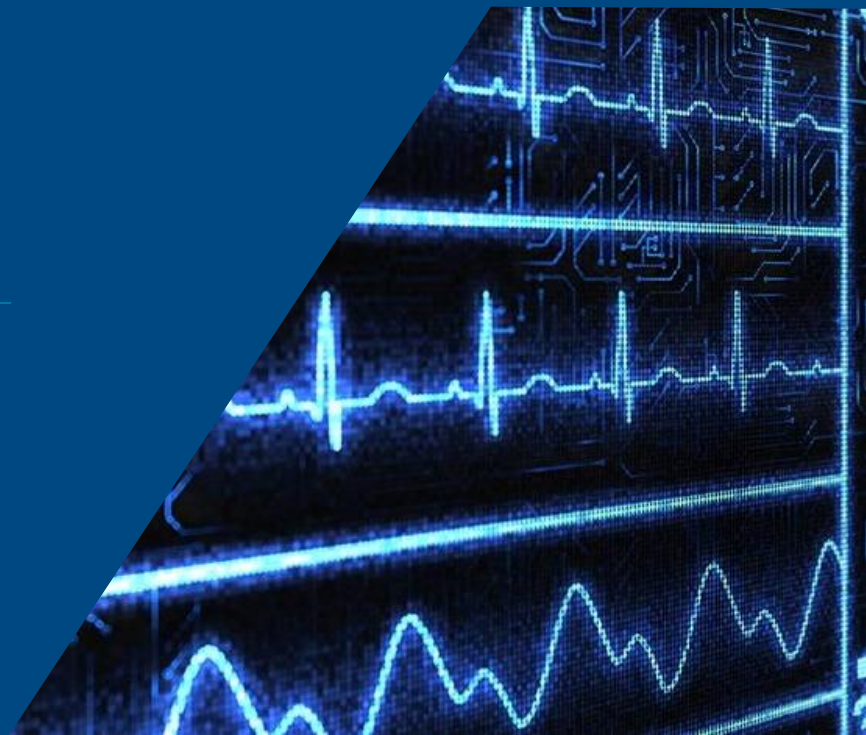
# Machine and Deep Learning for Medical Signals

**Ho Chi Minh City University of Technology (HCMUT)**

Kantika Wongkasem

*Ascendas Systems*



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## Machine Learning

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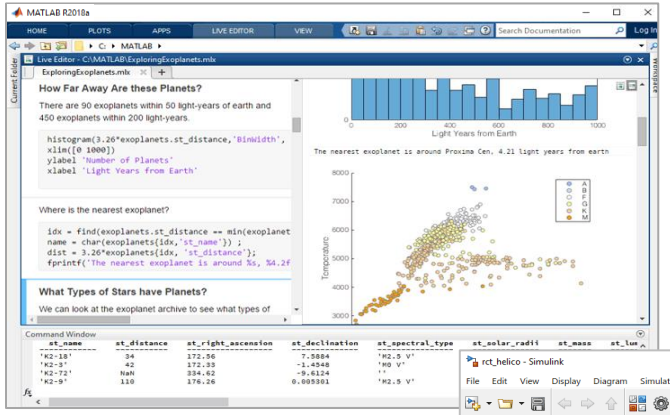
*Top Machine Learning Software Awards 2022 | Software Reviews

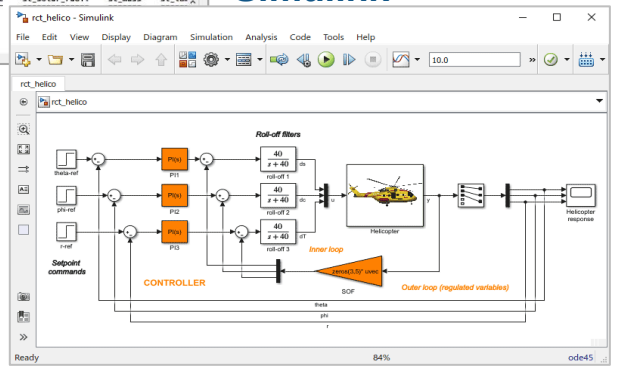
# MATLAB® & SIMULINK®

- **MATLAB** – Create algorithms and AI models for biomedical data analysis
- **Simulink** – Simulate complex medical devices with sensors and software
- **Over 100 add-on products** for specialized R&D tasks

**MATLAB**




**Simulink**



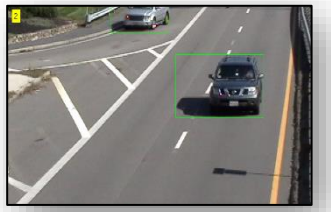
# Outline

- Overview of Machine Learning and Deep Learning Workflow
- Medical Signal Processing in Application
- Examples of Deep Learning in Medical Imaging
- Medical Device Applications
- Resources for further learning

# Machine Learning is Everywhere

## Solution is too complex for hand written rules or equations

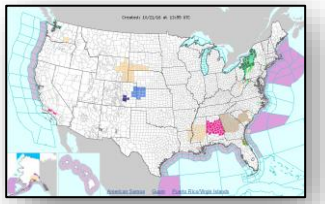
Speech Recognition


Object Recognition


Engine Health Monitoring

*learn complex non-linear relationships*

## Solution needs to adapt with changing data

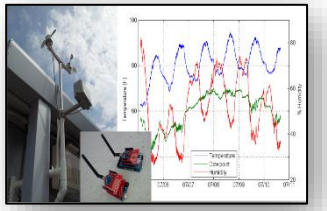

Weather Forecasting


Energy Load Forecasting

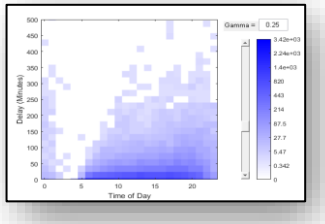

Stock Market Prediction

*update as more data becomes available*

## Solution needs to scale

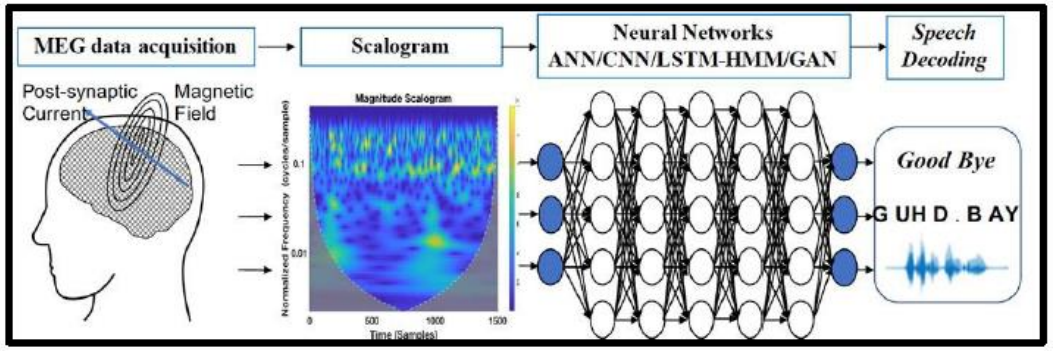

IoT Analytics

Taxi Availability

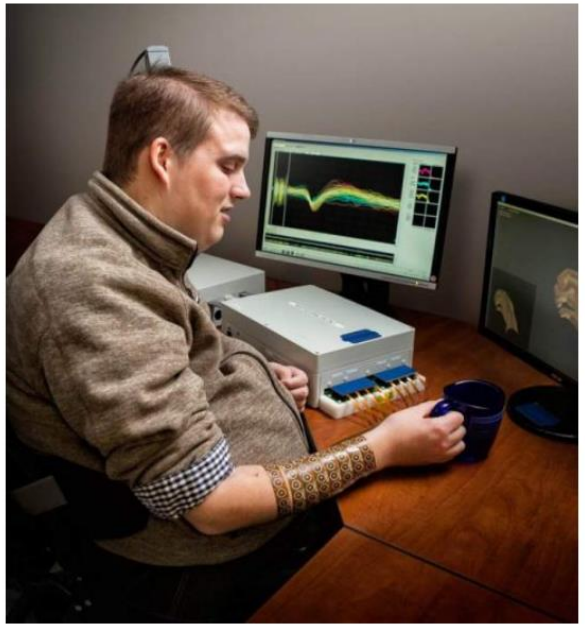

Airline Flight Delays

*learn efficiently from very large data sets*

# What about medical signals?

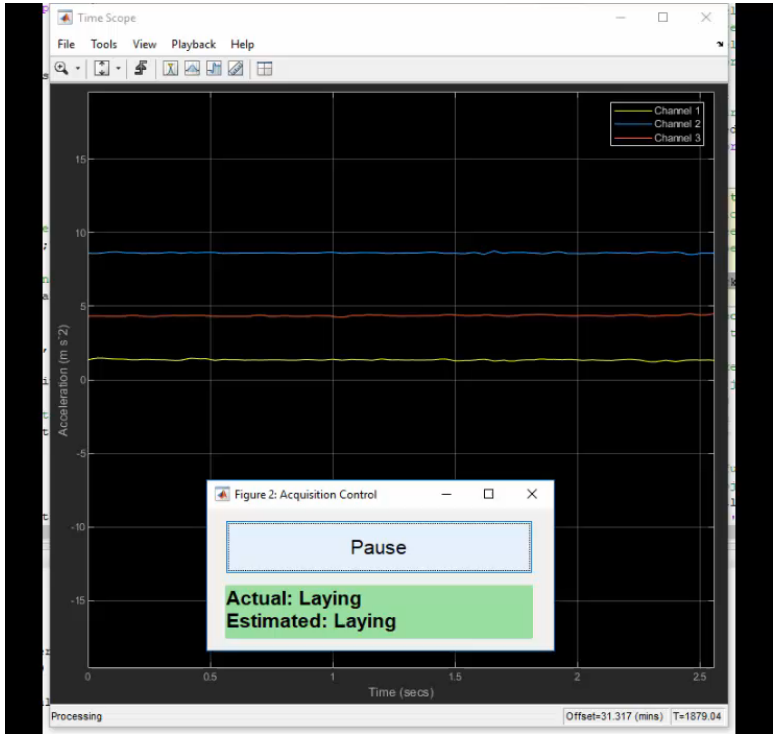



[Converting brain waves to speech to help ALS patients communicate](#) (Nov 2019)



Patient using the Battelle NeuroLife system.

The AirSonea device and mobile app housing the wheeze analysis algorithms.




**Signal Classification using LSTMs**

# Machine/Deep Learning Workflow

**Access and Explore Data**

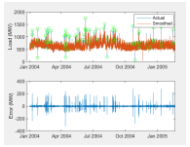
**Files**

**Databases**

**Sensors**

**Preprocess Data**

**Working with Messy Data**



**Data Reduction/ Transformation**

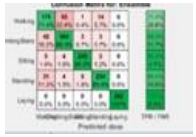
**Feature Extraction**

**Develop Predictive Models**

**Model Creation e.g. Machine Learning**

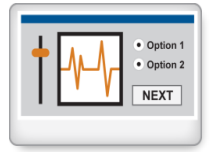

**Parameter Optimization**

**Model Validation**



**Integrate Analytics with Systems**

**Desktop Apps**



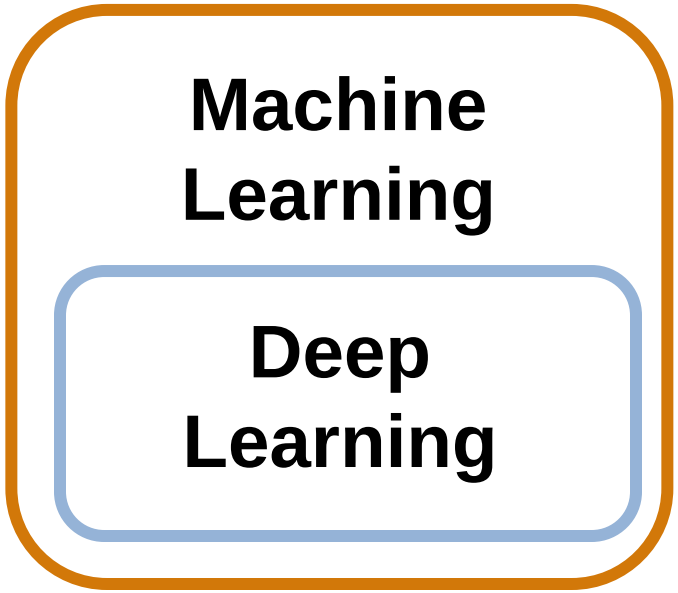

**Enterprise Scale Systems**

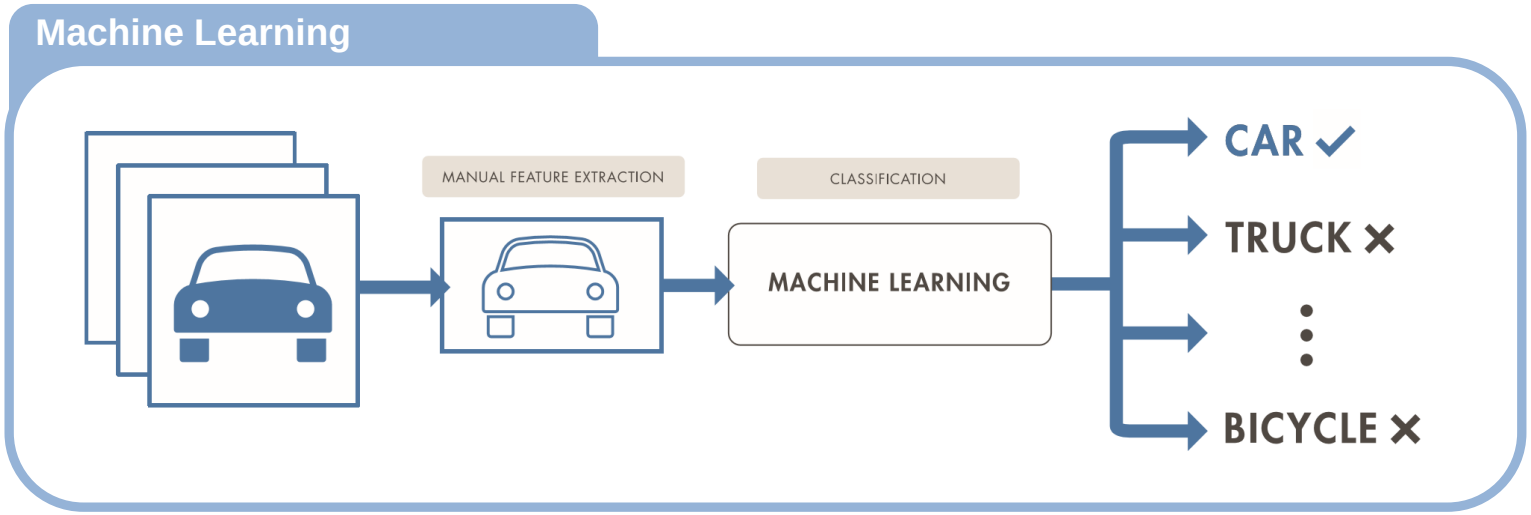
MATLAB Excel .NET .exe C/C++ Java .dll

**Embedded Devices and Hardware**

# Machine Learning…

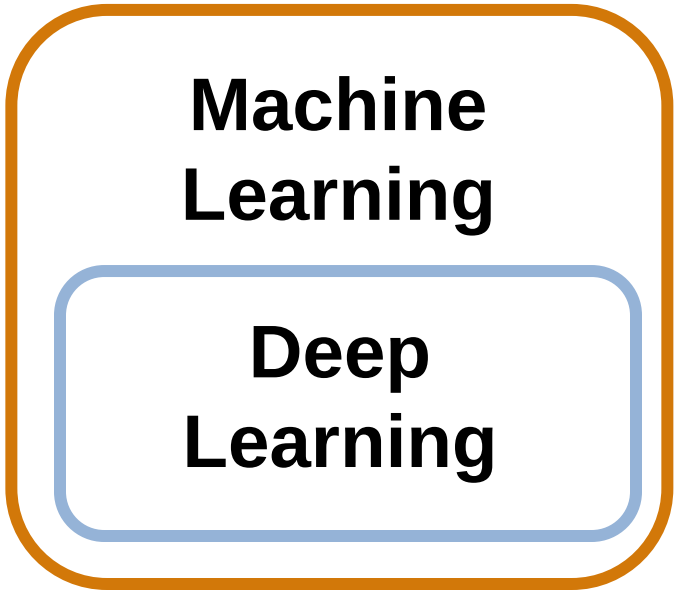
- Ability to learn from data inherently without being explicitly programmed
  - Learns complex non-linear relationship
  - Updates as more data becomes available
  - Requires manual feature extraction from most datasets (images, signals etc)

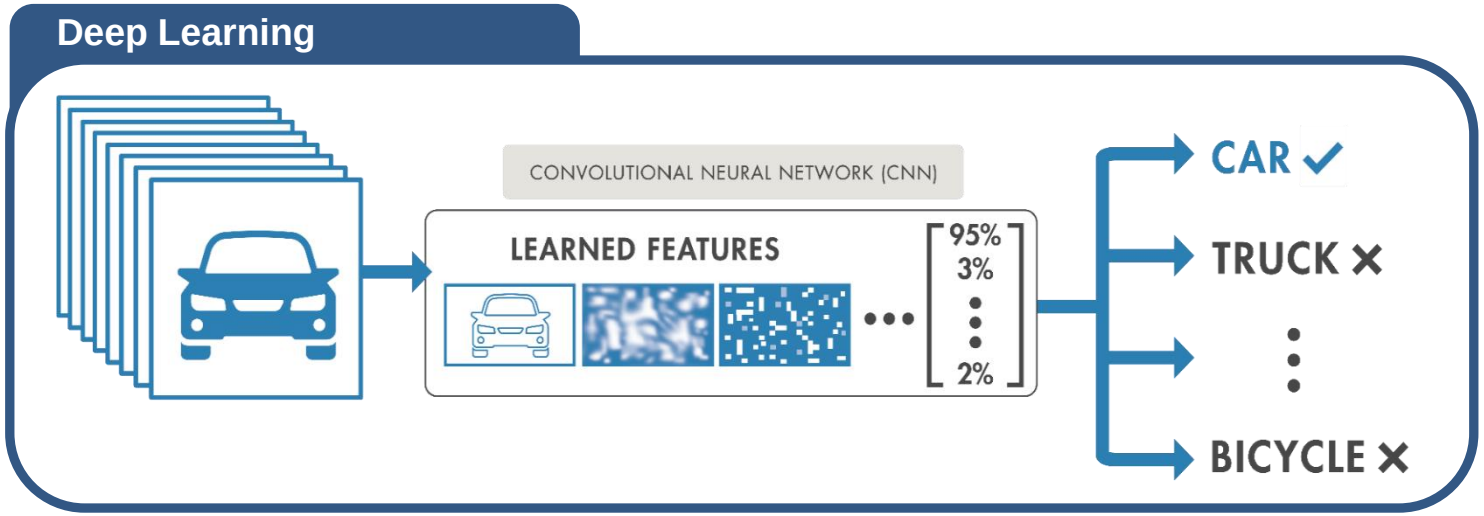


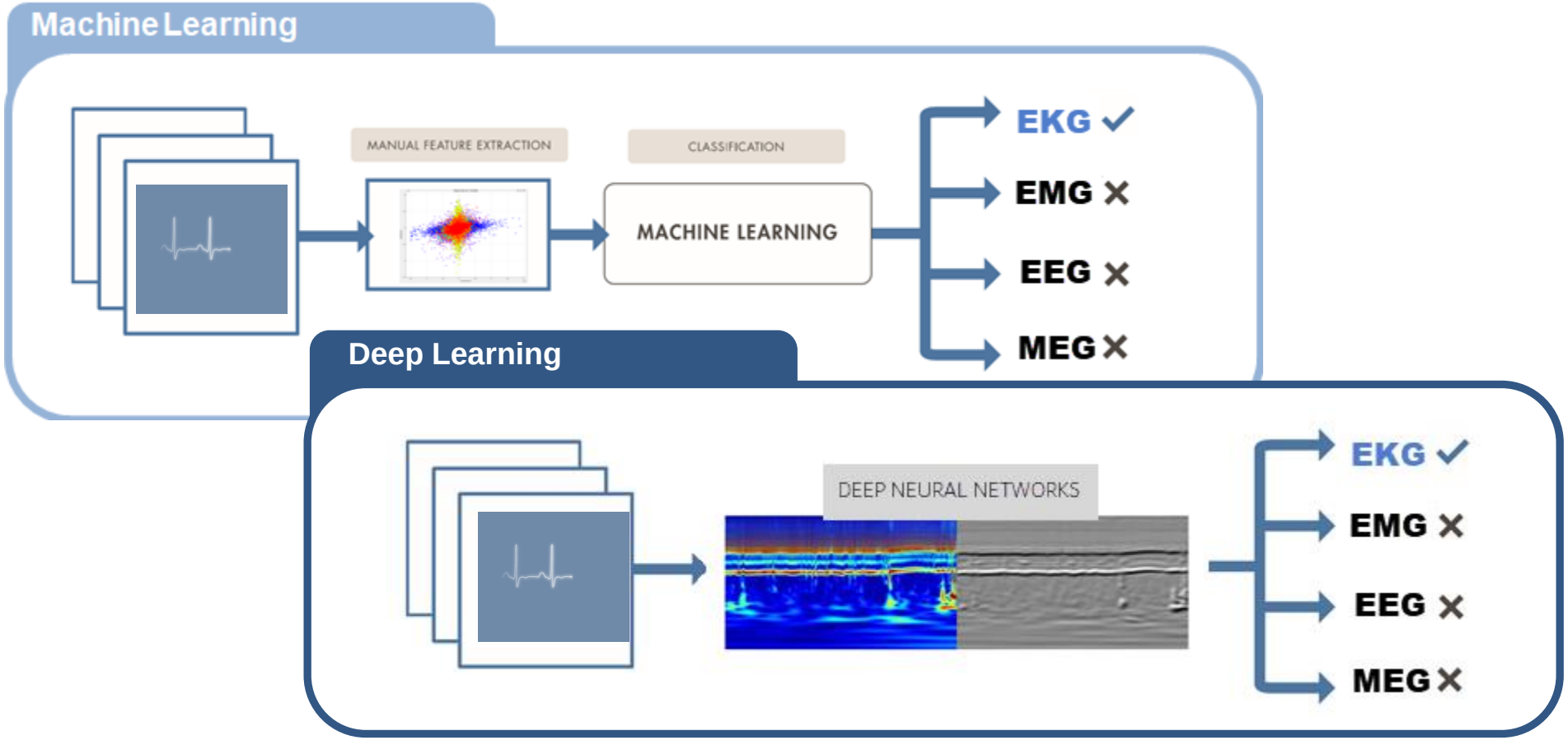
# Deep Learning…

- Subset of machine learning with automatic feature extraction
  - Learns features and tasks directly from data (images, text, signals etc.)
  - Can be supervised, unsupervised, or semi-supervised
  - More Data = better model



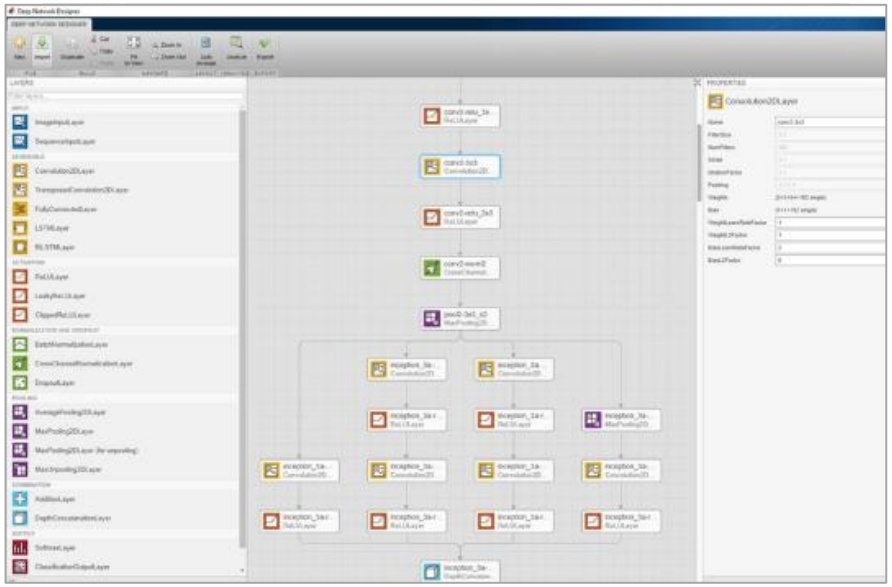
# Machine Learning vs Deep Learning



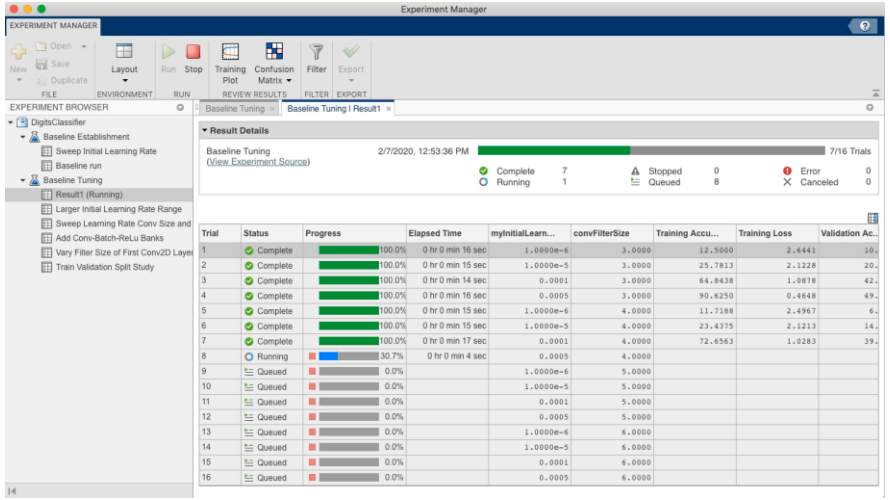

Deep learning performs **end-to-end learning** by learning **features, representations and tasks** directly from **images, text and signals**

# Increase productivity using Apps for design and analysis

Use MATLAB Apps to design deep learning networks, explore a wide range of classifiers, train regression models, train an optical character recognition model, and more.



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




**Experiment Manager** app to manage multiple deep learning experiments, analyze and compare results and code



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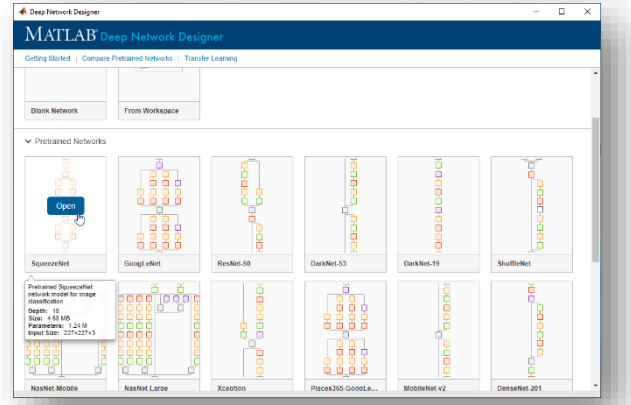
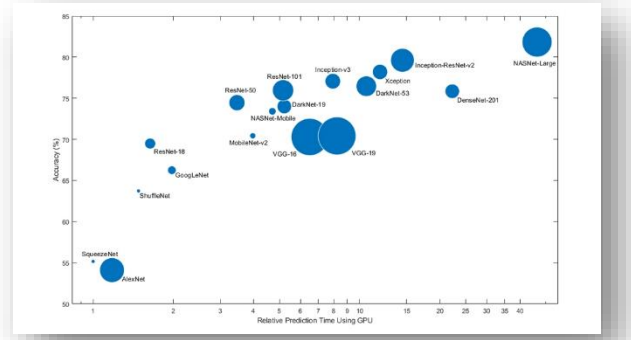
# Import pre-trained models for fast implementation

- **Access pretrained networks** and use them as a starting point for new models
  - Multiple pre-trained networks available online
- **Perform transfer learning** to use the learned features in the network for a specific task
- **Compare the accuracy of pre-trained networks** for a specific medical imaging task




*A list of pretrained networks*




*Analysis of pretrained models*

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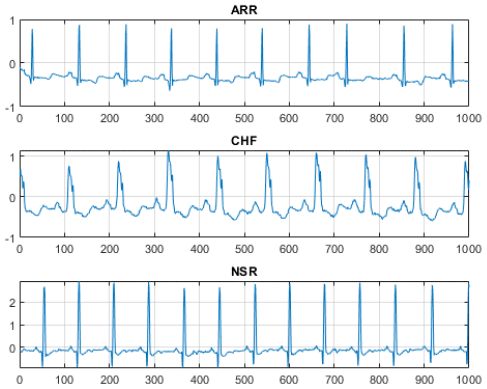
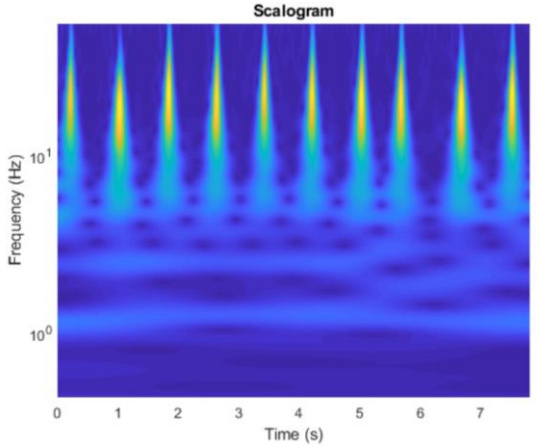
# Analyse and synthesise biomedical signals using wavelets

- **Use wavelets to extract features** from biomedical signals for machine and deep learning
- Continuous Wavelet Transform (CWT) is **ideal for analysing nonstationary signals**
- **Detect and analyse changes in frequency content** of signals over time
- **Use wavelets of biomedical signals as inputs** for deep learning models



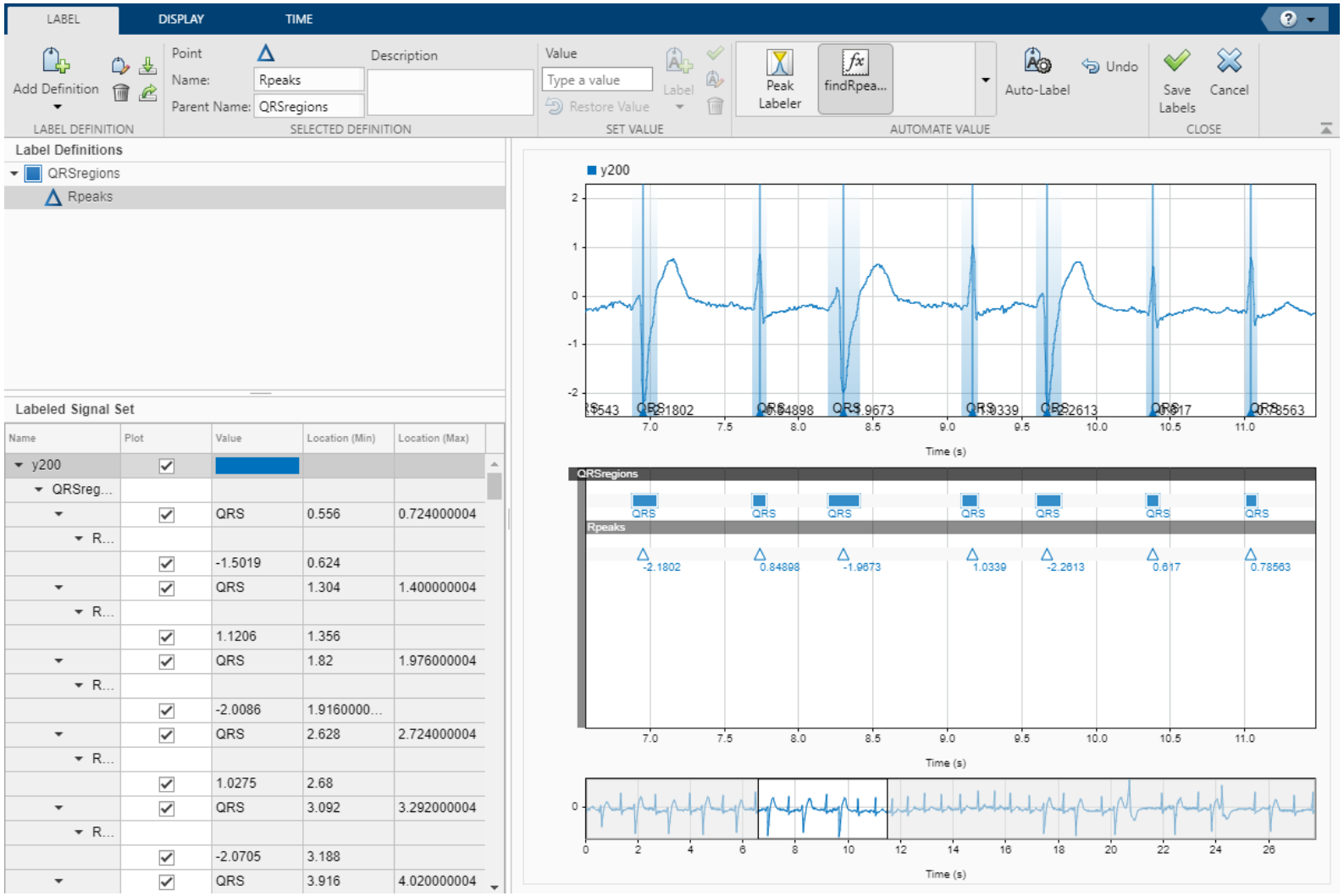

*Cardiac arrhythmia (ARR), congestive heart failure (CHF) and normal sinus rhythms (NSR)*



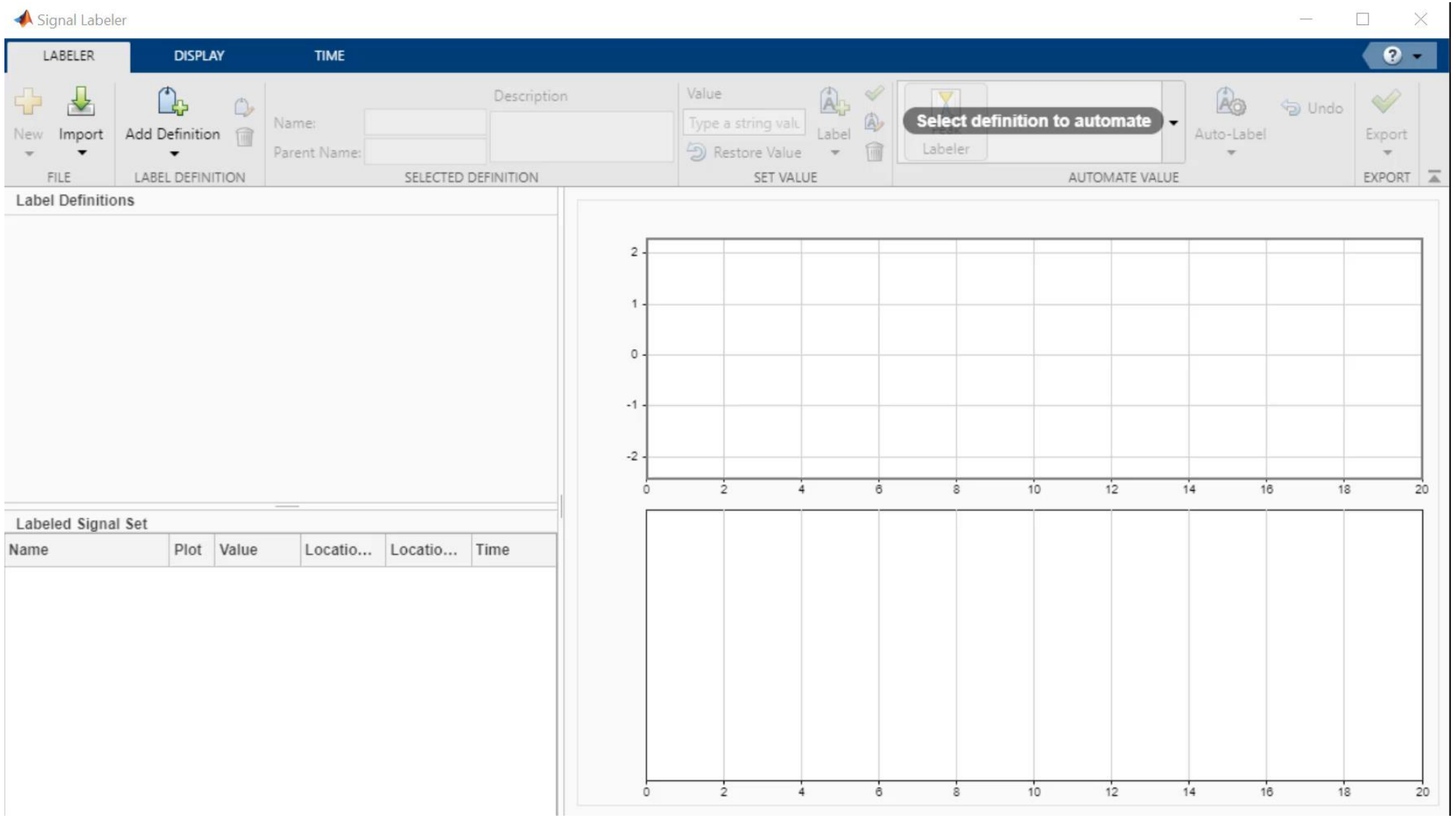

*CWT generated 2-D time-frequency maps of ECG time series data*

# Example: Label QRS Complexes and R Peaks

## **Signal Labeler**



# Signal Labeling app Video

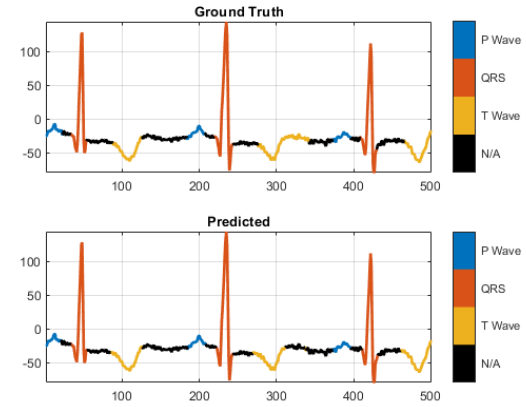


# Use advanced signal analysis techniques

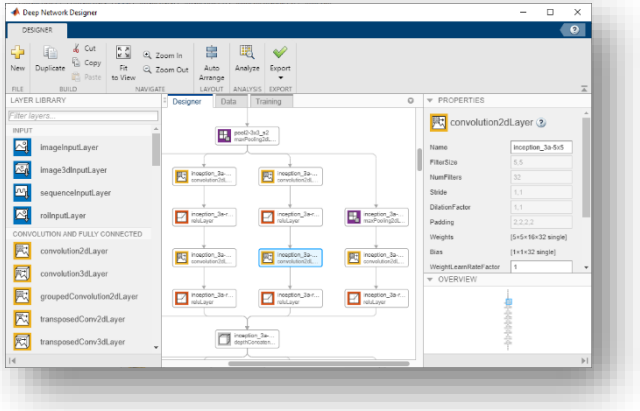
- **Use deep learning for biomedical signal processing tasks** such as segmentation, classification and detection

- **Interactively create and edit deep learning networks**
  - Built-in Deep Network Designer app

- Analyse network architecture to **detect errors and layer compatibility issues** before training




*ECG segmentation using deep learning and LSTM network*



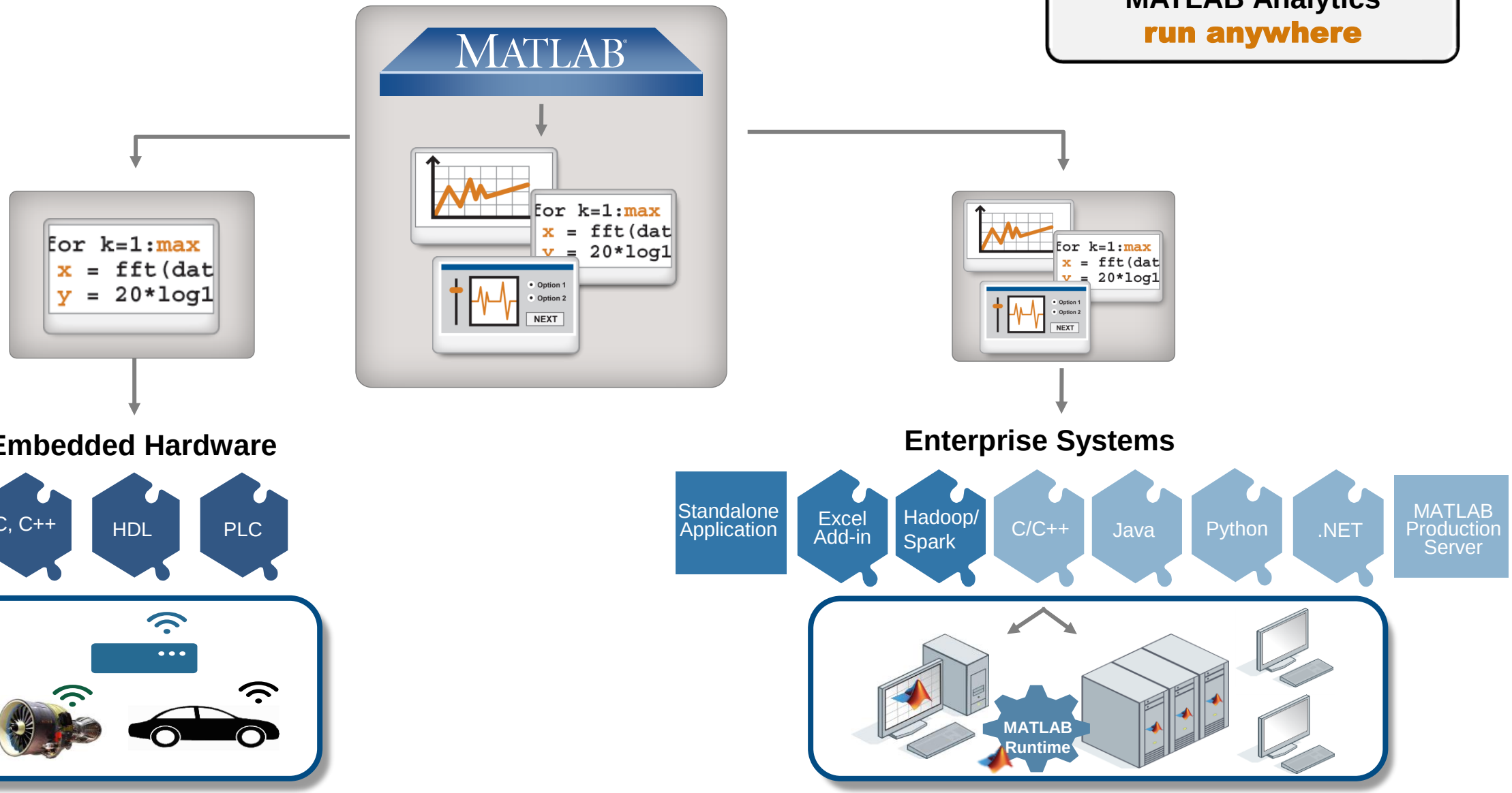

*Interactively build and visualise network structures*

# Deployment Solutions

## Embedded and Enterprise

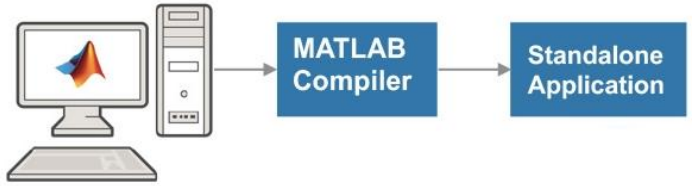
# Integrate analytics with systems

**MATLAB Analytics**
**run anywhere**

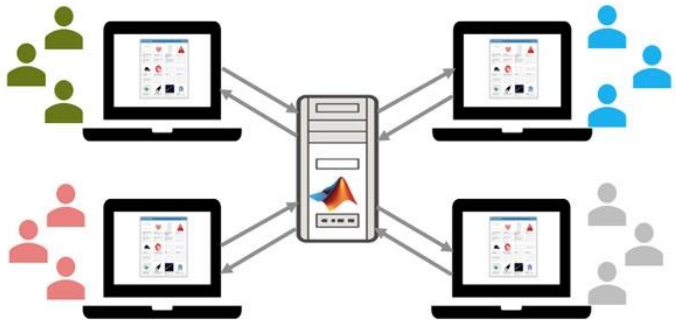


# Build desktop and web apps for validation

- MATLAB Compiler allows **sharing algorithms as standalone, web apps and MS Excel add-ins**
- Applications and add-ins can be **run on any computer using the MATLAB Runtime**
  - No need to install MATLAB
- Web applications can be hosted online and shared with users **in a trusted intranet environment**

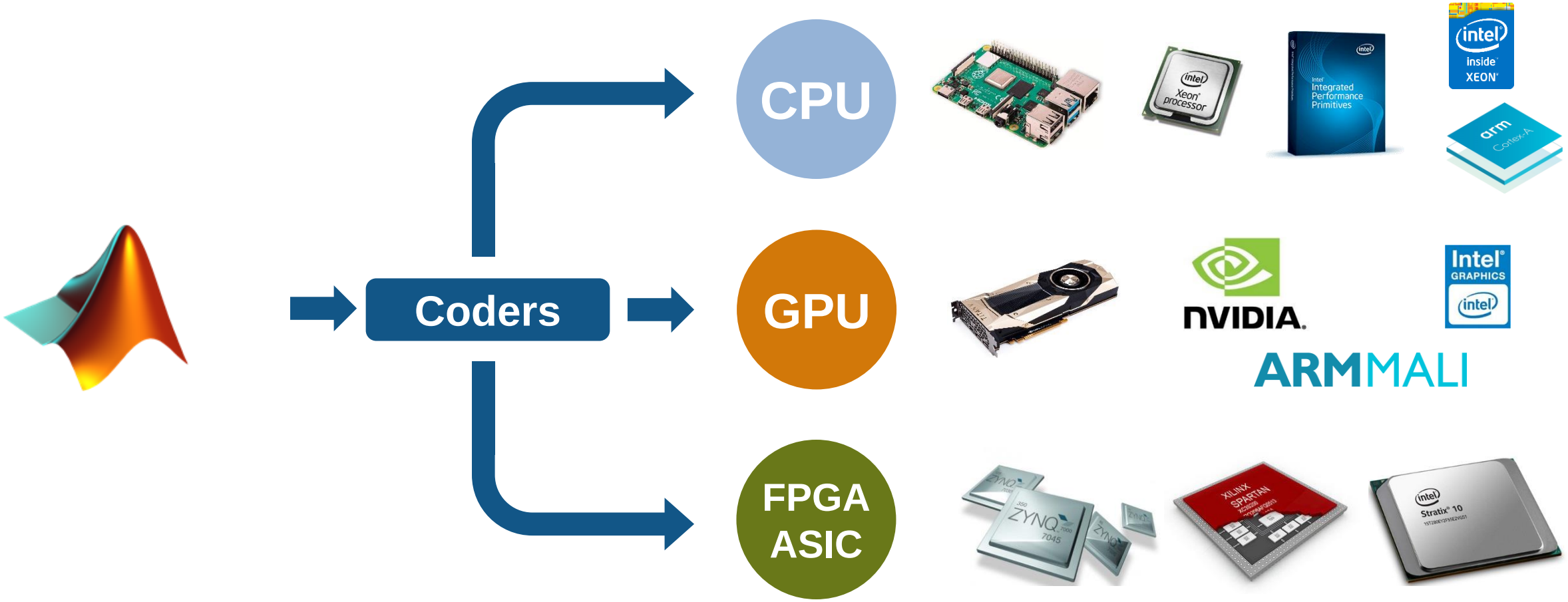



*Build standalone applications for desktop use*



*Share applications with users in a trusted intranet*

# Automatically generate code for target hardware



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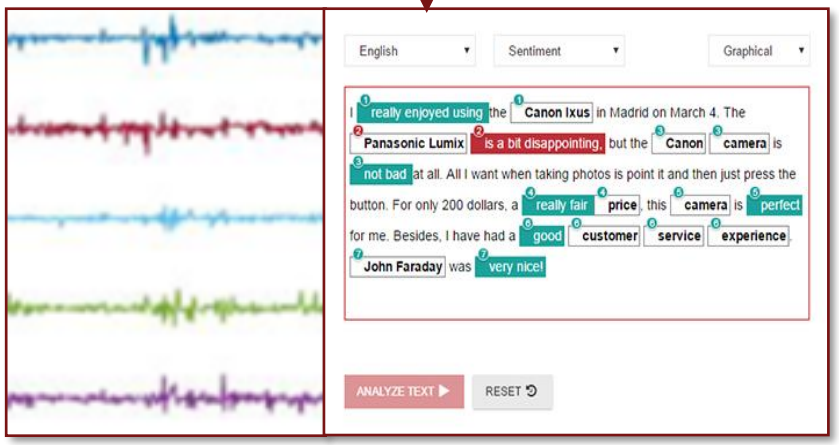
# Types of Data

## Numeric Data

| ID | WC_TA | RE_TA | EBIT_TA | MVE_BVTD | S_TA | Industry | Rating |
|---|---|---|---|---|---|---|---|
| 62394 | 0.013 | 0.104 | 0.036 | 0.447 | 0.142 | 3 | BB |
| 48608 | 0.232 | 0.335 | 0.062 | 1.969 | 0.281 | 8 | A |
| 42444 | 0.311 | 0.367 | 0.074 | 1.935 | 0.366 | 1 | A |
| 48631 | 0.194 | 0.263 | 0.062 | 1.017 | 0.228 | 4 | BBB |
| 43768 | 0.121 | 0.413 | 0.057 | 3.647 | 0.466 | 12 | AAA |
| 39255 | -0.117 | -0.799 | 0.01 | 0.179 | 0.082 | 4 | CCC |
| 62236 | 0.087 | 0.158 | 0.049 | 0.816 | 0.324 | 2 | BBB |
| 39354 | 0.005 | 0.181 | 0.034 | 2.597 | 0.388 | 7 | AA |
| 40326 | 0.47 | 0.752 | 0.07 | 11.596 | 1.12 | 8 | AAA |
| 51681 | 0.11 | 0.337 | 0.045 | 3.835 | 0.812 | 4 | AAA |

Machine Learning or LSTM

## Time Series/ Text Data

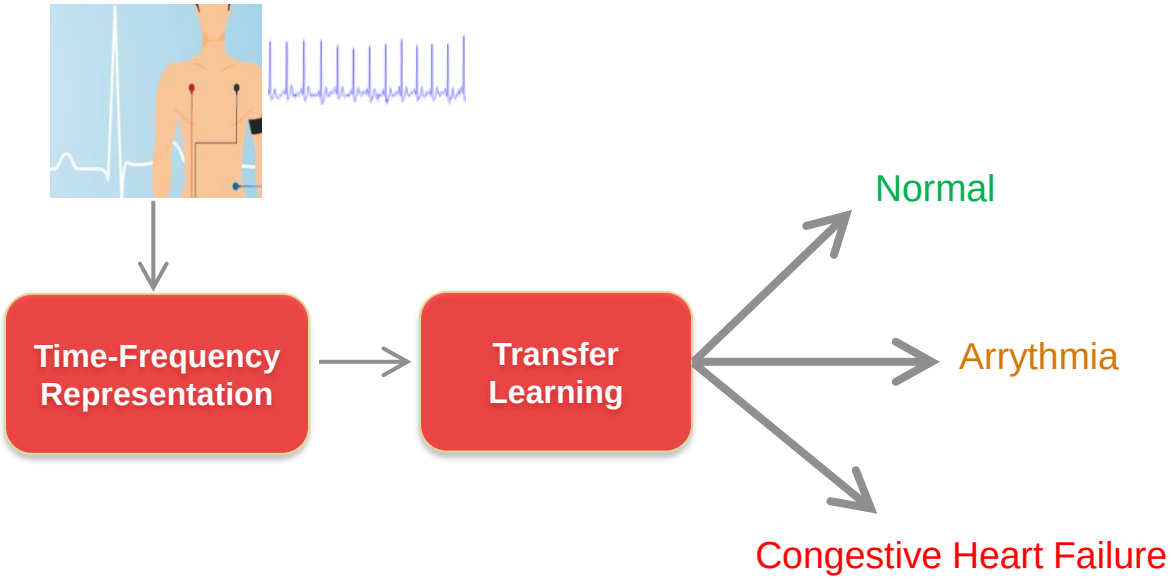



LSTM or CNN

## Image Data

CNN

# MATLAB Example: Transfer Learning for EKG Classification




- Customize pre-trained CNN architectures
- CNNs are great at extracting features from input representations
- Leverage time-frequency maps
  - convert 1-D signal to 2-D
- Quickly build a model

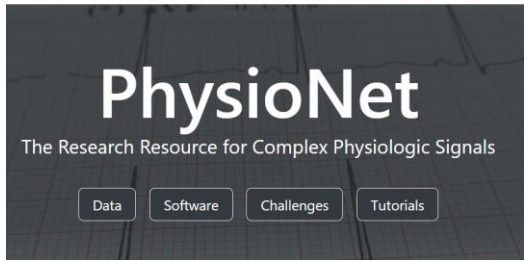
**Objective:**

- Develop a classifier quickly to classify EKG signals

## In other words …

# Learn how to implement the entire AI pipeline on real-world signal data

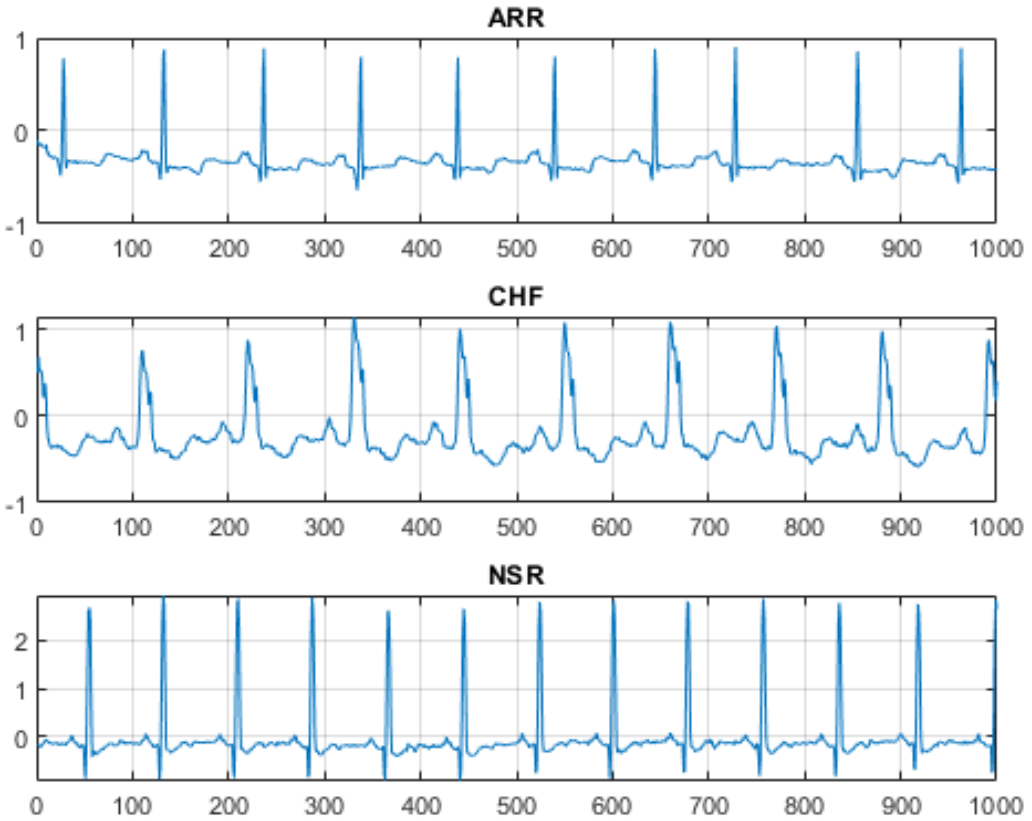
EKG Data Source :




162 EKG records of 3 classes

- NSR : Normal Sinus Rhythm h
- ARR : Cardiac Arrythmia
- CHF : Congestive Heart Failure

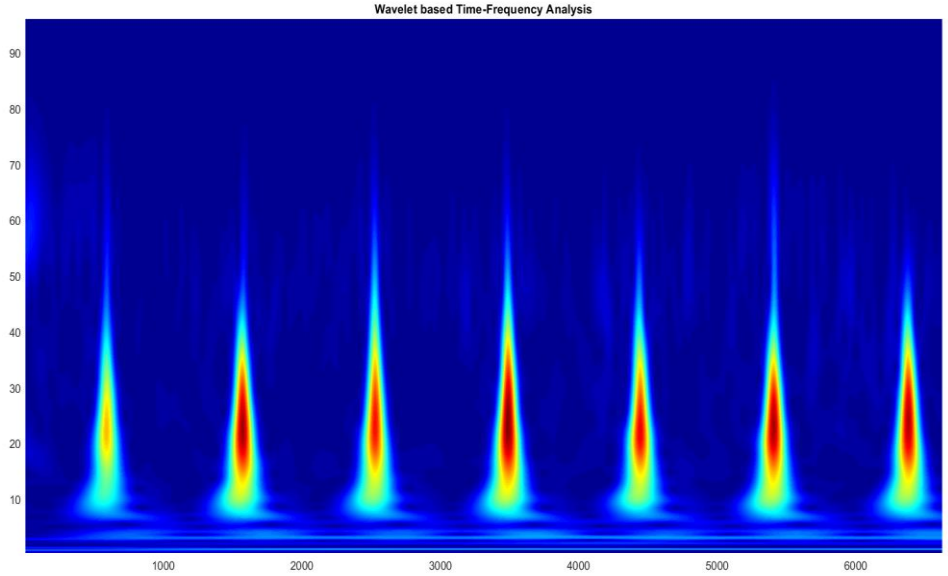
Each record has 65536 samples → 512s data @ 128 Hz



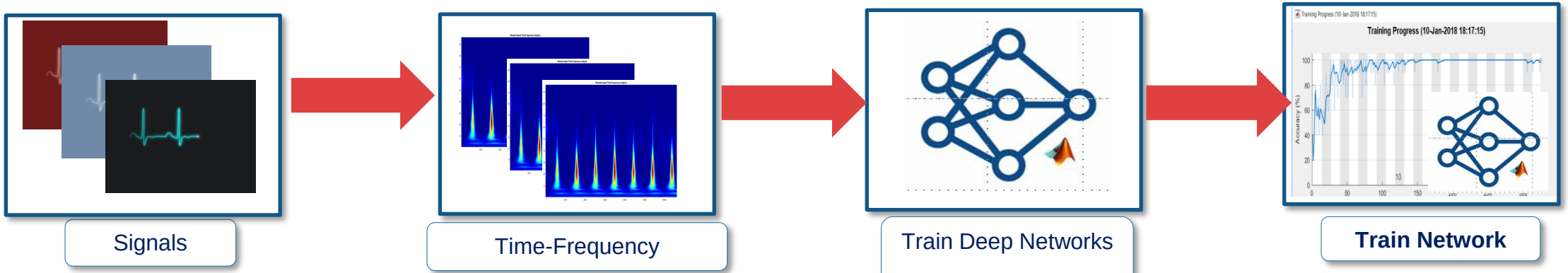
# Time-Frequency Representations in MATLAB

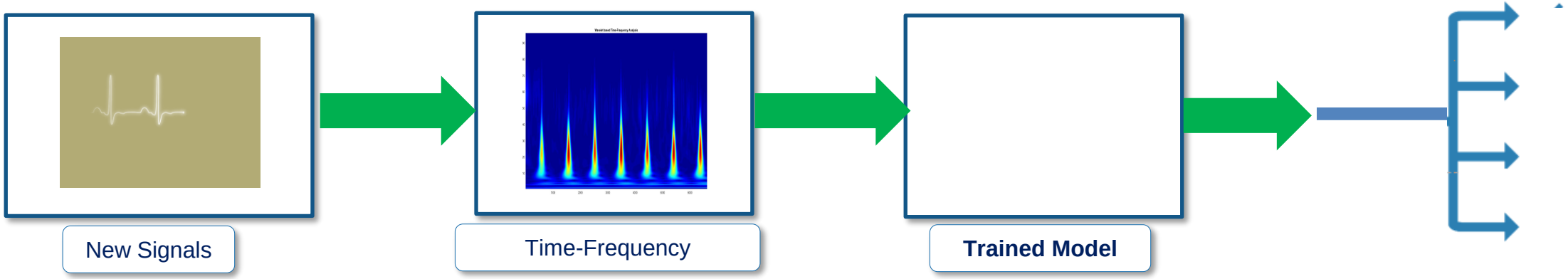
- A time-frequency representation captures how spectral content of signal evolves over time
  - can be saved as an image .

- Many time-frequency representations are available
  - spectrogram,
  - mel-frequency spectrograms,
  - scalogram (continuous wavelet transform)
  - Constant Q Transform etc.

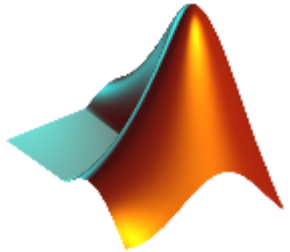


# Overall Workflow – Deep Learning on Signals with CNNs



# Open MATLAB



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# UT Austin Researchers Convert Brain Signals to Words and Phrases Using Wavelets and Deep Learning

## Challenge

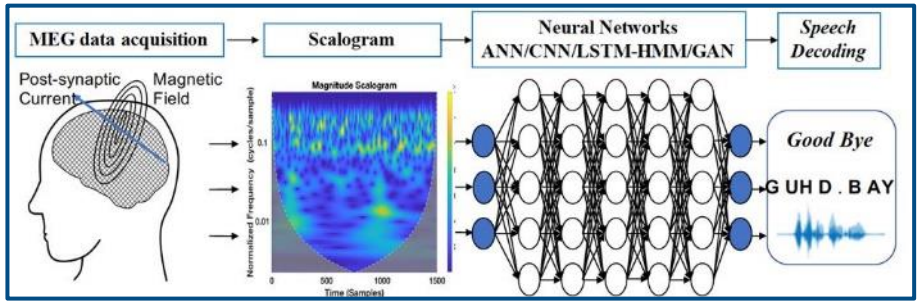
Create a speech-driven brain-computer interface to enable ALS patients to communicate by imagining the act of speaking specific phrases

## Solution

Use wavelet scalograms of MEG signals to train deep neural networks

## Results

- Classification accuracy of 96% achieved
- Wavelets and deep learning networks quickly combined
- Training times accelerated by a factor of 10




**Classifying the brain signals corresponding to the imagined word "goodbye" using feature extraction and deep neural networks.**

*"MATLAB is an industry-standard tool, and one that you can trust. It is easier to learn than other languages, and its toolboxes help you get started in new areas because you don't have to start from scratch."*

*- Dr. Jun Wang, UT Austin*

Link to user story

# VivaQuant Accelerates Development and Validation of Embedded Device for Ambulatory ECG Sensing

## Challenge

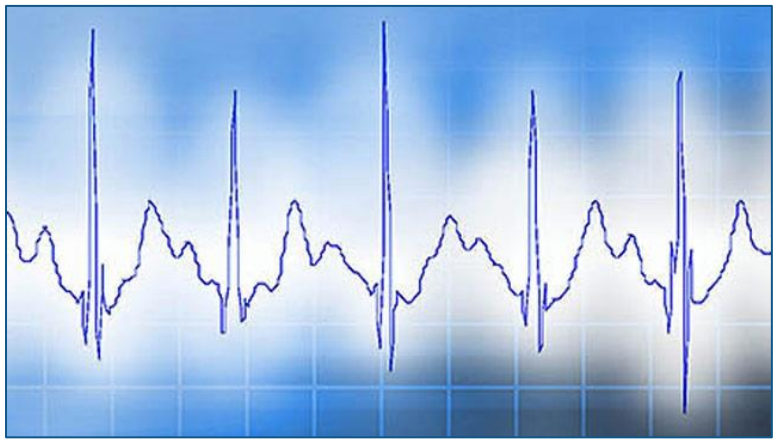
Design and implement an embedded system for extracting accurate information from noisy electrocardiogram signals

## Solution

Use MATLAB to develop an algorithm for removing in-band noise, and use Fixed-Point Designer and MATLAB Coder to implement it on an ARM Cortex-M series processor

## Results

- Development accelerated by 300%
- Power and memory consumption minimized
- Rigorous testing enabled



**ECG snippet after processing with VivaQuant's embedded in-band noise removal algorithm**

"MATLAB, MATLAB Coder, and Fixed-Point Designer enabled our small team to develop a complex real-time signal processing algorithm, optimize it to reduce power and memory requirements, accelerate embedded code implementation, and perform the rigorous testing required for medical device validation."

*- Marina Brockway, VivaQuant*

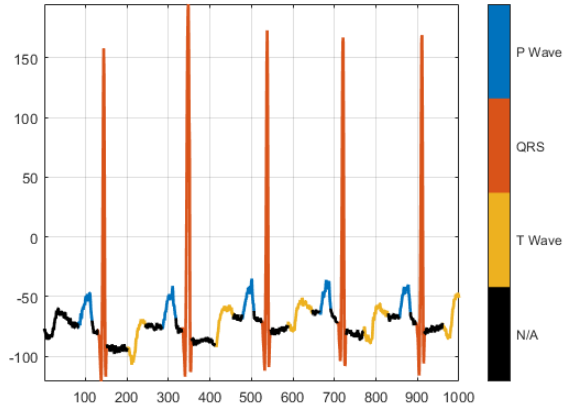
Link to user story

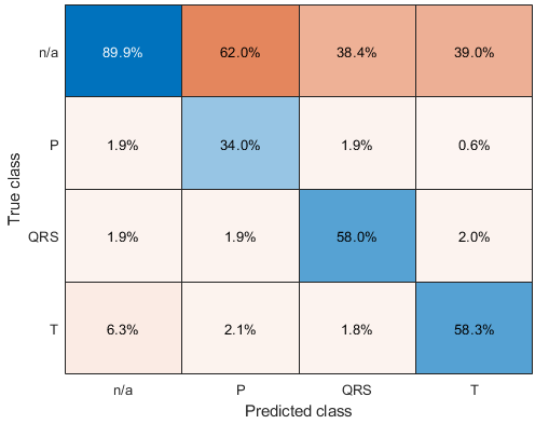
# Outline

- Overview of Machine Learning and Deep Learning Workflow
- Medical Signal Processing in Application
- Examples of Deep Learning in Medical Imaging
- Medical Device Applications
- Resources for further learning

# Online examples of deep learning for biomedical signals

- Classify ECG Signals Using Long Short-Term Memory Networks
- Classify ECG Time Series Using Wavelet Analysis and Deep Learning
- Label QRS Complexes and R Peaks of ECG Signals Using Deep Network
- ECG Waveform Segmentation Using Deep Learning
- Get Started with Deep Network Designer

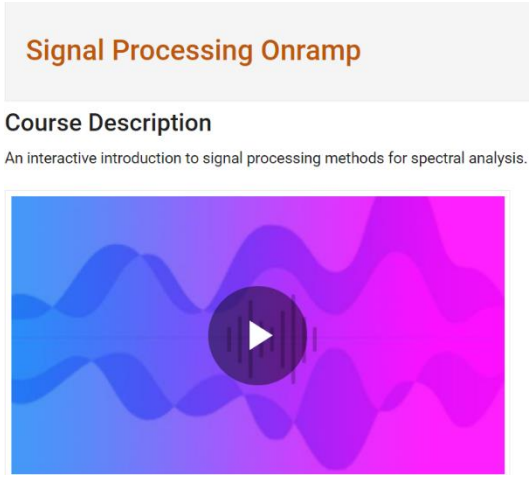


# Learn more

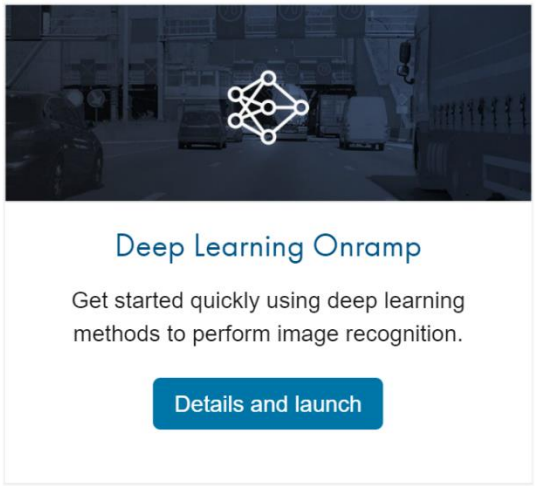
## Interactive tutorials

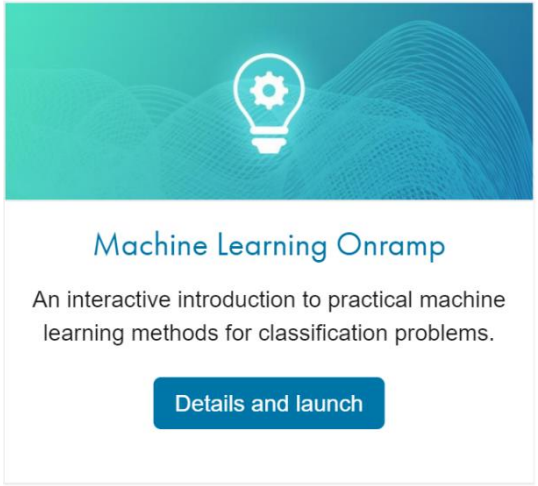
- MATLAB Onramp
- Simulink Onramp
- Stateflow Onramp


## Webinars

- What is MATLAB?
- What is Simulink?
- Model-Based Design with MATLAB and Simulink




## Onsite or self-paced training courses

- MATLAB Fundamentals
- Deep Learning with MATLAB
- Signal Processing with MATLAB

# Engineering support

- Trials and evaluations
- Consulting services
- Training services
- Technical support

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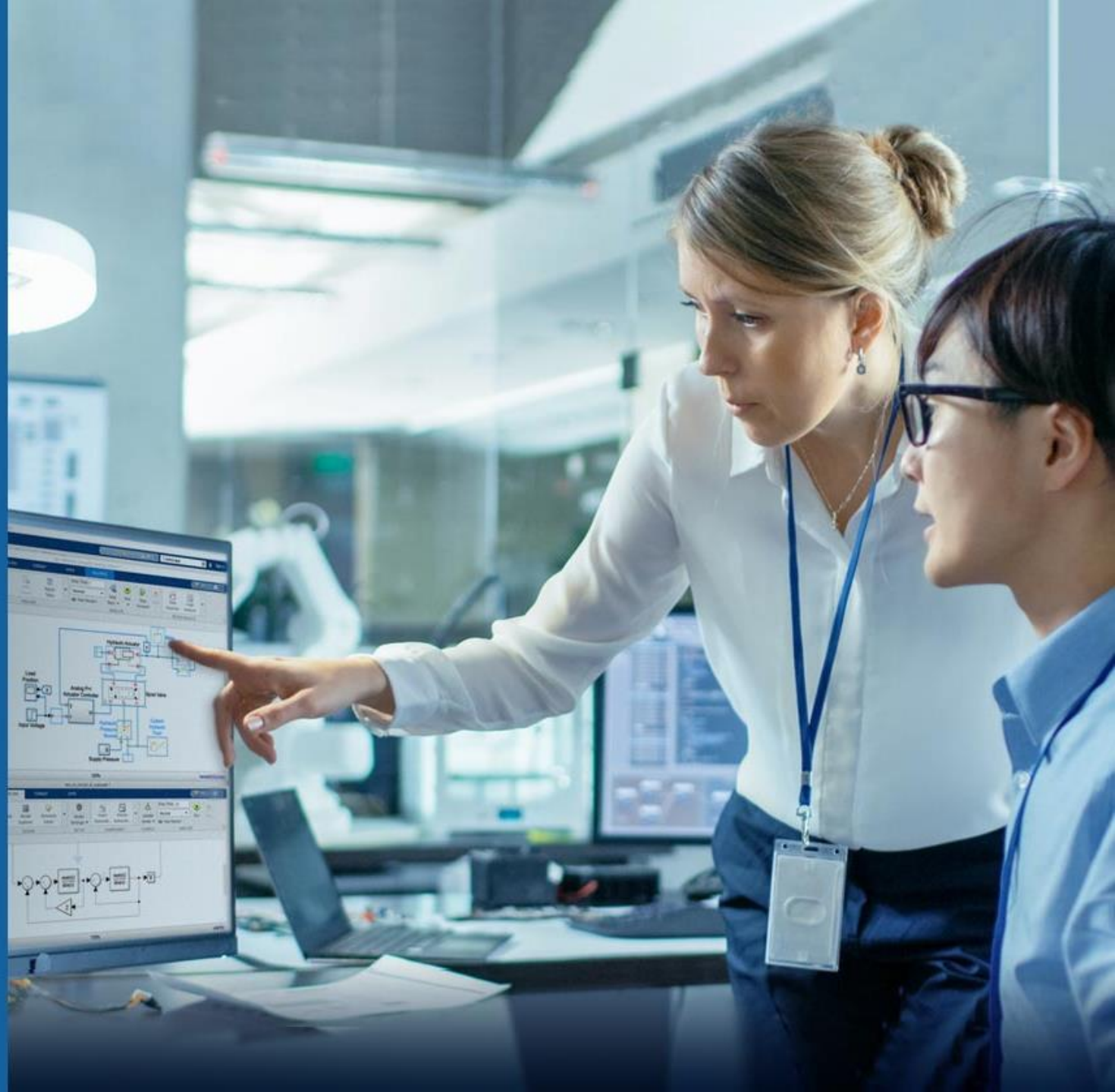

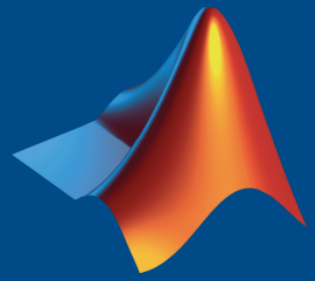

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