Integrating .m, .mdl and Real-Time Hardware for Math, Signal Processing, & Controls

Jacques Cilliers
Application Engineer

National Instruments
High-Level Design Models

Data Flow

C Code

Textual Math

Simulation

Statechart

1. c = 0.285 + 0.013i;
2. [X Y] = meshgrid(x, y);
3. z = X + iY;
4. for k = 1:30
   5. z = z.^2 + c;
6. end

Real-Time FPGAMicroprocessors

Desktop
Embedded Software Development

- Design
- Prototyping
- Deployment
- System Test
- HIL Validation

Kc → Kp

ni.com
Deploy to Hardware Through LabVIEW

- MathScript RT Module
- Control Design & Simulation Module

The MathWorks Inc. software development environment

- MATLAB®
- Simulink®
- Simulink Coder™

LabVIEW Real-Time

NI VeriStand

CompactRIO, Single-Board RIO, PXI, or desktop

ni.com

MATLAB® and Simulink® are registered trademarks of The MathWorks, Inc.
SW Product Overview

- Math & Optimization
- Statistics & Data Analysis
- Database Connectivity
- Application Deployment
- Computational Biology
- Financial Analysis

MATLAB®

- Control Design
- Signal Processing
- Communications
- Test and Measurement
- Image Processing

SIMULINK®

- Physical Modeling
- Fixed-Point Modeling
- Event-Based Modeling
- Simulation Graphics

- Code Generation
- RCP & HIL
- Embedded Targets
- Verification & Validation

MATLAB® and Simulink® are registered trademarks of The MathWorks, Inc.
SW Product Overview

- Math & Optimization
- Statistics & Data Analysis
- Database Connectivity
- Application Deployment
- Computational Biology
- Financial Analysis

- Control Design
- Signal Processing
- Communications
- Test and Measurement
- Image Processing

- Physical Modeling
- Fixed-Point Modeling
- Event-Based Modeling
- Simulation Graphics

- Code Generation
- RCP & HIL
- Embedded Targets
- Verification & Validation

MATLAB® and Simulink® are registered trademarks of The MathWorks, Inc.
SW Product Overview

- Math & Optimization
- Statistics & Data Analysis
- Database Connectivity
- Application Deployment
- Computational Biology
- Financial Analysis
- Control Design
- Signal Processing
- Communications
- Test and Measurement
- Image Processing

- Motion Control
- Sound & Vibration
- Physical Modeling
- Fixed-Point Modeling
- Event-Based Modeling
- Simulation Graphics
- Code Generation
- RCP & HIL
- Embedded Targets
- Verification & Validation

PLUS HARDWARE

ni.com
LabVIEW MathScript RT Module

- Text-based controls, signal processing, analysis, and math
  - 900 built-in functions / user-defined functions
  - Reuse many of your .m file scripts created with The MathWorks, Inc. MATLAB® software and others
  - Based on original math from NI MATRIXx software
- A native LabVIEW solution
  - Interactive and programmatic interfaces
  - Does not require 3rd-party software
  - Enables hybrid programming

MATLAB® is a registered trademark of The MathWorks, Inc.
Octave vs MathScript

Octave:
```octave
octave:1> A=[0,2,0,1;2,2,3,2;4,-3,0,1;6,1,-6,-5]
A =
     0   2   0   1
     2   2   3   2
     4  -3   0   1
     6   1  -6  -5
```
```
octave:14> det(A)
ans = -234
```
```
octave:11> cond(A)
ans = 9.7626
```

MathScript:
```matlab
>> A=[0,2,0,1;2,2,3,2;4,-3,0,1;6,1,-6,-5]
A =
     0   2   0   1
     2   2   3   2
     4  -3   0   1
     6   1  -6  -5
```
```
>> det(A)
ans =  -234
```
```
>> cond(A)
ans =  9.7626
```
LabVIEW MathScript RT Background

• Textual node & interactive window

• Added plug-ins:
  • LabVIEW Control Design & Simulation Module
  • LabVIEW Digital Filter Design Toolkit

• Compatible with The MathWorks, Inc.:
  • MATLAB®
  • Signal Processing Toolbox™
  • Control System Toolbox™
  • DSP System Toolbox™

• Useful for desktop or real-time applications with hardware

MATLAB® and Simulink® are registered trademarks of The MathWorks, Inc.
DEMO: MathScript Interactive Environment
LabVIEW MathScript DEMO

- Graphical and textual programming
- Interactive user-interface
LabVIEW MathScript – Heat Equation

C:\Program Files (x86)\National Instruments\LabVIEW 2013\examples\MathScript\MathScript - Heat Equation
Debugging A MathScript Node (DEMO)

- Execution highlighting and single-stepping
- Probe tool for:
  - Variables in each node
  - Output defined within node
- Syntax error indication for each line
- Error indicator for node
Importing your .m file and adding interactivity

Fs = 150; % Sampling frequency
t = 0:1/Fs:1; % Time vector of 1 second
f = 5; % Create a sine wave of f Hz.
x = sin(2*pi*t*f); % Value
nfft = 1024; % Length of FFT
% Take fft, padding with zeros so that length(X) is equal to nfft
X = fft(x,nfft); % Value
% FFT is symmetric, throw away second half
X = X(1:nfft/2);
% Take the magnitude of fft of x
mx = abs(X);
% Frequency vector
f = (0:nfft/2-1)*Fs/nfft;
% Generate the plot, title and labels.
figure(1);
plot(t,x);
title('Sine Wave Signal');
xlabel('Time (s)');
ylabel('Amplitude');
figure(2);
plot(f,mx);
title('Power Spectrum of a Sine Wave');
xlabel('Frequency (Hz)');
ylabel('Power');

http://www.utdallas.edu/~dlm/3350%20comm%20sys/FFTandMatLab-wanjun%20huang.pdf
Dr. Andy Clegg, Lead Engineer & ISC Managing Director: “We used the LabVIEW MathScript RT Module to run a textual node containing our m-file code, developed with MATLAB on a desktop, for kinematics on the real-time CompactRIO controller. MathScript has significant benefits for real-time deployment on the CompactRIO controller including determinism, easy debugging, and no extra compilation steps.”
Don’t Get Confused About the Nodes

- Native LabVIEW code
- Works with:
  - LabVIEW on Windows, Mac or Linux
  - LabVIEW Real-Time

- Requires MATLAB
- Only works with LabVIEW on Windows
- Does not work with LabVIEW Real-Time
Recommended options for analyzing data with MathScript (DEMO)

- DAQ Assistant plus MathScript node
- Instrument Drivers plus MathScript node
- I/O Asst plus MathScript node
Working with LabVIEW MathScript

- Develop scripts interactively with the MathScript Window
- Move to the MathScript Node to “Instrument your Algorithms”
- Move back and forth as necessary to complete your work
NI Platform for Control

LabVIEW Development Environment

Control Design & Simulation Module
MathScript RT Module
System ID Toolkit
Digital Filter Design Toolkit
VeriStand
Statechart Module

LabVIEW Real-Time
LabVIEW FPGA
LabVIEW C Generation

Targets
PXI
cRIO, sbRIO
Desktops & SBC’s
32-bit µp

ni.com
LabVIEW Control Design

Easily create interactive control design and analysis VIs
Use both textual .m file and graphical approach
Model construction, conversion and reduction
Time and frequency response
Dynamic characteristics
Classical control design including analytical PID
State-space control and estimation - LQR, LQG, Model Predictive Control, Kalman Filter..
Graphical and textual options

• Can use either textual or graphical approach or a hybrid combination
• Interactive user-interface

Professor Eric Fahrenthold, The University of Texas, Mechanical Engineering 344, Dynamic Systems and Controls Classroom Course
LabVIEW Control Design and Simulation Module

• Both signal flow and .m file development
• Single environment for:
  • Simulation of dynamic systems
  • Real-time implementation for rapid control prototyping or hardware-in-the-loop simulation
Standard Notation Reduces Learning Curve

LabVIEW Control Design & Simulation Module

The Simulink® software environment

Simulink® is a registered trademark of The MathWorks, Inc.
Control & Simulation DEMO
Control Software & Hardware Options

LV for Win or Mac, LV-RT

I/O Options
- DAQ I/O
- FPGA I/O
- Vision

Hardware Platform
- PCI/PXI
- USB (slow)
- PCI/PXI
- cRIO/sbRIO
Real-Time on Multicore Processors

Assign timed loops to specific processor cores.
LabVIEW Control Design & Simulation Benefits

- **Complete simulation and real-time implementation capability - stay in one environment from design to test to implementation**
- Easily create parallel and multirate simulation or control loops, *leverage multicore*
- Custom user interface to change and observe parameters as simulation or control system is running
- Use VIs or programming structures inside or outside of simulation loops:
  - Integrated design and simulation, batch simulation
  - DAQ, RIO, Vision, or CAN for I/O
Simulink® conversion

Convert plant and controller models you create in the Simulink® environment into LabVIEW Control Design & Simulation Module code.
Co-Simulation w/ Multidomain Modeling Tools

- LMS AMESim
- Dassault Systemes Dymola
- Maplesoft MapleSim
- The MathWorks, Inc. Simscape™
- ITI SimulationX
Efficiently design across both analog and digital domains

Design closed-loop point-by-point simulation and control logic
LabVIEW System Identification Toolkit

- Identify and validate linear models of systems from empirical data
- Seamless integration with NI I/O
- Parametric model estimation (both SISO and MIMO)
- Nonparametric model estimation
- Recursive model estimation
- Data preprocessing
- Model conversion, validation and presentation
- Closed loop system identification with feedback detection
- Partially known “grey box” system identification
- Parameterized nonlinear system identification
LabVIEW MathScript RT & Control Design and Simulation Module Benefits

- Quickly take code to hw targets
- Multicore ease-of-use
- Instrumenting your algorithm
- Graphical/textual combination
- LabVIEW includes full programming capability
- Integration of 3rd party IP – including .m and .mdl
- LabVIEW is a complete graphical system design environment w/ all of the MoC’s that you need