MATLAB EXPO 2018
KOREA
Agenda

▪ Radar and EW modeling
▪ Synthesizing data for Machine Learning workflows
▪ Machine Learning Examples
Radar and EW Simulation and Modeling Architecture

- Functions for calculations and analysis
- Apps for common workflows
- Parameterized components for system modeling
- Easy path to increased fidelity for antenna and RF design
- Code generation for deployment

\[ P_r = \frac{P_t G_t G_r \lambda^2 \sigma}{(4\pi)^3 R_t^2 R_r^2 L} \]
Design Phased Array Antennas

- Design an array
- Design subarrays
- Model imperfections
- Import antenna patterns

- Taper/thin arrays
- Synthesize arrays
- Model failures
- Model mutual coupling
Design Radar and EW Systems

Data cube processing

Detections

Polarization

Scenario visualization

Spatial signal processing

Targets & Environment

Wideband

Code generation

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▪ Radar and EW modeling

▪ Synthesizing data for Machine Learning workflows

▪ Machine Learning Examples
Machine 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
- Embedded Devices and Hardware
Synthesize Radar Data for Machine Learning

- Collect data
- Synthesize data

Create data set  Train on data  Measure accuracy

Learn

Validate
Synthesize Received Radar Signals

Signal Parameter Estimation in a Radar Warning Receiver
Modern aircraft often carry a radar warning receiver (RWR) with them. The RWR detects the radar emission and warns the pilot.

Scan Radar Using a Uniform Rectangular Array
Simulates a phased array radar that periodically scans a predefined surveillance region. A 960-element rectangular array is used in this example.
Define a Backscatter Target with Angle and Frequency

\[ \text{rcs}_\text{cyl} = \text{cylinderrcs}(r1,r2,H,c,fc,az,el); \]
Model Basic Shapes
Model Extended Targets with Multiple Scatters

RCS Pattern of Extended Target with 4 Scatters

RCS Pattern at 0° Elevation for Extended Target with 4 Scatters

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- Radar and EW modeling
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- Machine Learning Examples
Machine Learning for Radar Examples

Signals
Features
Time-frequency
Etc.

Classification

Statistics and Machine Learning Toolbox

Synthesize returns (radar cross section)
Synthesize micro-Doppler (Time-frequency)
Synthesize waveforms
Signal Processing and Wavelets for Feature Extraction

- **Signal Manipulation**
  - Signal Analysis App

- **Time-Frequency Analysis Capabilities**
  - Short Time Fourier Transform
  - Continuous Wavelet Transform
  - Synchrosqueezing

- **Multiresolution Analysis Capabilities**
  - Discrete Wavelet Analysis
  - Wavelet Packets
Signal Analyzer App

Analyze signals in time, frequency and time-frequency domains

- With the Signal Analyzer you can:
  - Import multichannel signals
  - Explore signals jointly in time-frequency domain
  - Zoom and pan signals
Identifying Features in Real World Signals

Quantify time-varying signals in frequency domain

- Characterizing signal features in spectral domain is often challenging as one needs to appropriate tools
- Accurate time-frequency measurements are possible using wavelet based time frequency analysis techniques
- Features once identified, can be extracted from signals for further processing
- In this demo, we will characterize features in EKG signals using Continuous Wavelet Transform
Filtering Frequency Localized Components

- Sometimes unwanted signals can get captured during signal acquisition process
- A traditional filter cannot be used if the frequency range of the interference lies within the frequency range of the signal
- Unwanted components can be localized jointly in time and frequency using wavelets and removed
Wavelet Synchrosqueezing

- For certain non-stationary signals, wavelet Synchrosqueezing can be used to identify and extract signal modes.
- Wavelet Synchrosqueezing helps extract signal components from localized regions of time frequency plane.
Example 1: Radar Echoes from Cylinder and Cone
Generate law radar data from models

Create data set

Randomize parameters

Generate many data sets

Train on data
Extract features: 700 samples/object -> 8 samples/object with Wavelet Transform

```matlab
trainingData = varfun(@(x)modwptHelper(x,'fk6',2),RCSReturns);
trainingData = array2table(table2array(trainingData))';
trainingData.Type = shapeTypes([ones(50,1); zeros(50,1)]+1); % 50 cylinders followed by 50 cones
```
Testing Against Training Data

- Collect data
- Synthesize data

Create data set  Learn  Validate

Train on data  Measure accuracy

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<tbody>
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accuracy =

Test Accuracy 82.00
Classification Learner App

- Algorithms for training
- MATLAB code gen
- Classification metrics
Example 2: Micro-Doppler for Drones

Range-Doppler from Parrot Quadcopter

Micro-Doppler returns

We can identify:
- Rotation rate
- Number of blades
- Tip velocity
- Blade length
Synthesize Micro-Doppler Motion

Radar return

Range-Doppler of blade

Micro-Doppler Time-frequency

Rotation rate
Number of blades
Tip velocity
Blade length
Micro-Doppler in Time-Frequency Domain

Detection of small UAV helicopters using micro-Doppler by David Tahmoush
Example 3: Waveform Modulation ID for RWR
Radar & EW Classification – Workflow

Access and Explore Data
- Files
  - Databases
- Phased Array System Toolbox

Preprocess Data
- Statistics & Machine Learning Toolbox
  - Wavelet Toolbox
- Signal Processing Toolbox
  - Extraction
- Statistics & Machine Learning Toolbox
  - Validation
- Model Creation e.g. Machine Learning
  - Parameter Optimization

Develop Predictive Models
- Enterprise Scale Systems
  - Desktop Apps
  - MATLAB Coder

Integrate Analytics with Systems
- Embedded Devices and Hardware
Key Takeaways

- Radar and EW modeling
- Synthesizing data for Machine Learning workflows
- Machine Learning Examples
  - Synthesize Return, Micro-Doppler, Waveform
  - Classification: Target, Radar
Resources to Help You Get Started

매트랩과 머신러닝 (eBook)

MATLAB과 머신 러닝

머신 러닝에 관심을 가진 주셔서 감사합니다.

이제 다음 eBook을 다운로드할 수 있습니다.

- 챕션 1: 머신 러닝 소개
- 챕션 2: 머신 러닝 시작하기
- 챕션 3: 비지도(unsupervised) 학습 적용
- 챕션 4: 지도(supervised) 학습 적용

머신 러닝에 대한 추가 정보:

- 머신 러닝으로 간편하게 (34:34)
- 센서 데이터 분석을 위한 신호 처리 및 머신 러닝 기법 (42:45)
- 지도(supervised) 학습 워크플로우 및 알고리즘
- MATLAB 분석을 사용한 데이터 기반 통찰력: 에너지 부하 예측 사례 연구
- MATLAB 머신 러닝 예제

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