Introduction to Matlab

Functional Programming
and

Current Uses at ITTC

Instructor

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M-Files

• M-files
  – M-files can be used to create functional programs
    • Loops, switches, if…then statements
    • Functions
Loops

- Loops
  
  ```matlab
  for variable = expression
    statement...
  end
  
  while logical_expr
    statement...
  end
  ```
Switches

- Switches

```matlab
switch switch_expr
    case case_expr
        statement...
    case case_expr
        statement...
    otherwise
        statement...
end
```
if...then

• if...then
  
  if logical_expr
  statement...
  else
  statement...
  end
Functions

• Functions are stored in m-files
• M-file must begin with a declaration

```matlab
function [out] = function_name(arg1, arg2, ..., argN)
```
Functions

• Example: Trapezoid Rule for Numerical Integration

\[ \int_{a}^{b} f(x) \, dx \approx h \left( \frac{1}{2} y_0 + y_1 + y_2 + \ldots + \frac{1}{2} y_n \right) \]
function [sum] = trpzdint(f,a1,b1,points)

x=linspace(a1,b1,points);

h=x(2)-x(1);

f=eval(f);

sum=0;

for n=1:points
    if((n==1)||(n==points))
        sum=sum+(1/2)*f(n);
    else
        sum=sum+f(n);
    end
end

sum=h*sum;
Matlab Uses

• Common Engineering Uses
  – Mathematical Modeling
  – Interpretation / Presentation of Results
  – Filter Synthesis
  – System Stability Analysis
  – Statistics
  – Computer-controlled Experiments
  – Logging Experimental Data
Objective:
To characterize surface and sub-surface layers of Mars.

Principles:
- Every material on earth can be characterized by its Permittivity.
- Permittivity contrast in layered media causes reflection of incident EM Wave.

Challenges:
- Radar return is corrupted by noise & scattering components.
- This is a non-linear problem!

Solution:
Model Based Signal Processing!
Model Based Signal Processing
Model Based Signal Processing

- Model the radar return using Propagation model, scattering model and noise model.

- Permittivity profile can be obtained by minimizing the mean square error (MSE) between measured and modeled data.

```
Propagation and scattering model --- System Model

Modeled radar return

Actual radar return --- Model-Based Algorithm

Enhanced sub-surface features

Permittivity Profile
```
Model Based Signal Processing

How can MATLAB help?

Modeling:
Simulation of physical phenomenon (e.g., propagation, scattering, noise).

Signal Processing:
Filtering, System effect compensation, model parameter estimation.

Analysis:
Spectral Analysis (using Fourier transforms, other spectral estimation techniques)
Model Based Signal Processing
Model Based Signal Processing

$$S_r(t) = \sum_{k=0}^{L-1} A_k \Gamma_k \prod_{j=1}^{k-1} T_j \cos\left\{2\pi \left( f_0 \tau + \alpha \left[ 2t\tau_k - \tau_k^2 \right] \right) \right\} + n$$

Do they match?

Use Iterative Non-linear parameter Estimation techniques
Model Based Signal Processing

Simulation results

- Type of radar: FMCW radar
- Freq range: 2-8 GHz
- Duration of chirp: 10 mS
- Free space Range resolution: 2.5cm
- SNR of simulated data: 10 dB
Near-Surface Internal Layers in Polar Ice Sheets

Collected by KU-RSL during 2003 Season

Tree Cross Section
Annular Rings

Ice Sheet Surface
Bedrock
Annular Internal Layers
The Clutter Problem

- Aircraft
- Receive Antenna
- Sidelobe Clutter
- Rough Surface
- Desired Response

Layers:
- Layer-1
- Layer-2
- Layer-3

Signal (without Clutter)

Signal (with Surface Clutter)
The Solution – Phased Array Processing

- **Basic Principle:**
  Constructive & Destructive Interference

- **Actual Implementation**

  ![Diagram showing phasing in an antenna array with weights and incident signals leading to constructive and destructive interference]

  - Antenna-1
  - Antenna-2
  - Waves from this direction reinforce each other at the output
  - Waves from this direction cancel each other at the output
  - $d = \lambda$
  - $60^\circ$
Computer Simulation of Rough Surface Clutter using MATLAB
Signal Processing Techniques Applied to Simulated Data

After Conventional Beamforming

After Clutter Cancellation