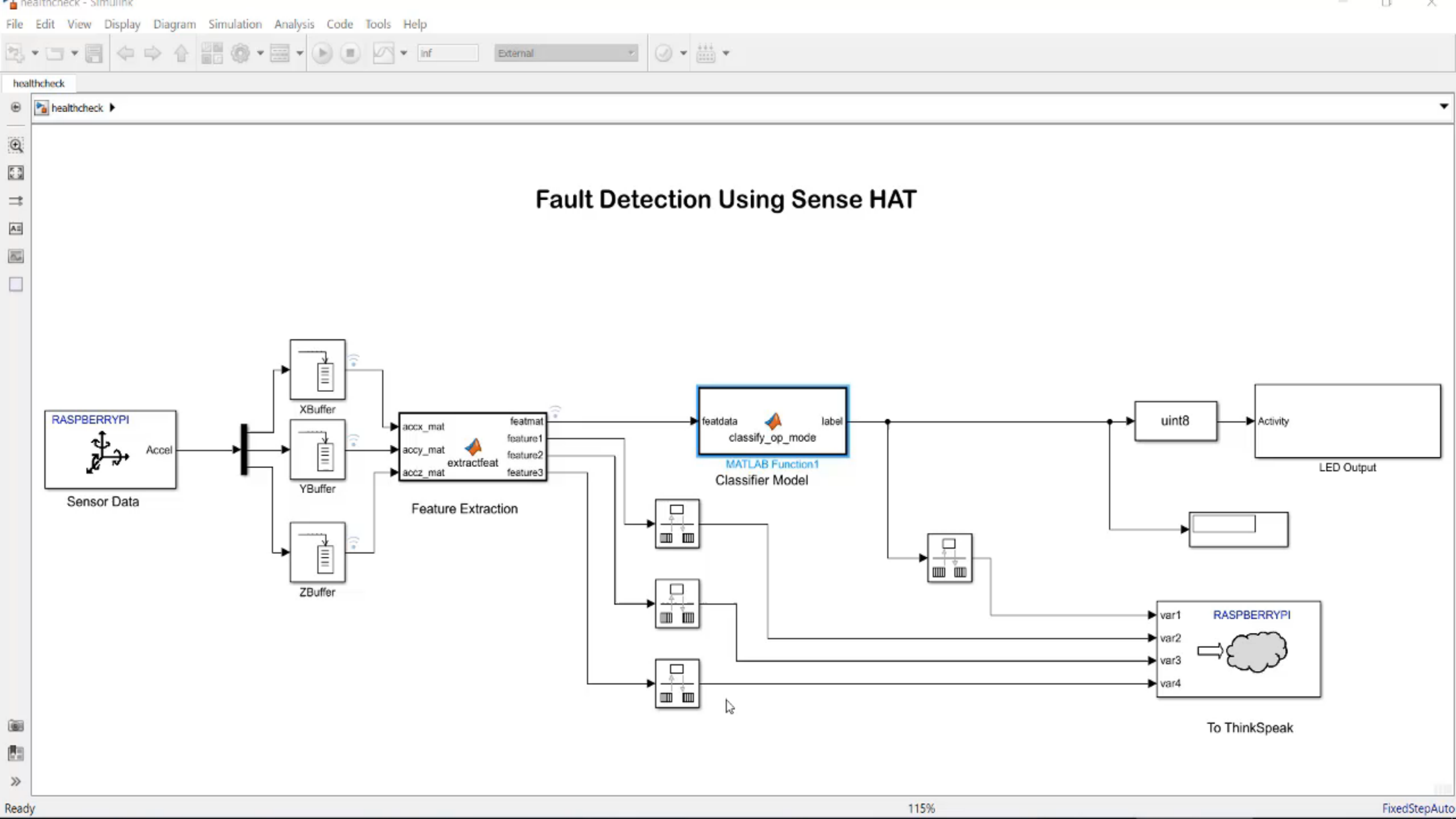
Algorithm Design and Code Generation in MATLAB/ Simulink

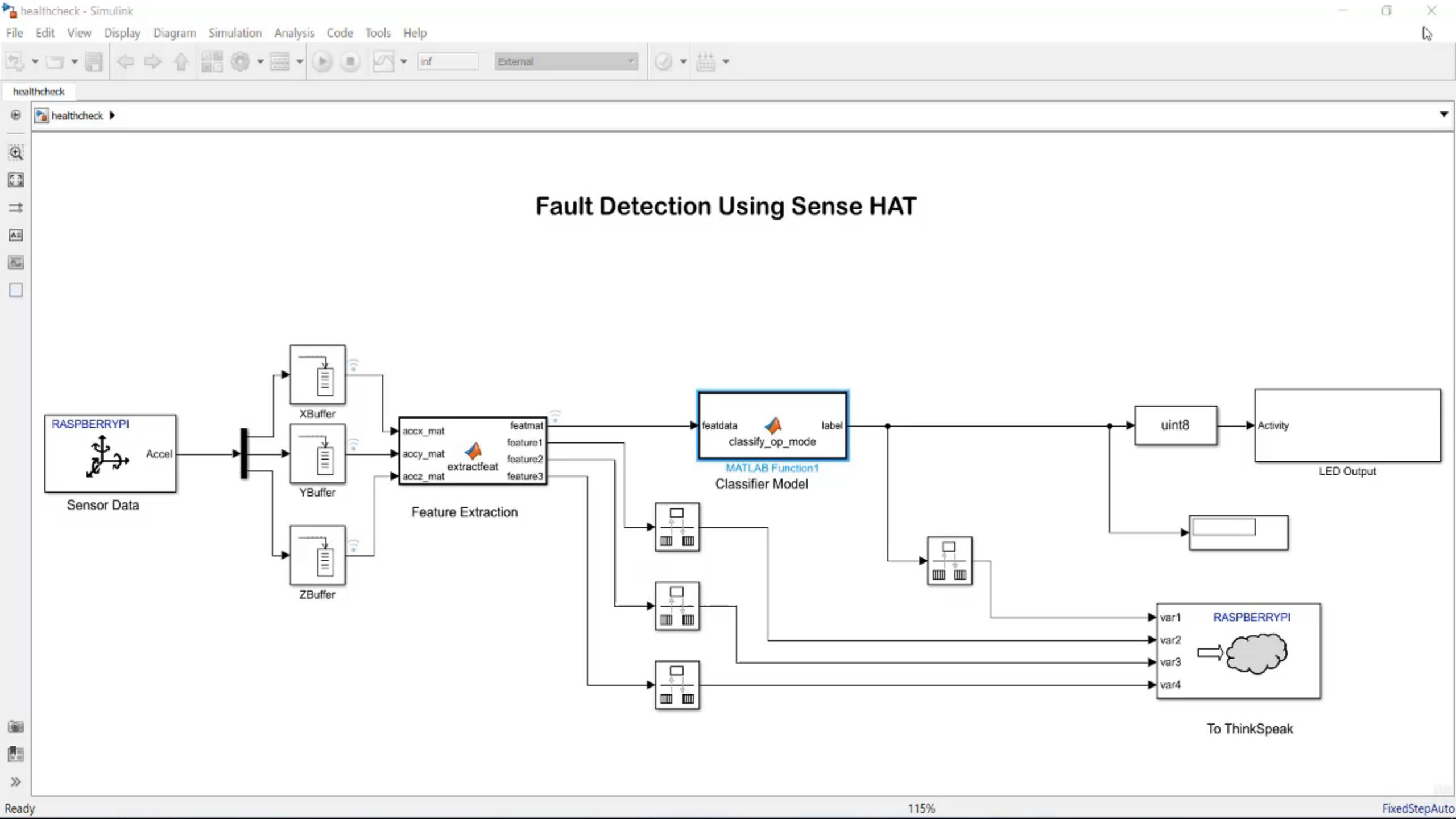
With automatic code generation, design engineers can:

- Maintain one design across simulation and implementation
- Design faster and get to C
- Test more systematically and frequently
- Spend more time improving algorithms

Challenges with manual coding:

- Separate functional and implementation specification
  - Leads to multiple implementations that are inconsistent
  - Hard to modify requirements during development
- Manual coding errors
- Time-consuming and expensive process


Fault Detection Using Sense HAT
RASPBERRYPI
Accel
Sensor Data
XBuffer
YBuffer
ZBuffer
accx_mat
accy_mat
accz_mat
extractfeat
featmat
feature1
feature2
feature3
Feature Extraction
featdata
classify_op_mode
label
MATLAB Function1
Classifier Model
uint8
Activity
LED Output
var1
var2
var3
var4
RASPBERRYPI
To ThinkSpeak


healthcheck - Simulink
File Edit View Display Diagram Simulation Analysis Code Tools Help
healthcheck
Fault Detection Using Sense HAT
RASPBERRYPI
Accel
Sensor Data
XBuffer
YBuffer
ZBuffer
accx_mat
accy_mat
accz_mat
extractfeat
featmat
feature1
feature2
feature3
Feature Extraction
featdata
classify_op_mode
label
MATLAB Function1
Classifier Model
uint8
Activity
LED Output
var1
var2
var3
var4
RASPBERRYPI
To ThinkSpeak
Ready
115%
FixedStepAuto

Code Generation Report

Find: Match Case

Contents

Generated Code

- [-] Main file
  - ert_main.c
- [-] Model files
  - healthcheck.c
  - healthcheck.h
  - healthcheck_private.h
  - healthcheck_types.h
- [-] Data files
  - healthcheck_data.c
- [+] Utility files (8)
- [+] Interface files (2)
- [+] Static files (2)
- [+] Other files (2)

Code Generation Report for 'healthcheck'

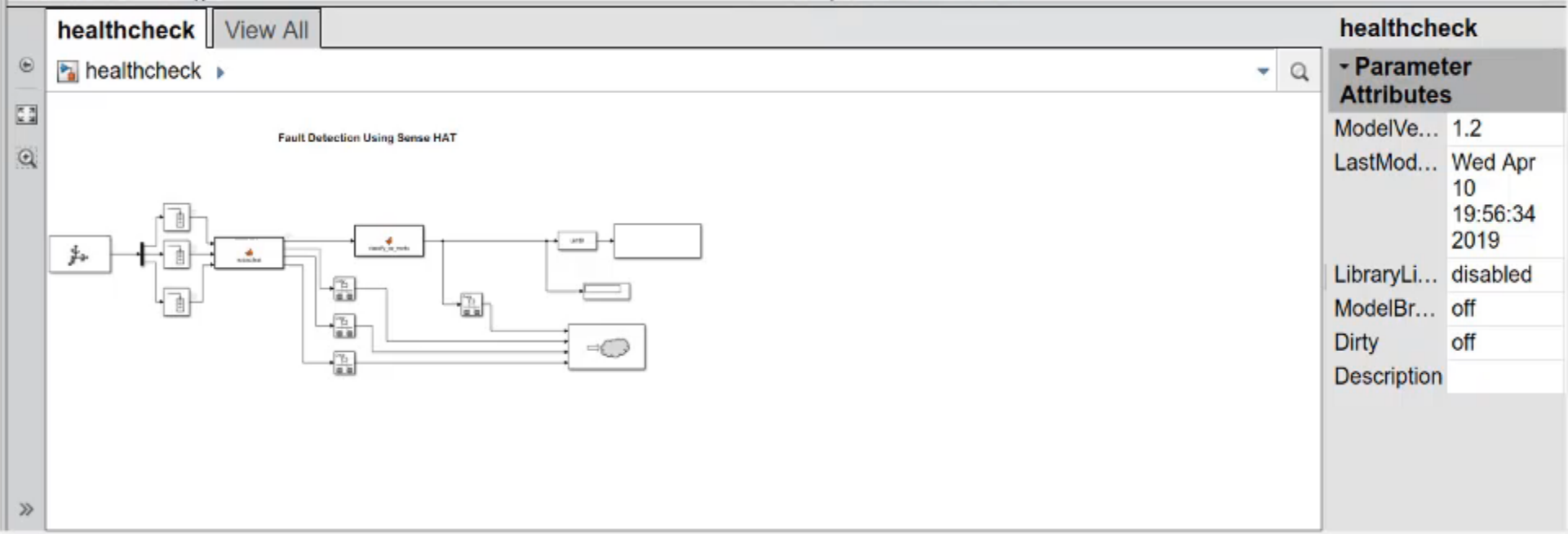
Model Information

Author	nitinrai
Last Modified By	nitinrai
Model Version	1.2
Tasking Mode	MultiTasking

Configuration settings at time of code generation

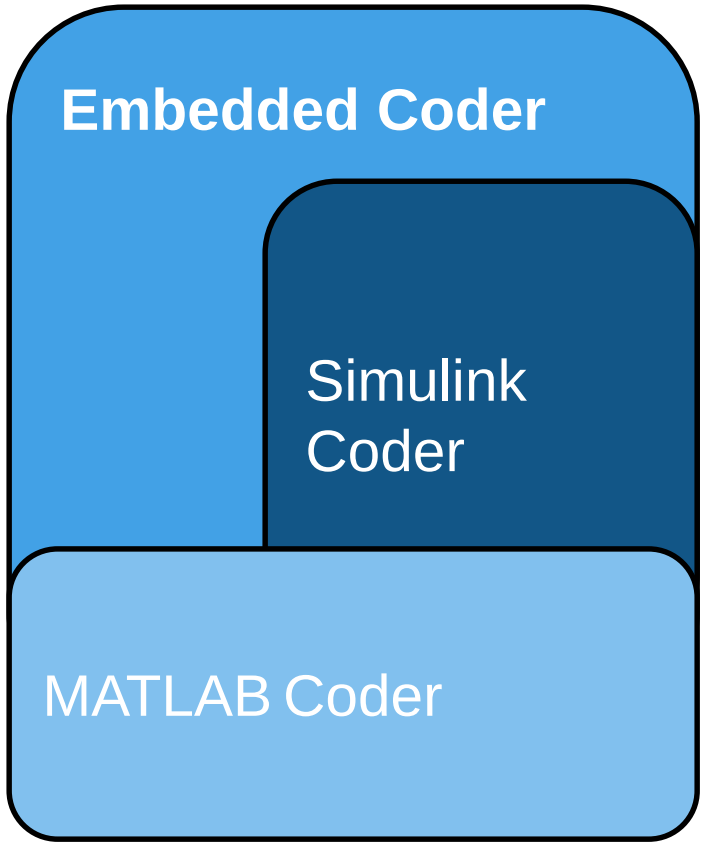
Code Information

System Target File	ert.tlc
Hardware Device Type	ARM Compatible->ARM Cortex



OK Help

Code Generation Products for C/C++



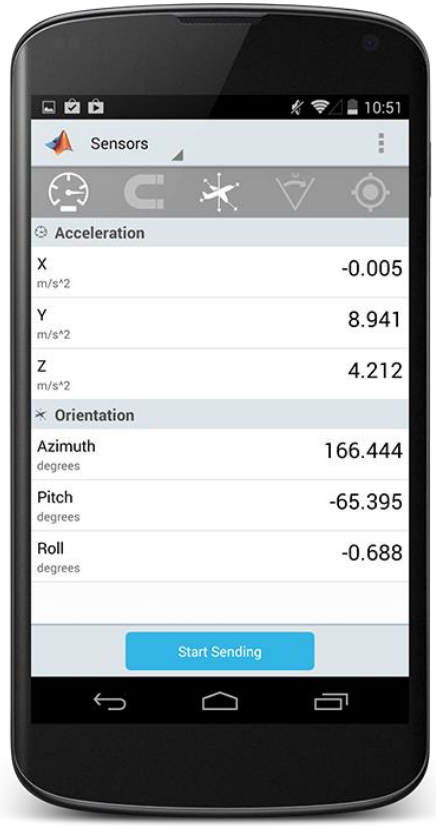
Embedded Coder™
Automatically generate C and C++ optimized for embedded systems

Simulink® Coder™
Automatically generate C and C++ from **Simulink** models and **Stateflow** charts

MATLAB® Coder™
Automatically generate C and C++ from **MATLAB** code

Connecting MATLAB and Simulink to Hardware

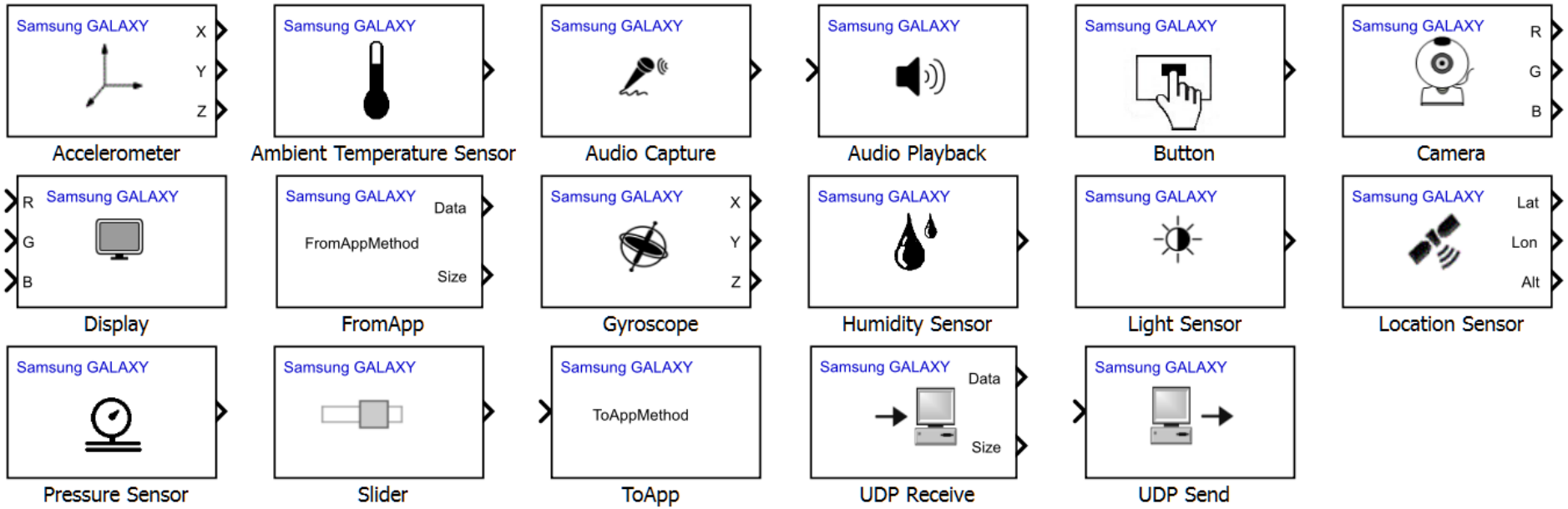
- Android and iOS
- Arduino® Uno , Mega 2560
- LEGO® MINDSTORMS® NXT
- Raspberry Pi Model B
- BeagleBoard-xM
- PandaBoard
- BeagleBone Black
- RTL-SDR



[Hardware Support]

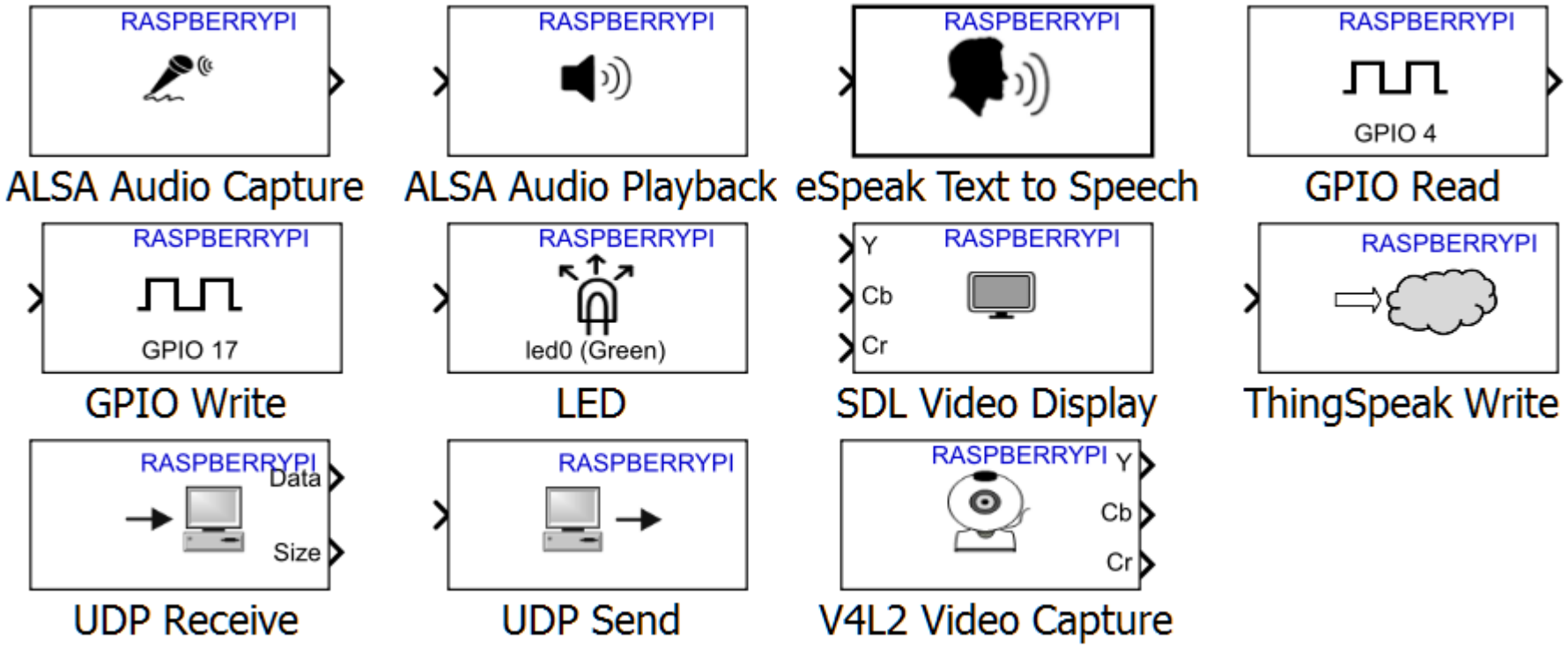
Simulink Support Package for Android Devices

- Interactive parameter tuning and signal monitoring
- Model deployment for standalone operation
- Simple UI using sliders and buttons
- Generation of Android Studio compatible projects



Simulink Support Package for Raspberry Pi

- Interactive parameter tuning and signal monitoring
- Model deployment for standalone operation

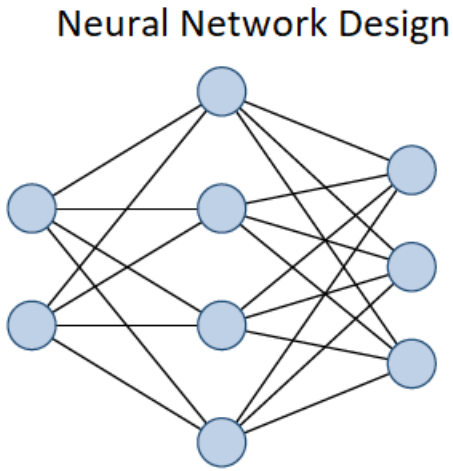


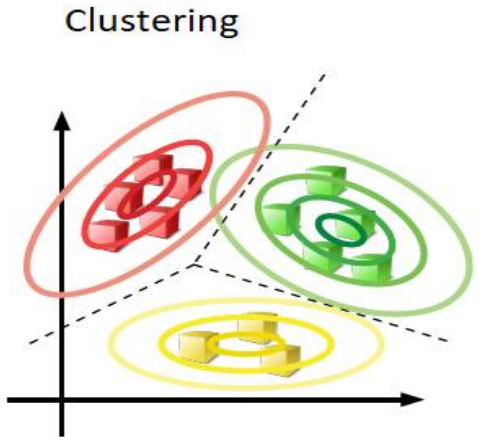
Key Takeaways

- Data access from multiple sensors on embedded device
- Iterative feature extraction and Machine learning model development
- Tuning model for embedded deployment
- Implementing and deploying models on embedded devices

Machine Learning with MATLAB

- This two-day course focuses on data analytics and machine learning techniques in MATLAB. The course demonstrates the use of unsupervised learning to discover features in large data sets and supervised learning to build predictive models. Topics include:
- Organizing and preprocessing data
- Clustering data
- Creating classification and regression models
- Interpreting and evaluating models
- Simplifying data sets
- Using ensembles to improve model performance



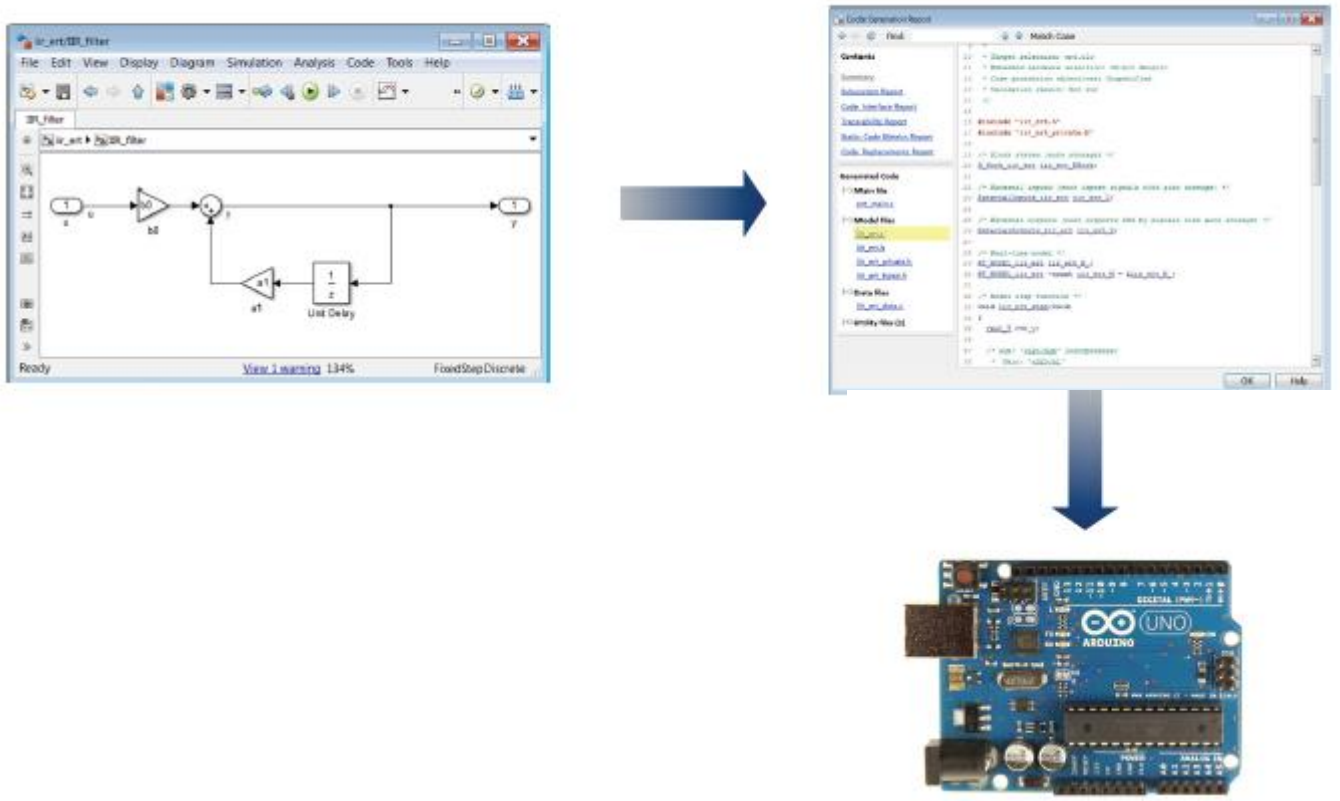


Embedded Coder for Production Code Generation

This hands-on, three-day course focuses on developing models in the Simulink® environment to deploy on embedded systems. The course is designed for Simulink users who intend to generate, validate, and deploy embedded code using Embedded Coder®.

Topics include:

- Generated code structure and execution
- Code generation options and optimizations
- Integrating generated code with external code
- Generating code for multirate systems
- Customizing generated code
- Customizing data
- Deploying code



MATLAB EXPO 2019

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