INVESTICE DO ROZVOJE VZDĚLÁVÁNÍ

Simulace snímačů a řízení

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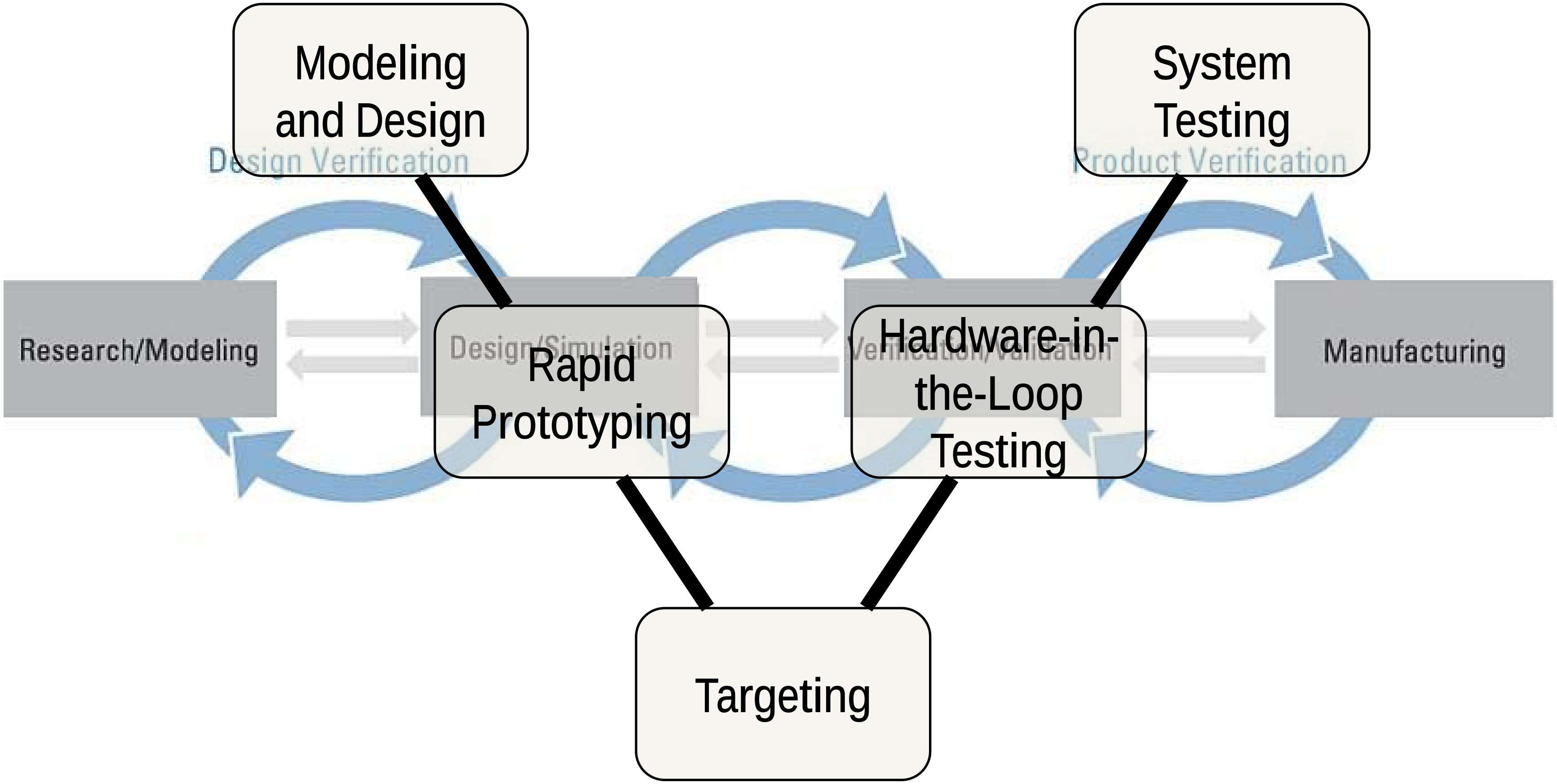
12. 2. 2010

Tato prezentace je spolufinancována Evropským sociálním fondem a státním rozpočtem České republiky.

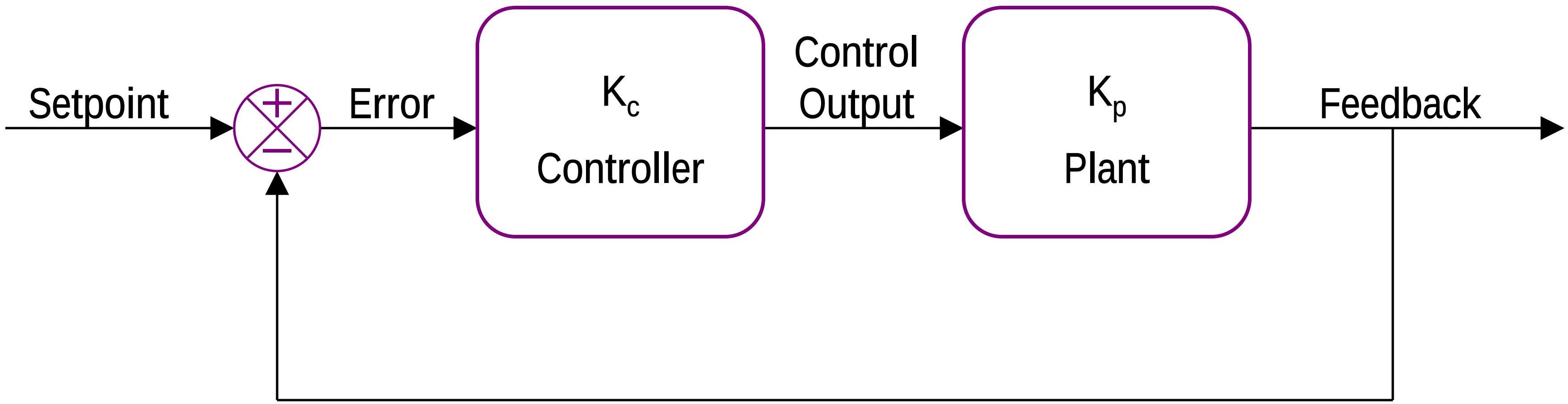
Agenda

- SW tools for control and design
- Sensor simulation
- HW equipment used for control
- Motion
- Robotics

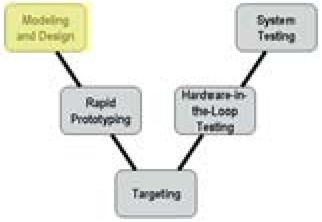
PC-Based Control and Simulation



Modeling and Design

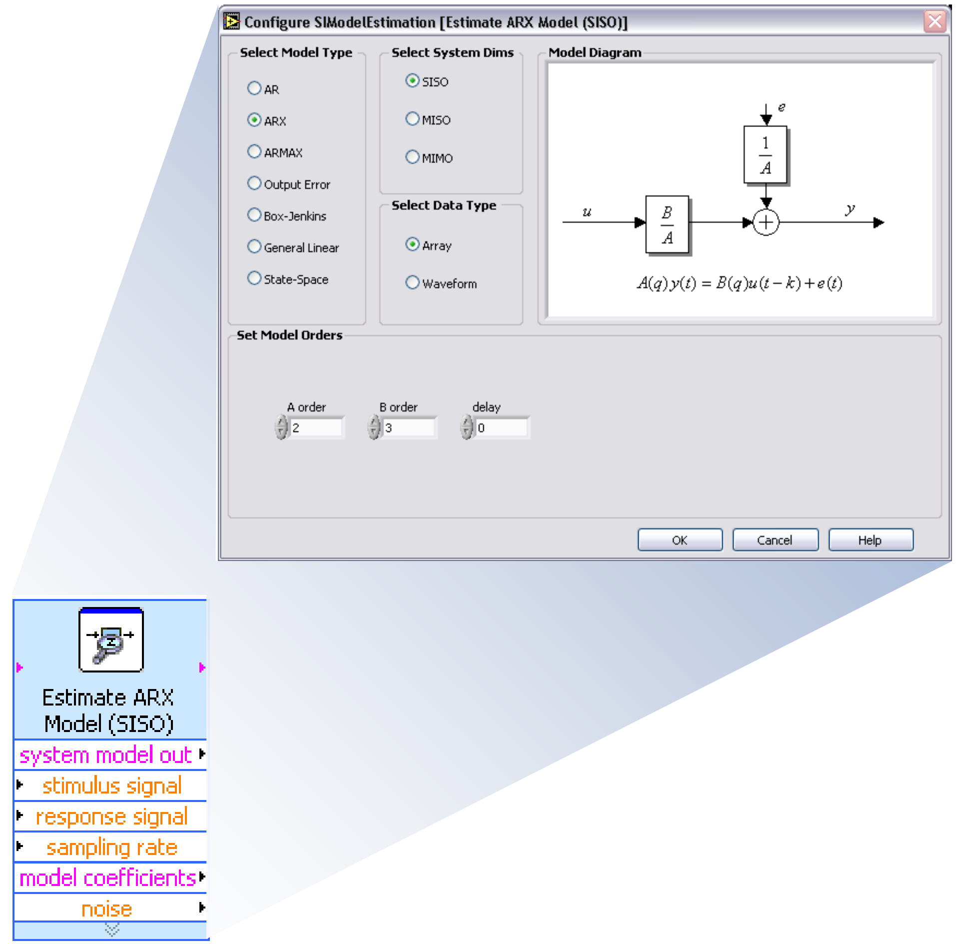


Modeling and design produce controller and plant models

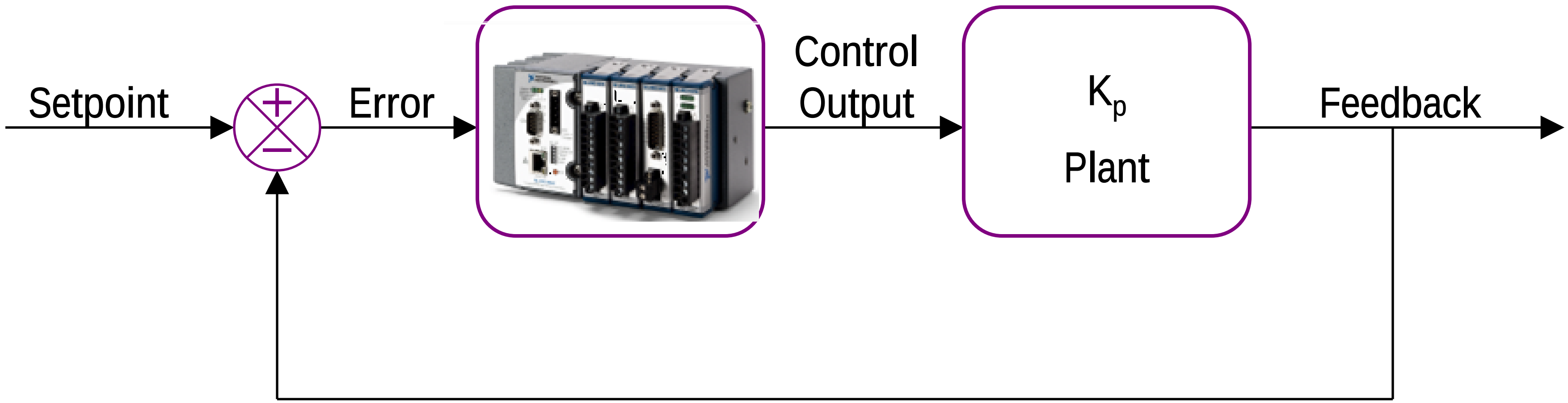


LabVIEW System Identification Toolkit

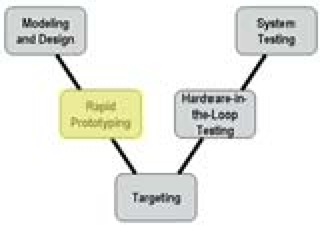
- **Identify and validate linear models of systems from empirical data**
- **Seamless integration with NI I/O**
- Parametric model estimation (both SISO and MIMO)
- Nonparametric model estimation
- Recursive model estimation
- Data preprocessing
- Model conversion, validation, and presentation
- Closed-loop system identification with feedback detection
- Partially known “grey box” system identification



Rapid Control Prototyping (RCP)

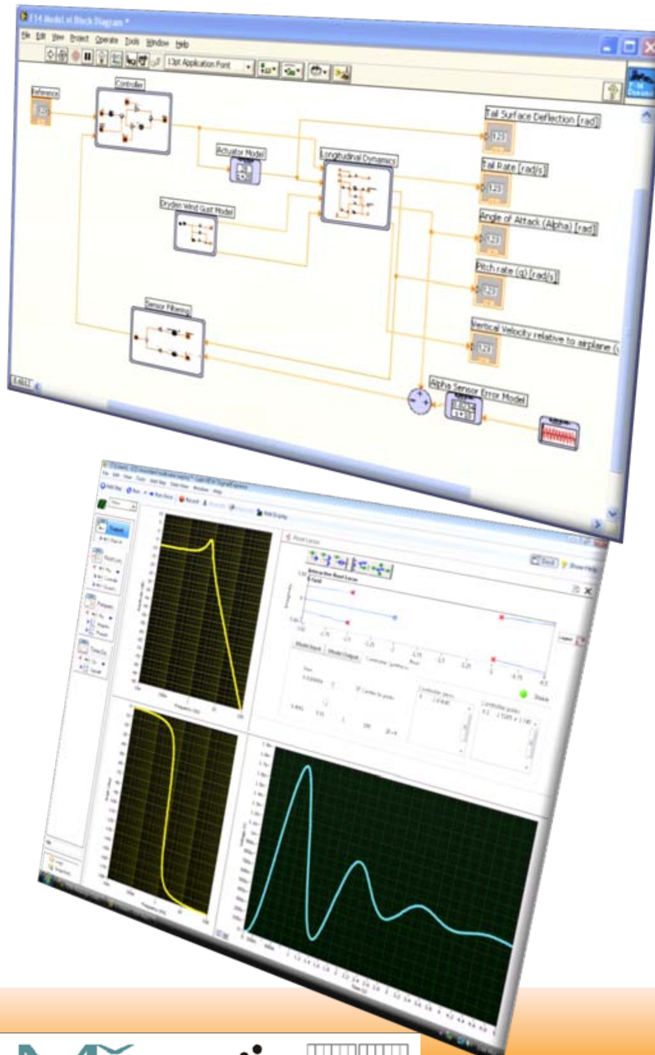


Creating a functional prototype of the controller

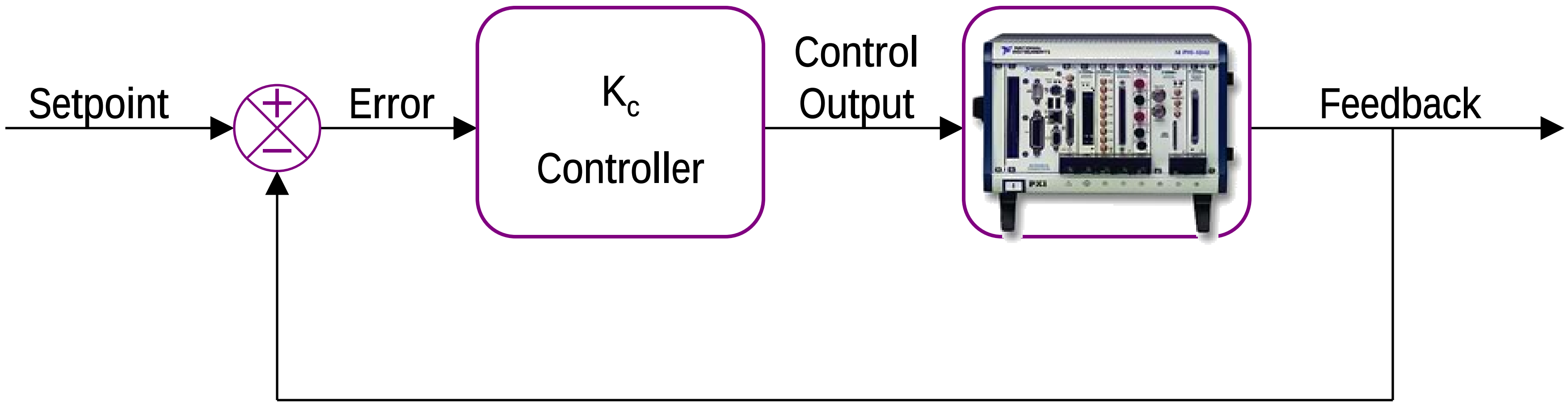


LabVIEW Control Design and Simulation Module

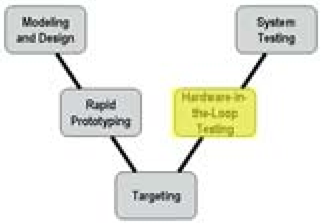
- Develop advanced control and analysis applications quickly
- Use on-board FPGA more efficiently
- Perform PID and non-linear control
- Leverage control capabilities including:
  - Model construction, conversion, interconnection and reduction
  - Time and frequency response
  - State-space model analysis and state feedback design
  - Kahlman filters
  - Simulation for linear and non-linear systems
  - Discrete systems
  - Signal arithmetic



Hardware-in-the-Loop (HIL) Simulation

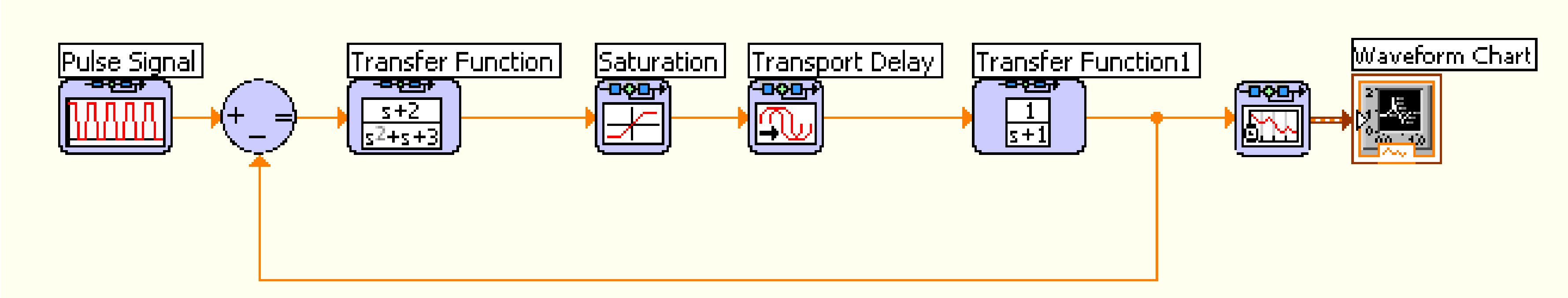


Testing production controller with simulated plant

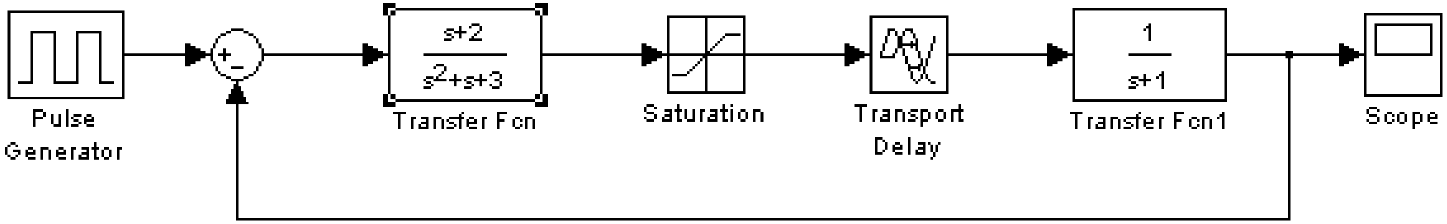


Little or No Learning Curve for The MathWorks, Inc. Simulink® Software Users

- LabVIEW Simulation Module



- The Simulink Software Environment



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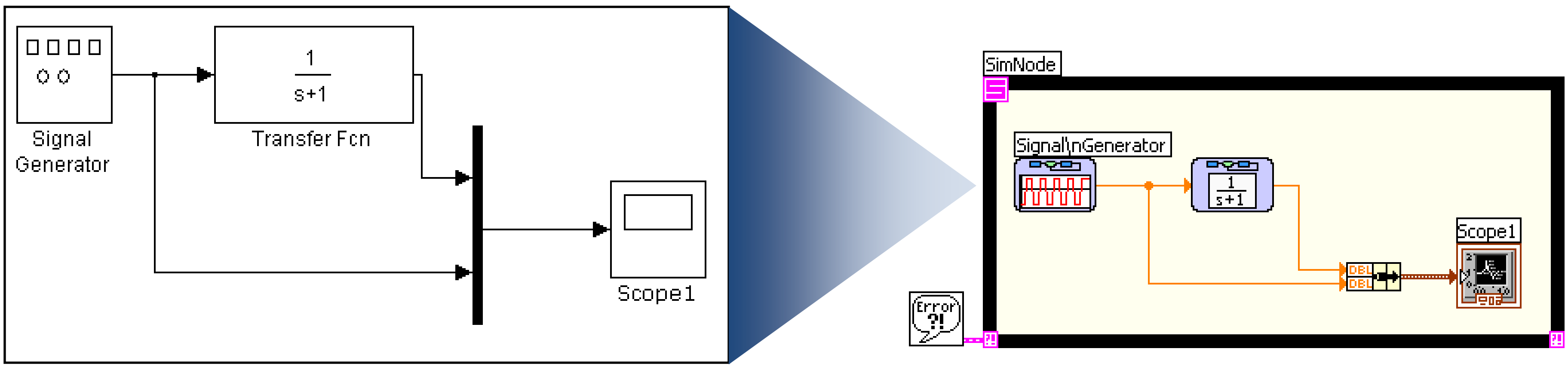
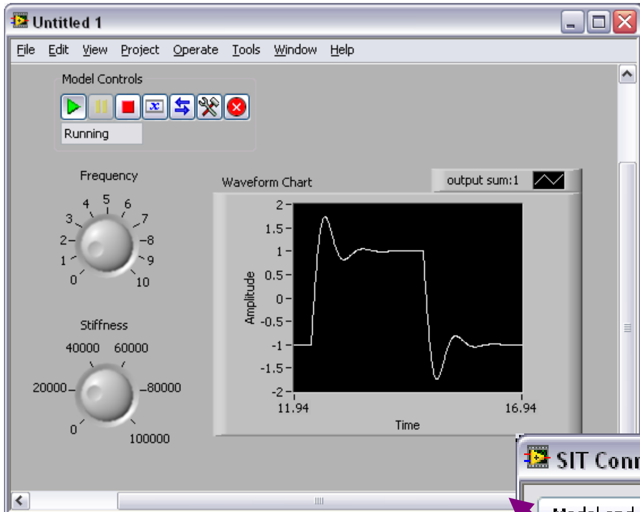
Simulation Model Conversion

– Convert your plant and controller models developed in The MathWorks, Inc. Simulink® environment into LabVIEW Simulation Module code

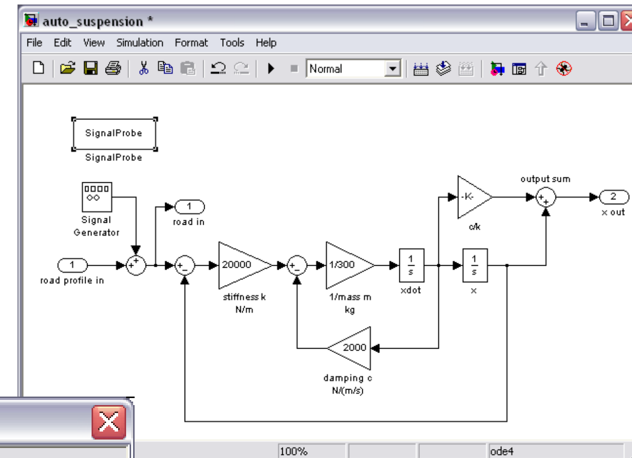


LabVIEW Simulation Interface Toolkit (SIT)

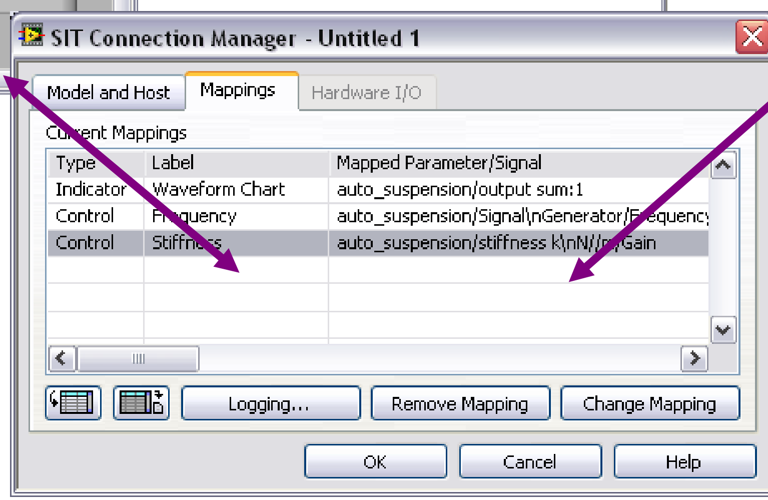
LabVIEW Front Panel



Simulation Model



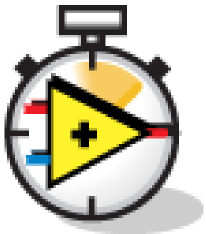
SIT Connection Manager



LabVIEW Controls and Indicators

Model Parameters and Signals

PC-Based Real-Time and Embedded
What is Real-Time?



- Real-time **does not** always mean real fast
- Real-time means **absolute reliability**
- Real-time systems have timing constraints that must be met to avoid failure
- Determinism is the ability to complete a task within a fixed amount of time

Operating System Characteristics

General Purpose OS

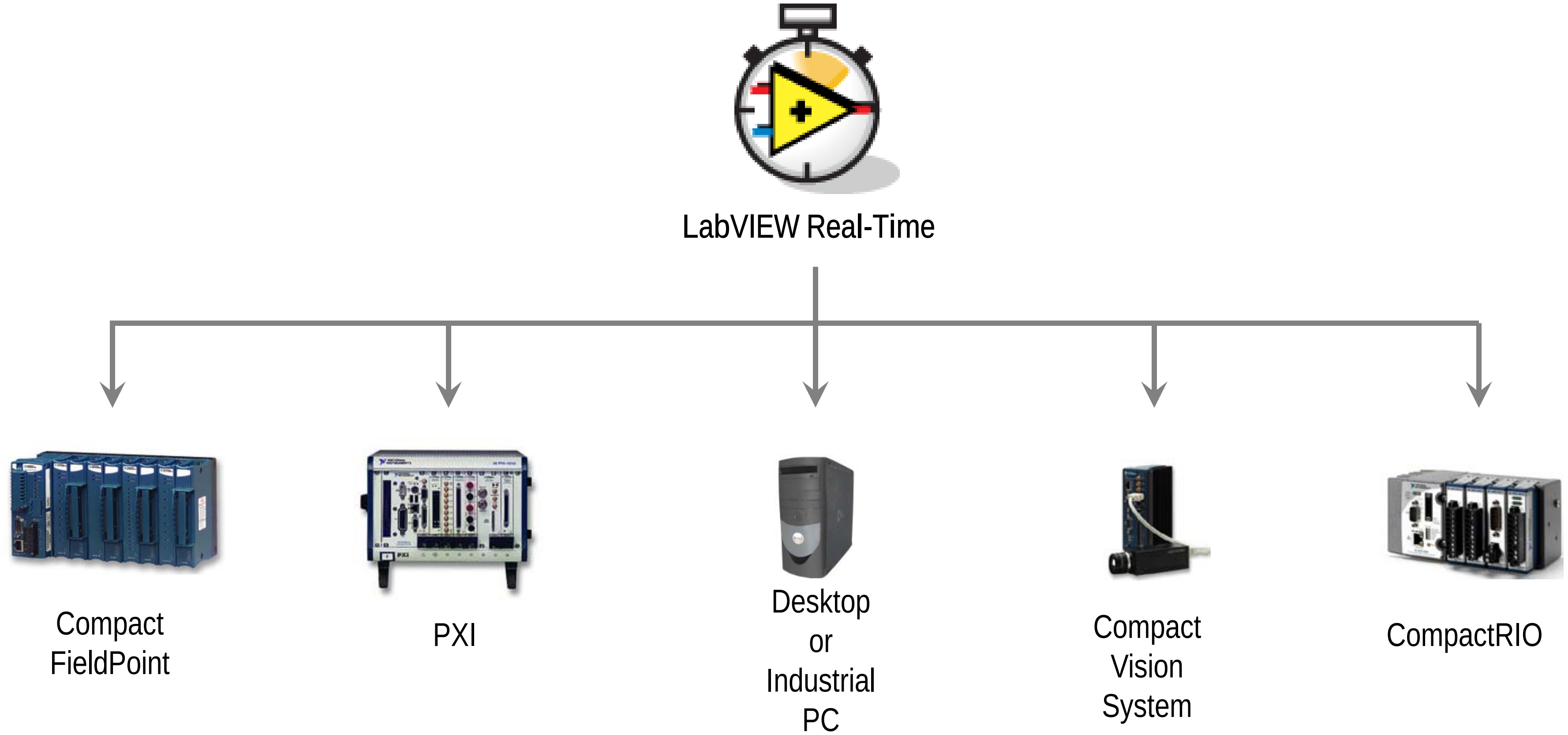
- High-priority tasks can be preempted by lower-priority tasks
- Extraneous background programs
  - Screen savers, disk utilities, virus software, etc.
- Peripheral Interrupts
  - Mouse, keyboard, etc.

Real-Time OS

- Scheduler ensures high-priority tasks execute first
- Direct control over all tasks
- Stand-alone (no mouse, keyboard, etc.)

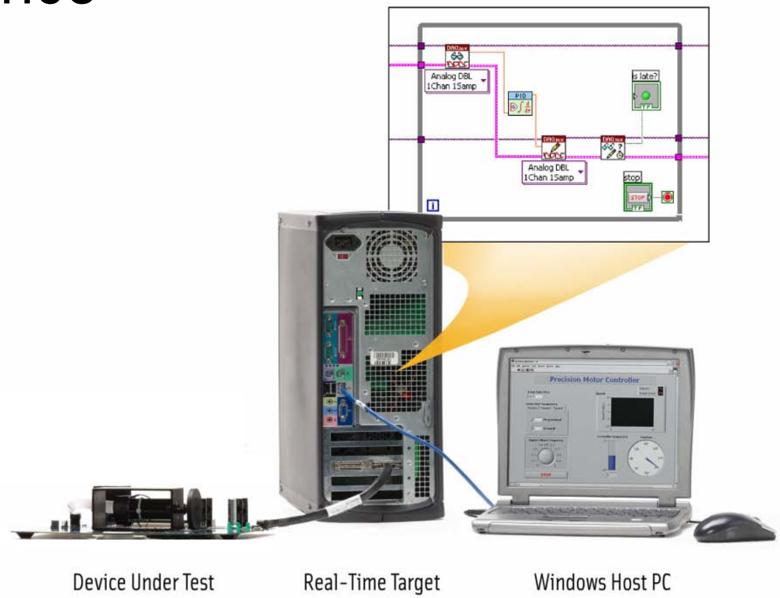
Loop Rate	Software Jitter
10-100 Hz	Unbounded
Up to 50 kHz	Bounded

LabVIEW Real-Time Hardware Targets



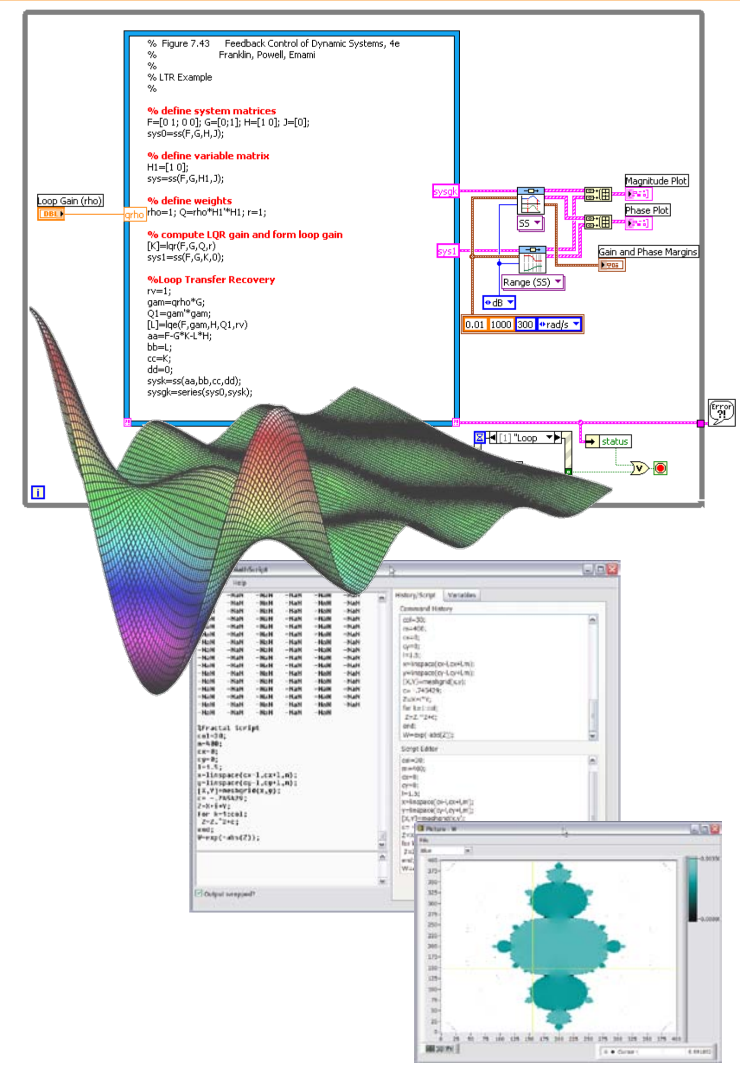
Desktop PC as Real-Time Target

- Convert desktop and industrial PCs into Real-Time targets
- Integrate large variety of PCI I/O hardware
- Leverage high desktop performance



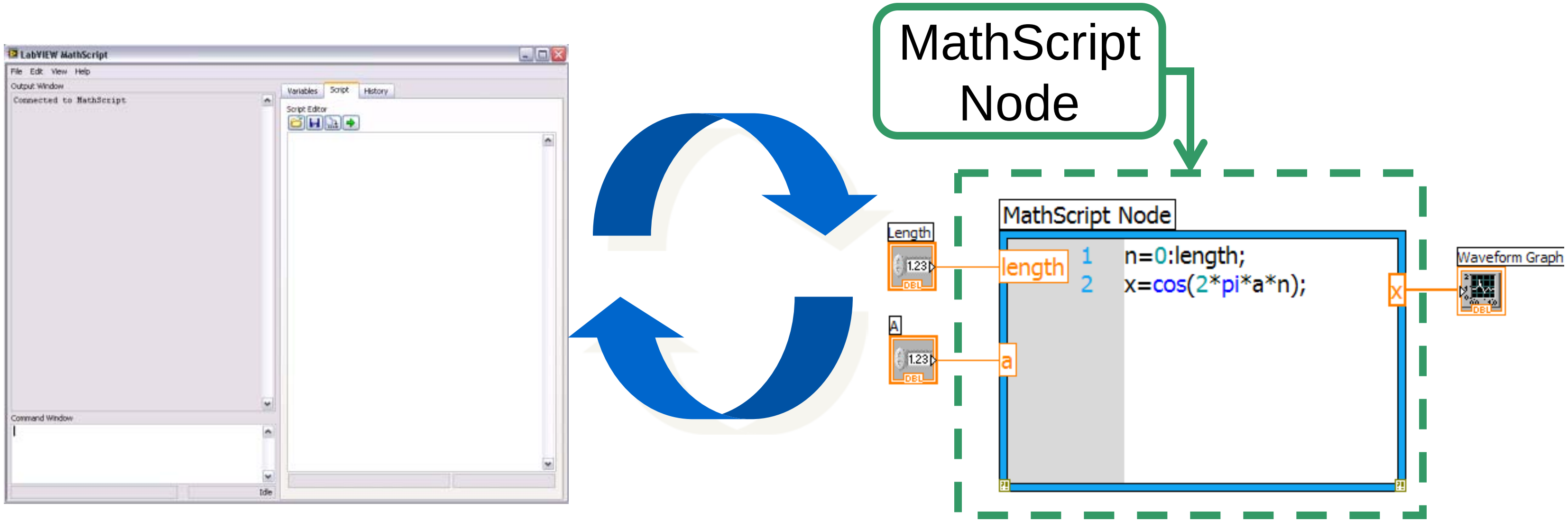
LabVIEW MathScript

- **Powerful textual programming for signal processing, analysis, and math**
  - More than 800 built-in functions
  - Reuse many of your m-file scripts created with The MathWorks, Inc. MATLAB® software and others
  - Partially based on original math from NI MATRIXx
- **A native LabVIEW solution**
  - Interactive and programmatic interfaces
  - Does not require third-party software

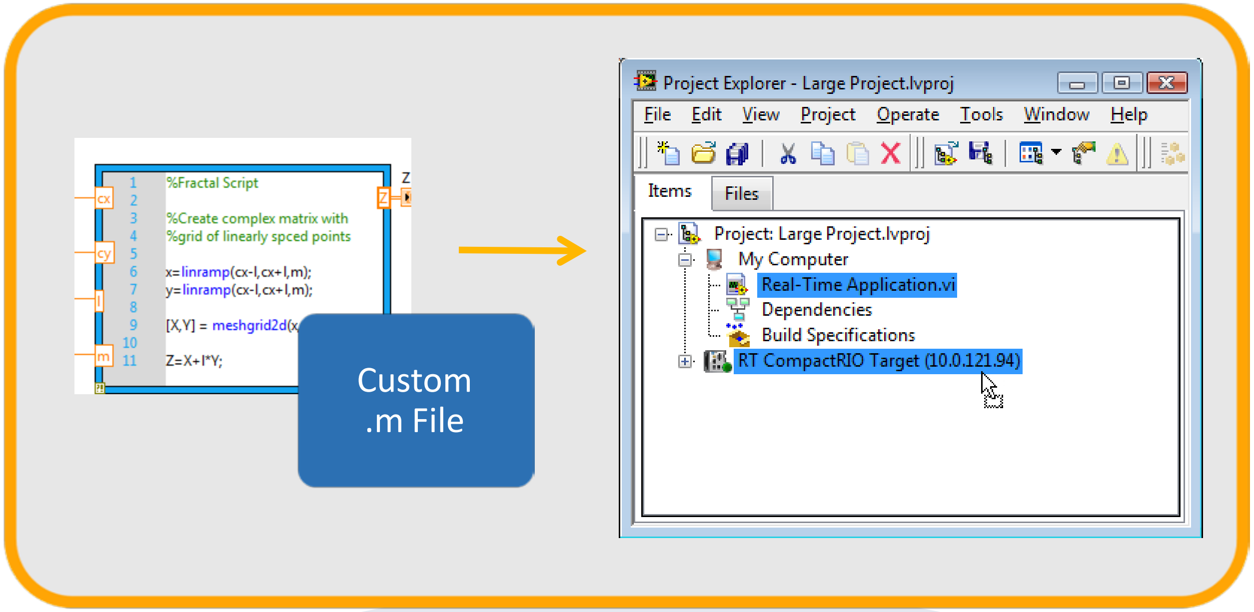


Working with LabVIEW MathScript

- Develop scripts interactively with the MathScript Window
- *Instrument your algorithms* by deploying with the MathScript Node
- Move back and forth as necessary to complete your work
- MathScript Window and MathScript Node share a global variable space



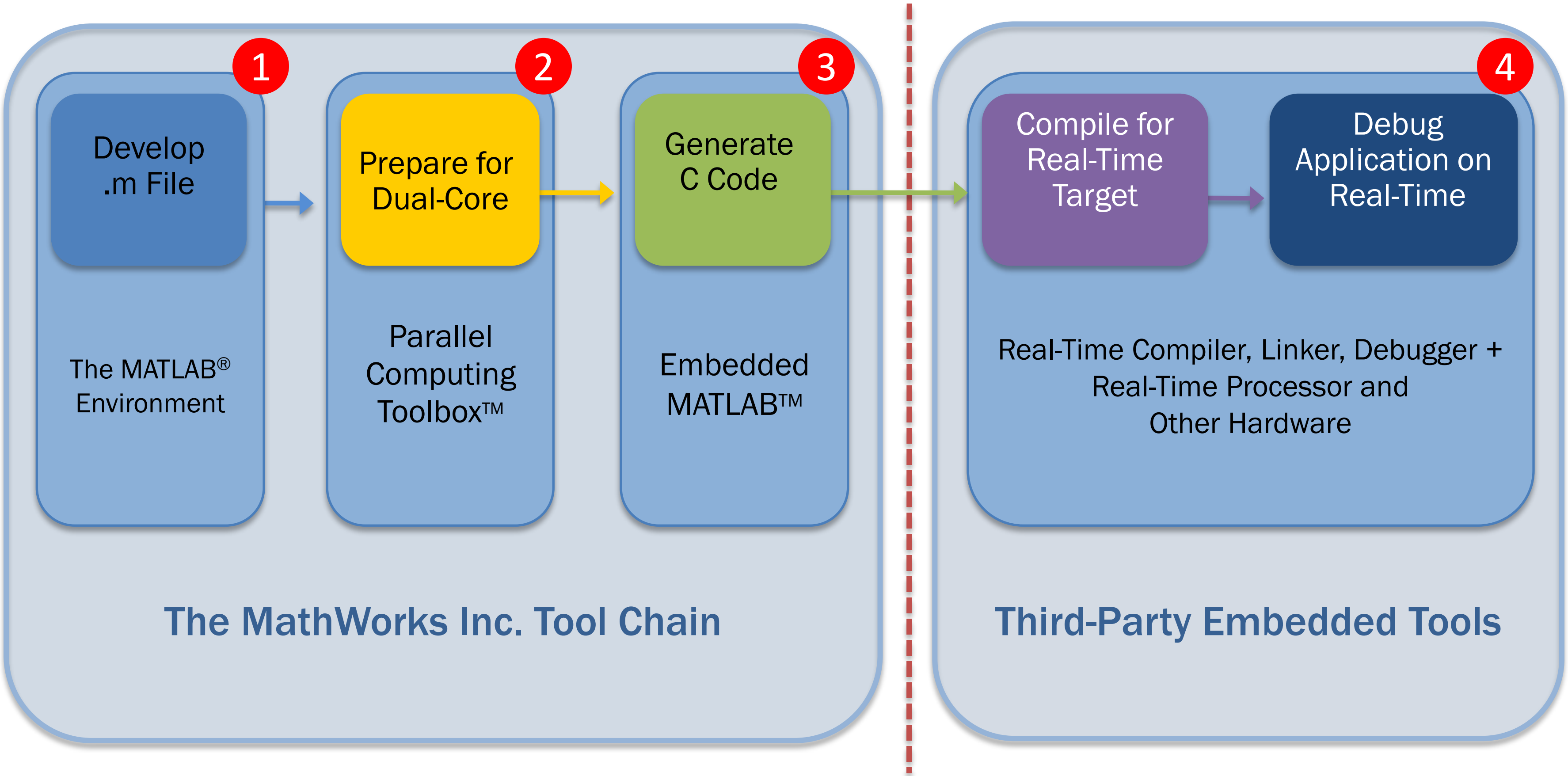
LabVIEW 2009 MathScript RT Module



Why Is This Functionality Important?

```
% Program P2_1
% Simulation of an M-point Moving Average Filter
% Generate the input signal
n = 0:100;
s1 = cos(2*pi*0.05*n); % A low-frequency sinusoid
s2 = cos(2*pi*0.47*n); % A high frequency sinusoid
x = s1+s2;
% Implementation of the moving average filter
M = input('Desired length of the filter = ');
num = ones(1,M);
y = filter(num,1,x)/M;
% Display the input and output signals
clf;
subplot(2,2,1);
plot(n, s1);
axis([0, 100, -2, 2]);
xlabel('Time index n'); ylabel('Amplitude');
title('Signal #1');
subplot(2,2,2);
plot(n, s2);
axis([0, 100, -2, 2]);
xlabel('Time index n'); ylabel('Amplitude');
title('Signal #2');
subplot(2,2,3);
plot(n, x);
axis([0, 100, -2, 2]);
xlabel('Time index n'); ylabel('Amplitude');
title('Input Signal');
subplot(2,2,4);
plot(n, y);
axis([0, 100, -2, 2]);
xlabel('Time index n'); ylabel('Amplitude');
title('Output Signal');
axis;
```

Deployment with Traditional Tools



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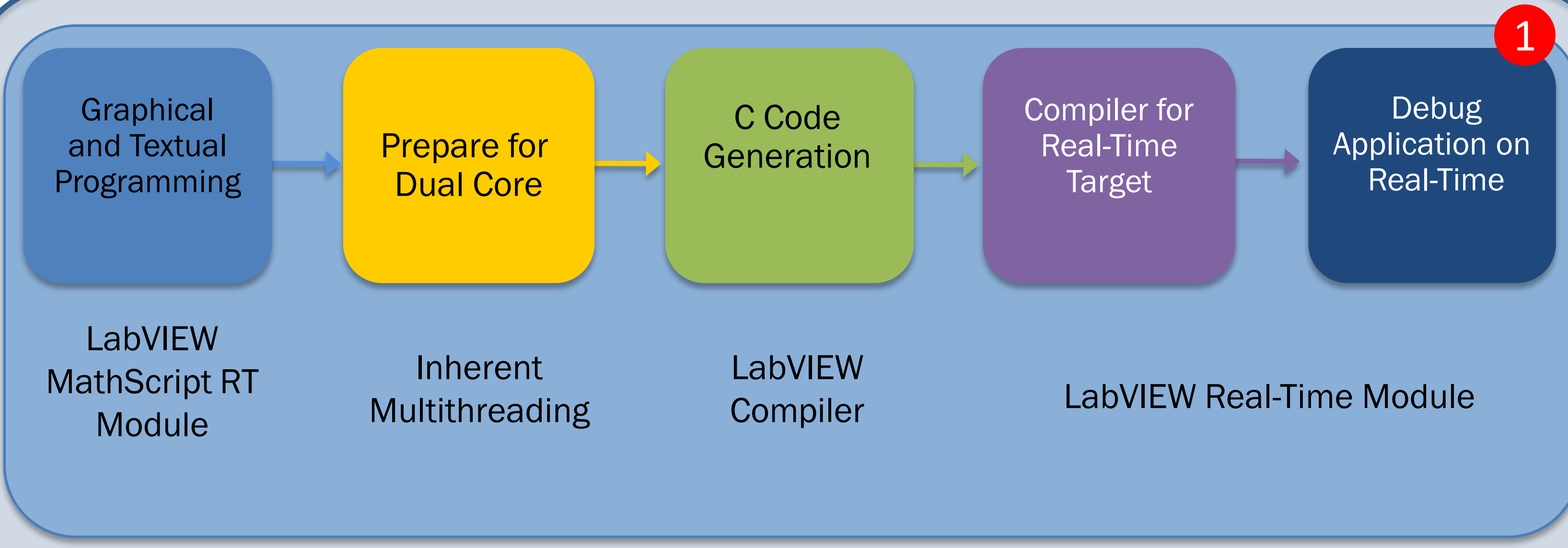
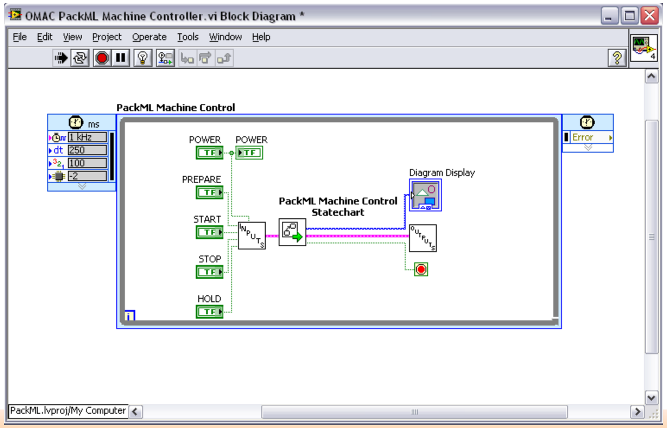
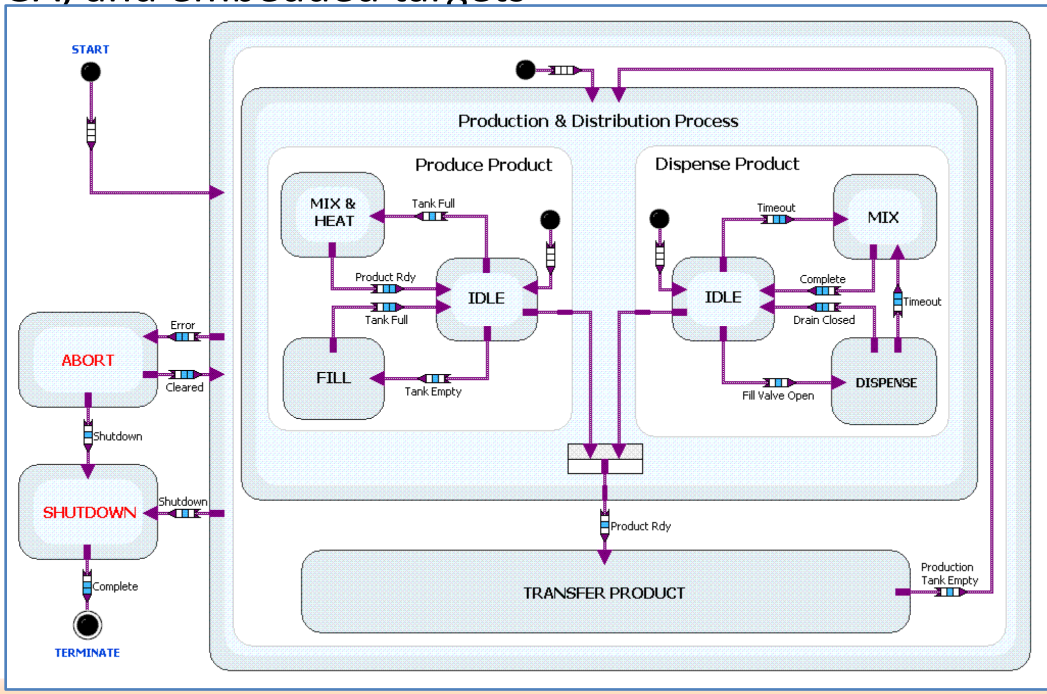
Deployment with LabVIEW 2009



LabVIEW Statechart Module

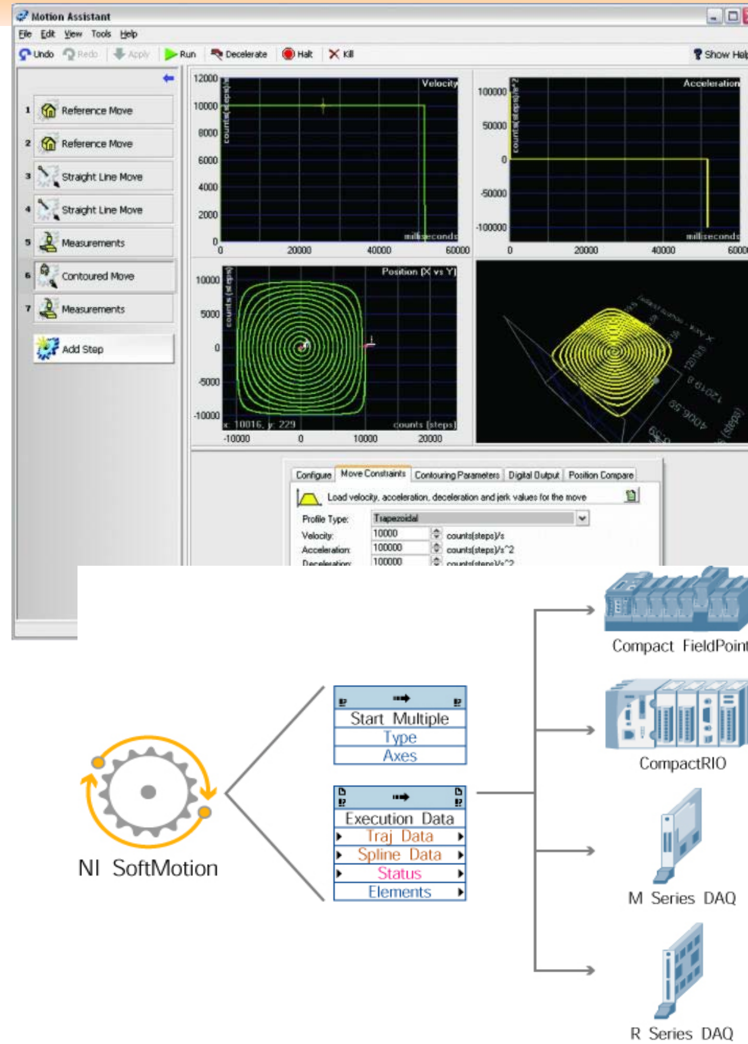
- Statecharts provide high-level abstraction for state based applications
  - Simple semantics represent complex systems
  - Self-documenting design
- Integrate statecharts into existing LabVIEW applications
- Generate code for desktop, Real-time, FPGA, and embedded targets





Motion Control with LabVIEW

- **NI Motion Assistant**
  - Interactive environment with 3D visualization
  - Ready-to-run LabVIEW or C code creation
  - Easy trapezoidal or S-curve velocity profile implementation
  - Teach pendant for easy prototyping
- **NI SoftMotion Controller for CANopen and IEEE 1394**
  - Use LabVIEW and NI Motion Assistant to program distributed motion control applications
  - Compatible with intelligent CANopen drives from Copley and IEEE 1394 drives from ORMEC
- **NI SoftMotion Development Module**
  - Develop custom motion controllers in LabVIEW Real-Time or LabVIEW FPGA
  - Use trajectory generation, spline interpolation, position, velocity control, and encoder implementation VIs



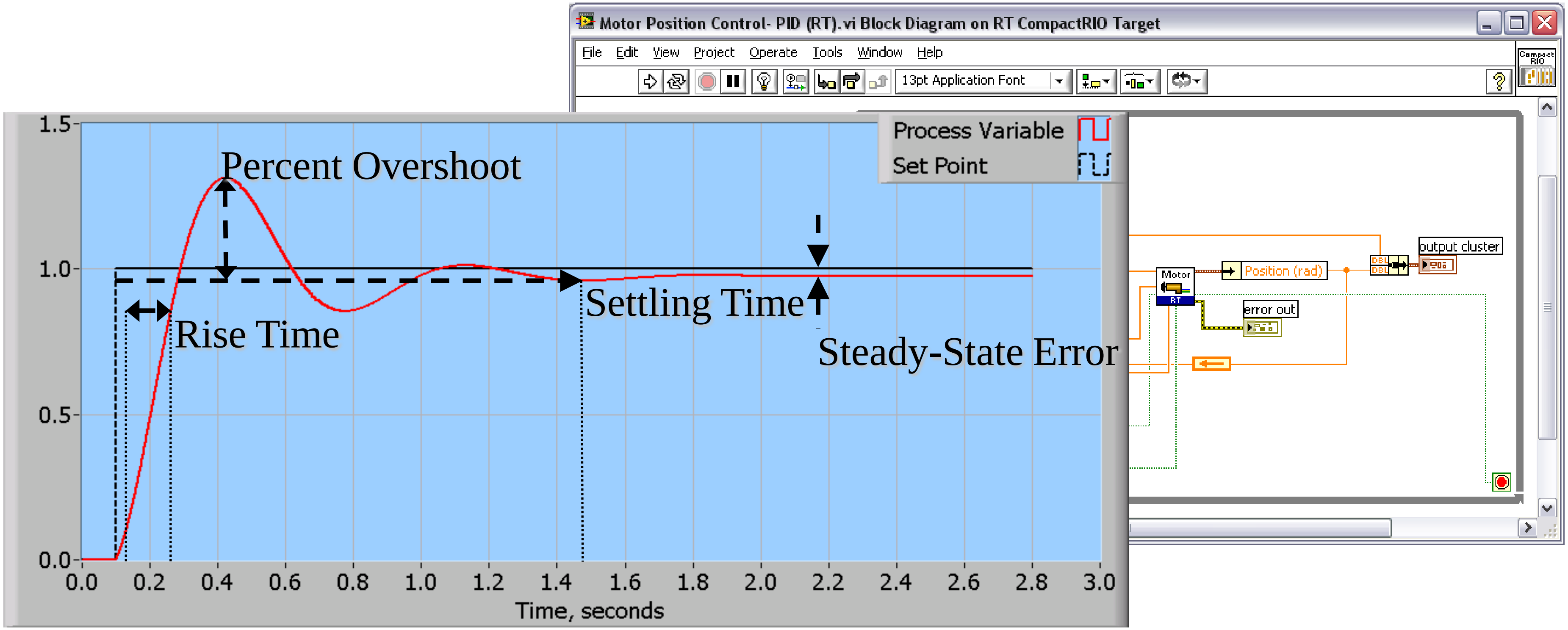
PID Control Toolkit

PID Control

- Autotuning
- Gain scheduling

Fuzzy Logic

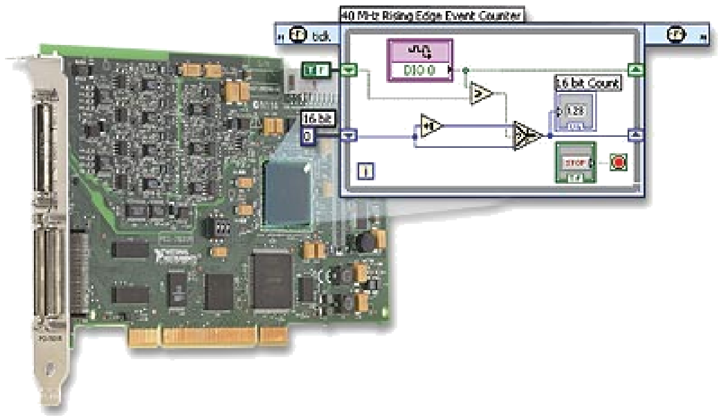
- Control strategies
- Decision making



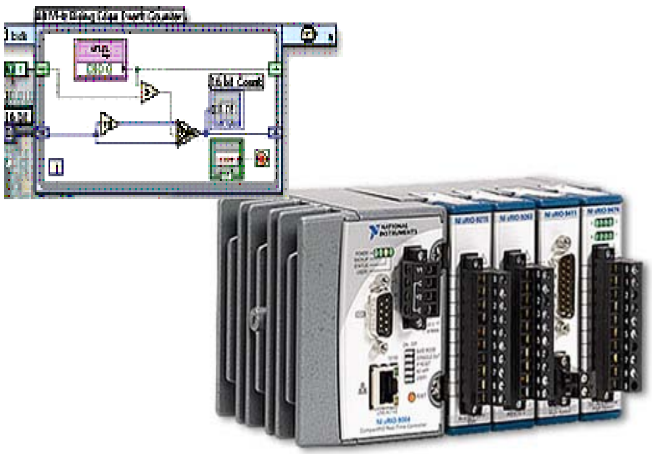
LabVIEW FPGA Module

Field Programmable Gate Array

- Define custom FPGA I/O without VHDL programming
- Achieve hardware deterministic response within 25ns
- Execute tasks with true parallelism



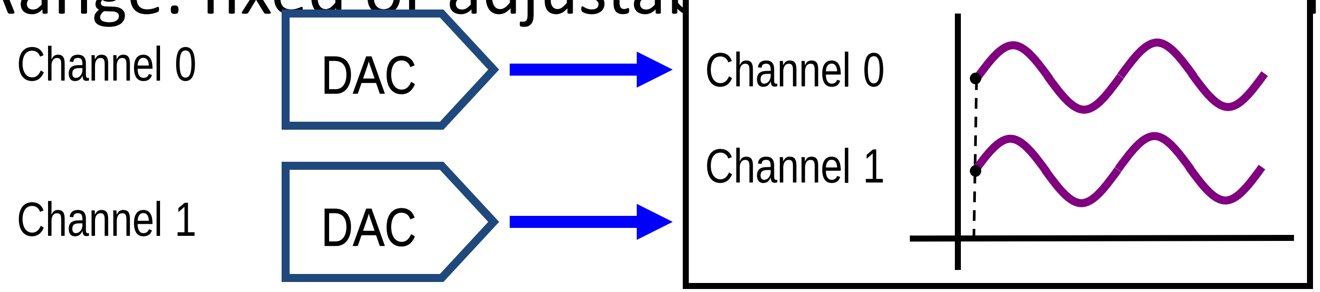
R Series Intelligent DAQ



NI CompactRIO

Analog Output – Considerations

- Accuracy: digital-to-analog converter (DAC) resolution
- Update Rate: settling time and waveform frequency
- Range: fixed or adjustable output voltage/current

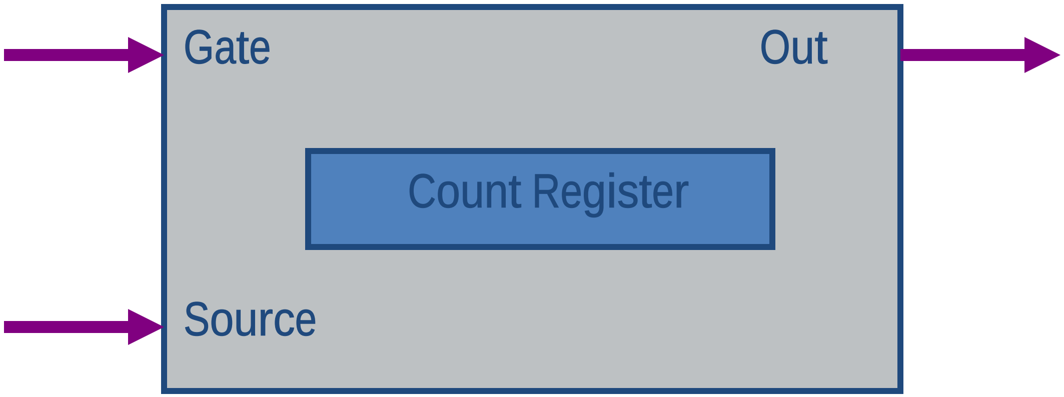


- 16-bit
- 100 kS/sec
- ±10 VDC, 0–20 mA

Digital I/O – Terminology

- General Terminology
  - Bit – The smallest unit of data. Each bit is either a 1 or a 0.
  - Line – One individual signal in a port. *Bit* refers to the data transferred. *Line* refers to the hardware.
  - Port – A collection of digital lines (usually 8)
- Hardware-clocked (buffered digital I/O)
  - 1−10 MHz digital pattern I/O
  - Synchronization with AI and AO
  - Works as logic analyzer/generator

Counter/Timers – Parts and Functions



- Two basic functions
  - To “count” based on the comparison of input signals (Gate, Source…)
  - To generate pulses based upon inputs and register value

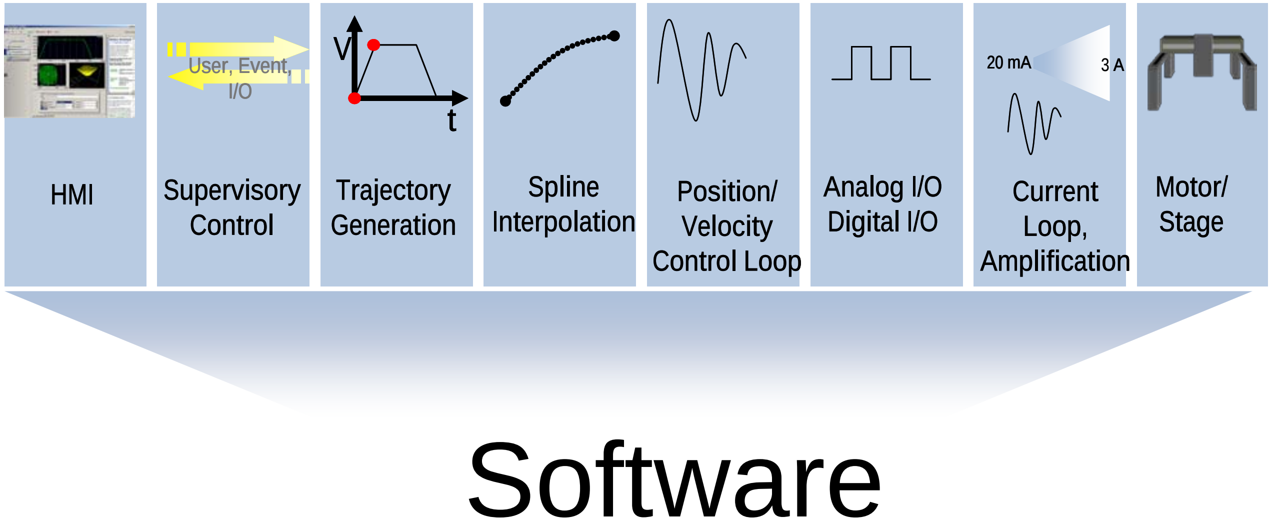
Counter/Timers – Applications

- Edge Counting
  - Simple Edge Counting
  - Time Measurement
- Pulse Generation
  - Single Pulse Generation
  - Pulse Train Generation
- Pulse Measurement
  - Period Measurement
  - Pulse Width Measurement
- Frequency Measurement
- Position Measurement
- Quadrature Encoder Measurement / simulation

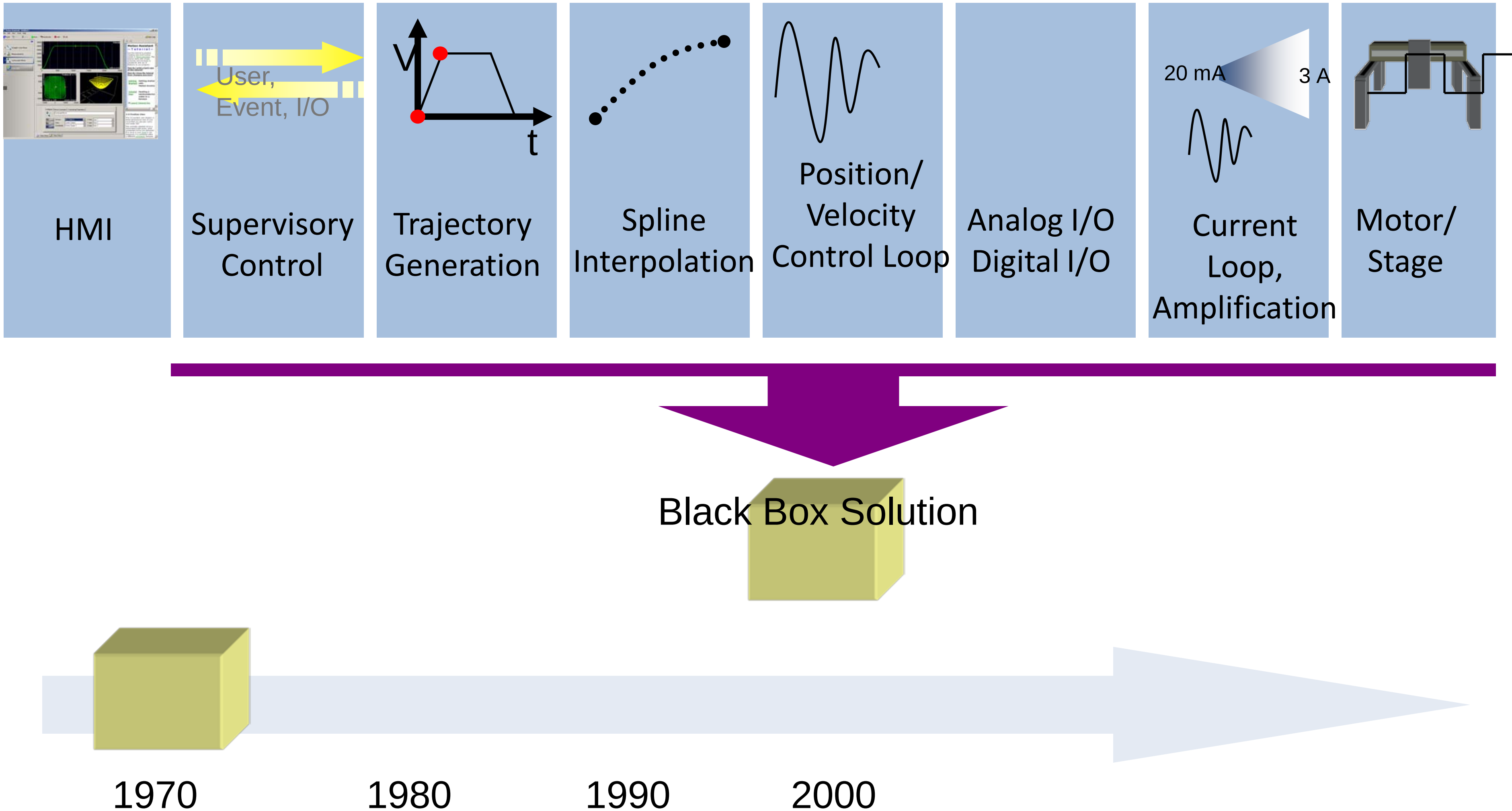
What is Soft Motion?

– Implement parts of a motion control system in software

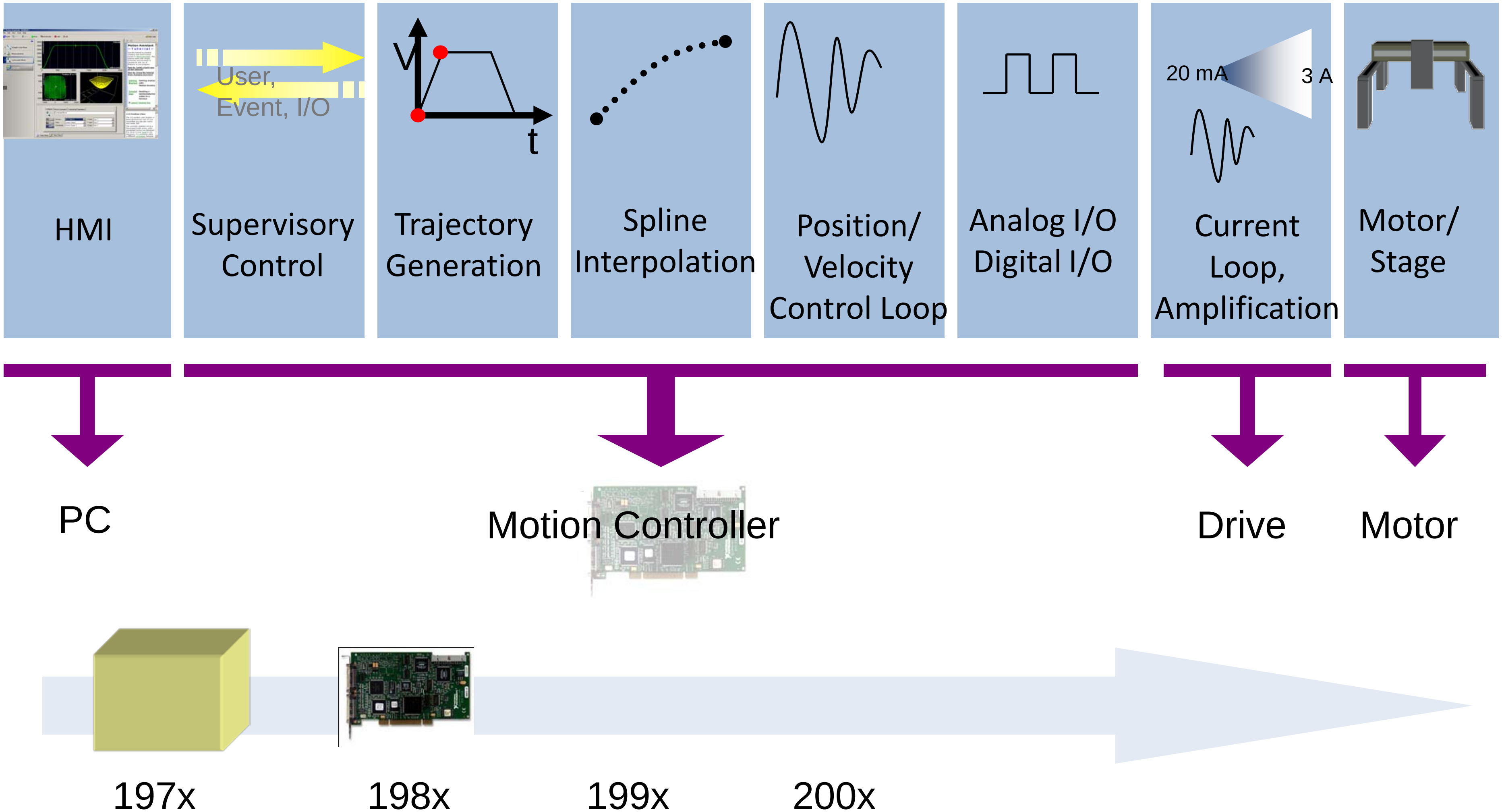
– Disaggregate a motion control system into modular components that are open, flexible, and customizable



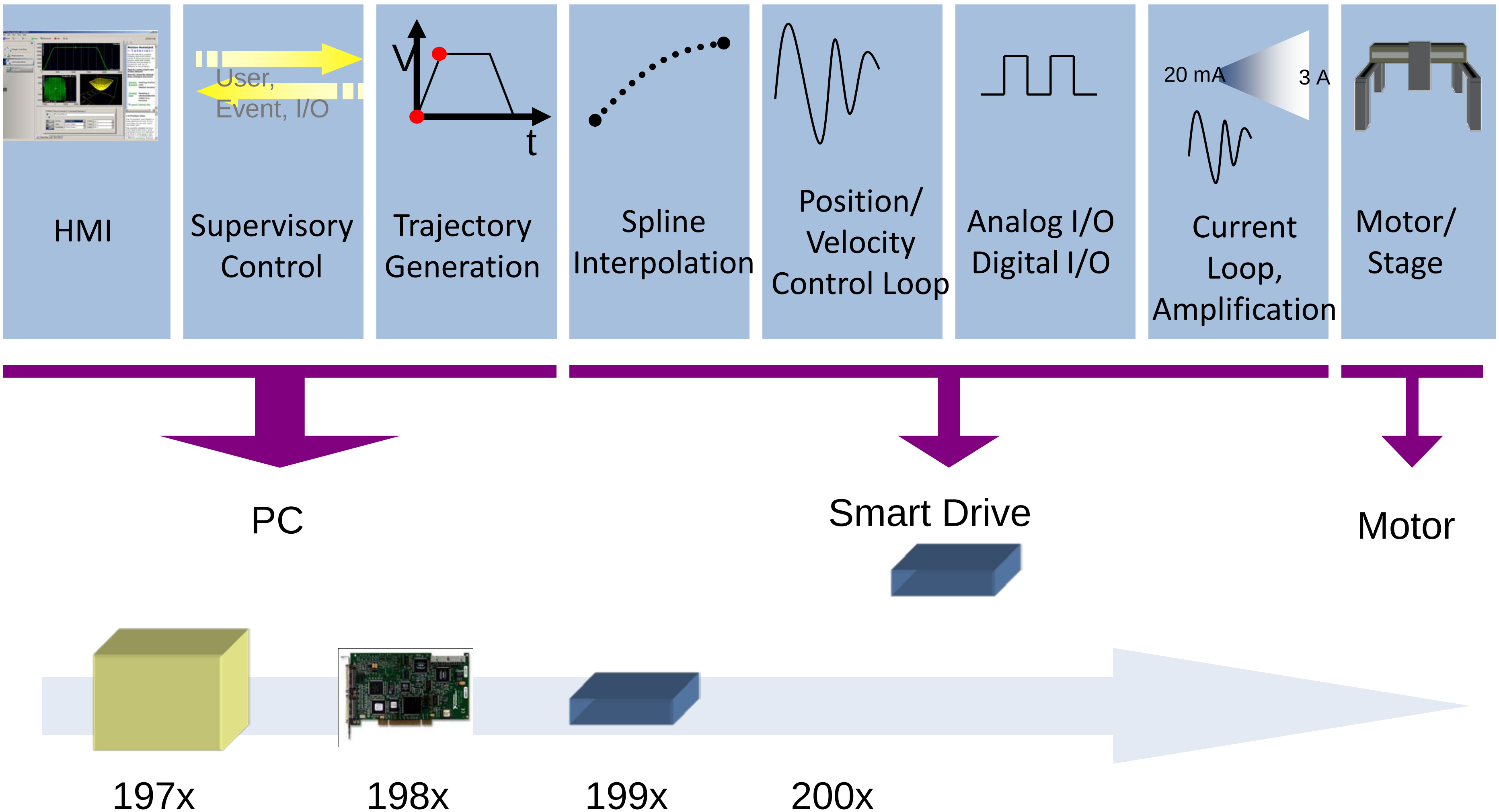
1970s: Black Box Solution



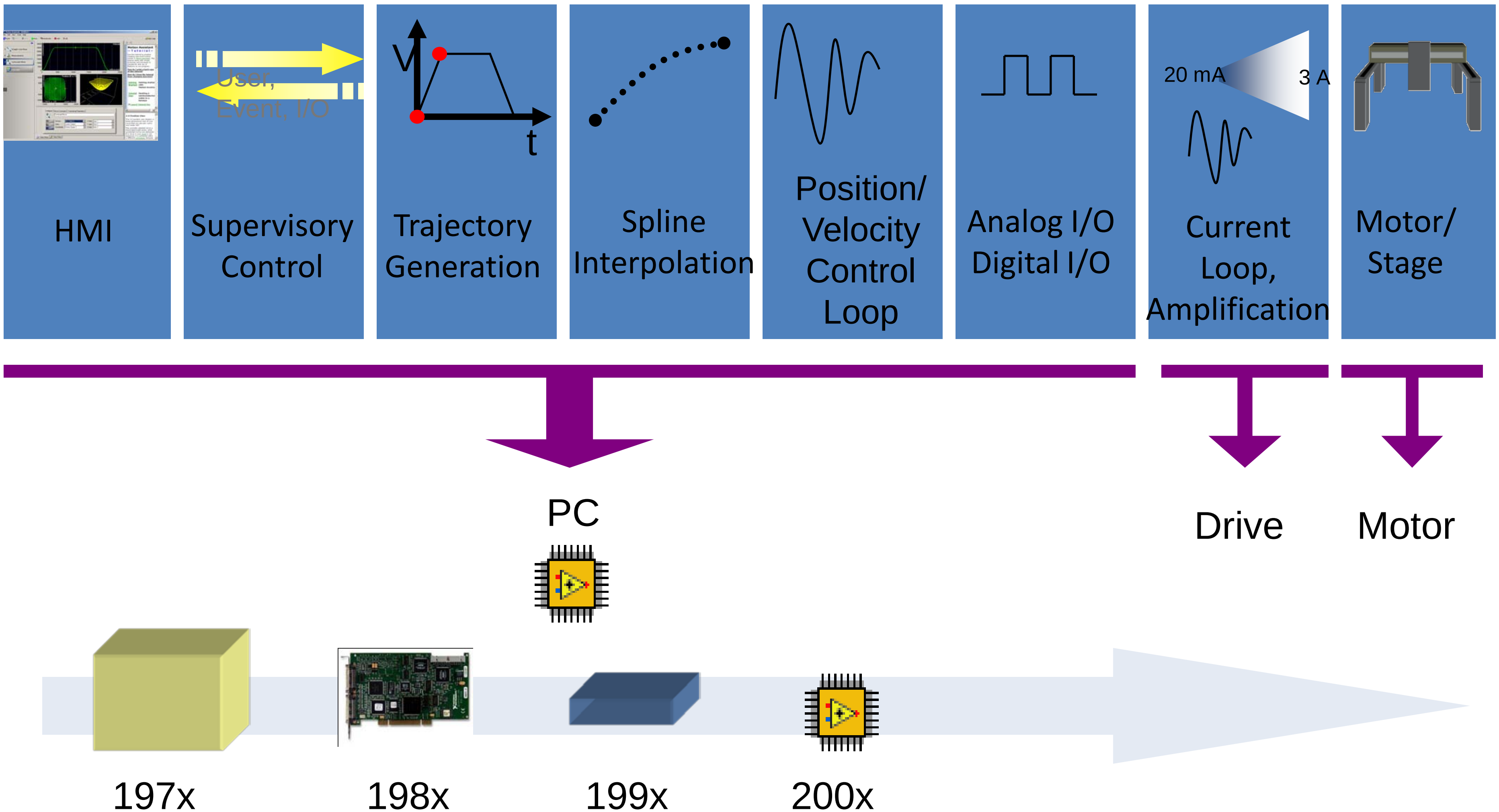
1980s: Emergence of Bus Technology



1990s: Emergence of Smart Drives



2000s: Emergence of RIO Technology



Motion Controller Architecture

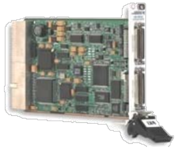
Traditional Plug-in Motion Controllers

NI Motion Assistant

NI-Motion for LabVIEW

DSP on Motion Controller

Supervisory Control	Trajectory Generation	Spline Interpolation	Position, Velocity Control Loop



NI 73xx Motion Controllers

NI-SoftMotion Development Module for LabVIEW

Traditional Plug-in Motion Controllers

NI Motion Assistant

NI-Motion for LabVIEW

DSP on Motion Controller

- Supervisory Control
- Trajectory Generation
- Spline Interpolation
- Position, Velocity Control Loop

NI 73xx Motion Controllers

NI SoftMotion Technology

NI SoftMotion Development Module for LabVIEW

- Supervisory Control
- Trajectory Generation
- Spline Interpolation
- Position, Velocity Control Loop

LabVIEW Real-Time and / or LabVIEW FPGA

Single Board Computers

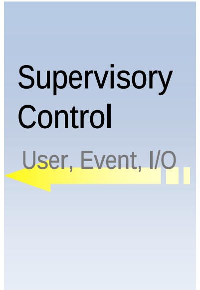
Compact FieldPoint

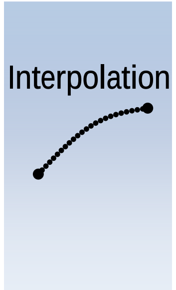
M Series DAQ

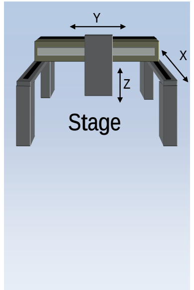
R Series DAQ

CompactRIO

Architecting Your Custom Motion Controller







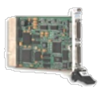
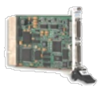
LabVIEW / Motion Asst

Motion Controller, 62.5 us

Drive

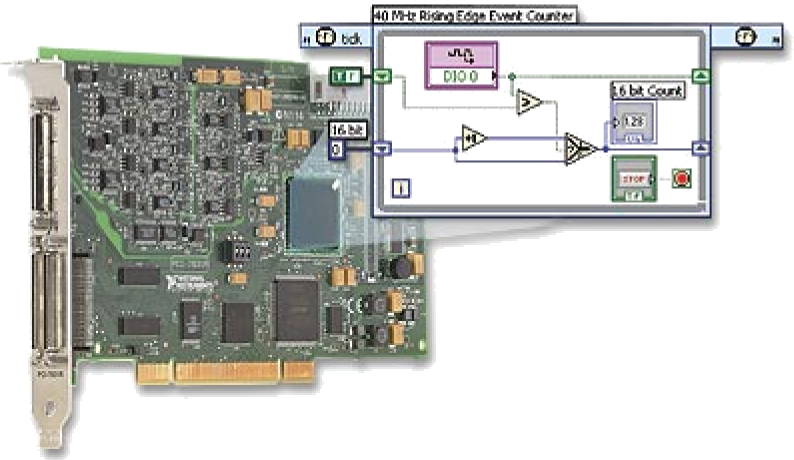
Motor / Stage

Choosing the Right Platform

Hardware Platform	Trajectory Generator	Spline Interpolation	Position/Velocity Control Loop	Encoder Implementation	Control Loop Rate	Applications
CompactRIO 	LabVIEW Real-Time	LabVIEW-FPGA			5 us	Ultra high precision machines for nanotech and MEMS applications
PC/PXI with R-Series 	LabVIEW Real-Time	LabVIEW-FPGA			5 us	Ultra high precision machines in nanotech and MEMS applications,
PC/PXI with Plug-in Motion Controller 	DSP on Motion Controller				62.5 us	High precision machines in semiconductor, healthcare applications
PC/PXI with Plug-in Data Acquisition 	LabVIEW Real-Time			-	1 ms	Packaging, material handling applications
Compact FieldPoint 	LabVIEW Real-Time			-	10 ms	Servo hydraulics, conveyors, high inertia systems

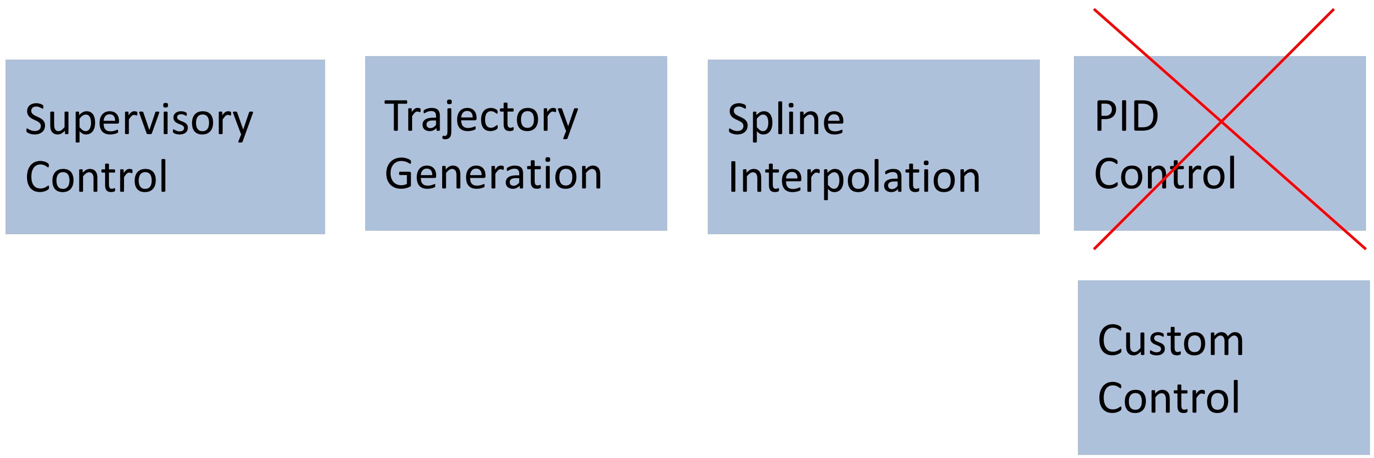
Taking Performance to a New Level

- RIO technology – program your own FPGA
- 5 microsecond / 200 kHz servo update rates with RIO and NI SoftMotion
- Compare to 50 kHz with DSP based fixed personality controllers

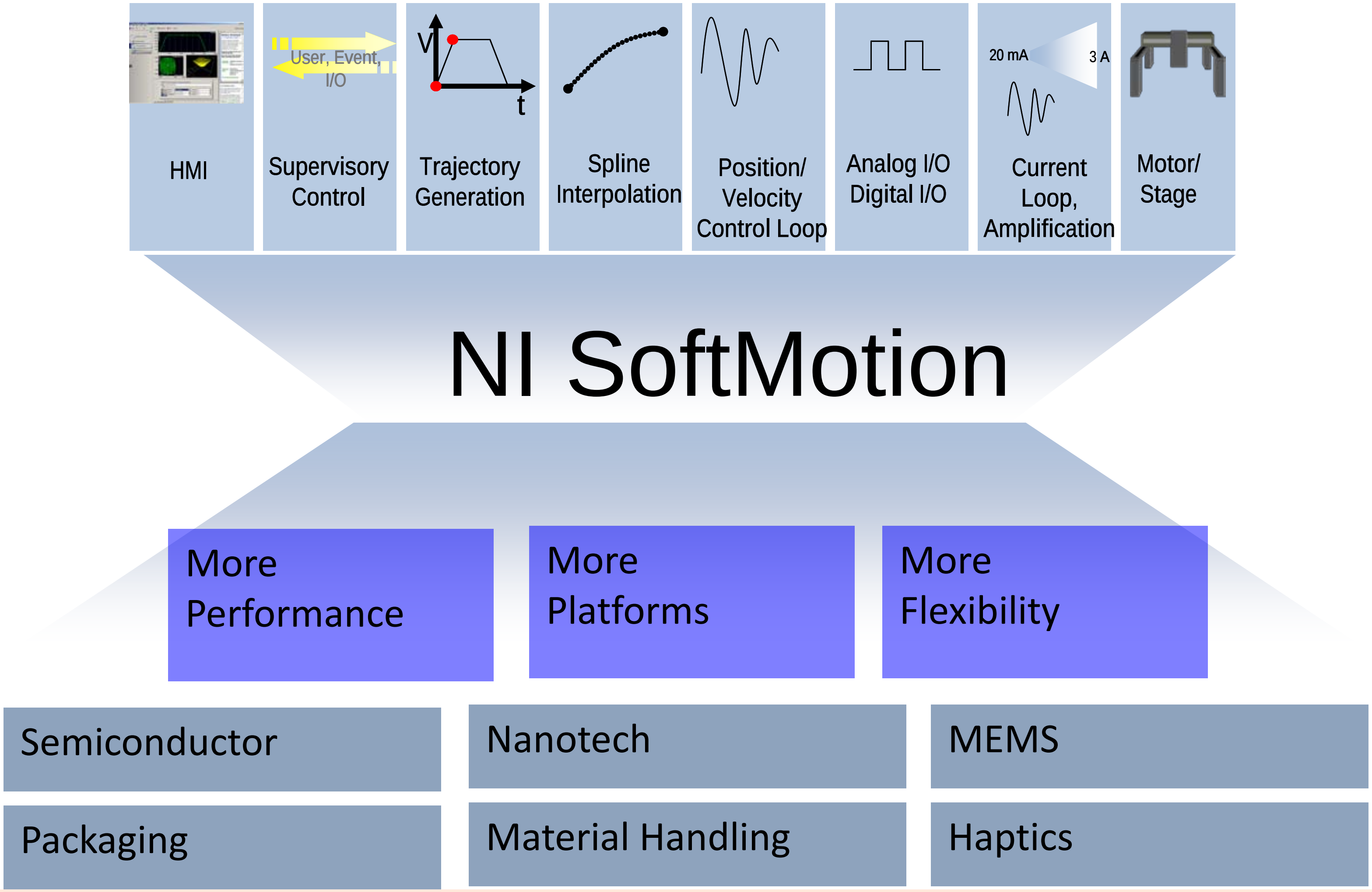


Taking Flexibility to a New Level

- Create custom motion controllers
- Replace PID with your own custom algorithm
- Not possible with fixed personality DSP-based controllers



NI SoftMotion Technology Opens New Doors



DARPA Urban Challenge

- Autonomously navigate 60 mile urban environment
- Follow all traffic laws
- Safely navigate around obstacles/barriers
- Safely interact with other UGV and manned vehicles at stop signs during passing, parking

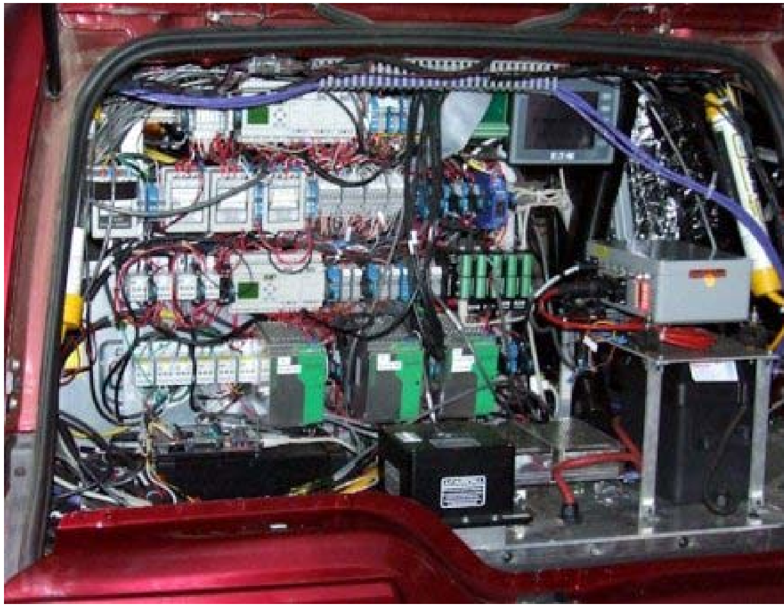
Odin – 3rd Place Winner
Virginia Tech
Powered by LabVIEW and CompactRIO

LabVIEW / RIO for Robotics

Virginia Tech (LabVIEW + CompactRIO)

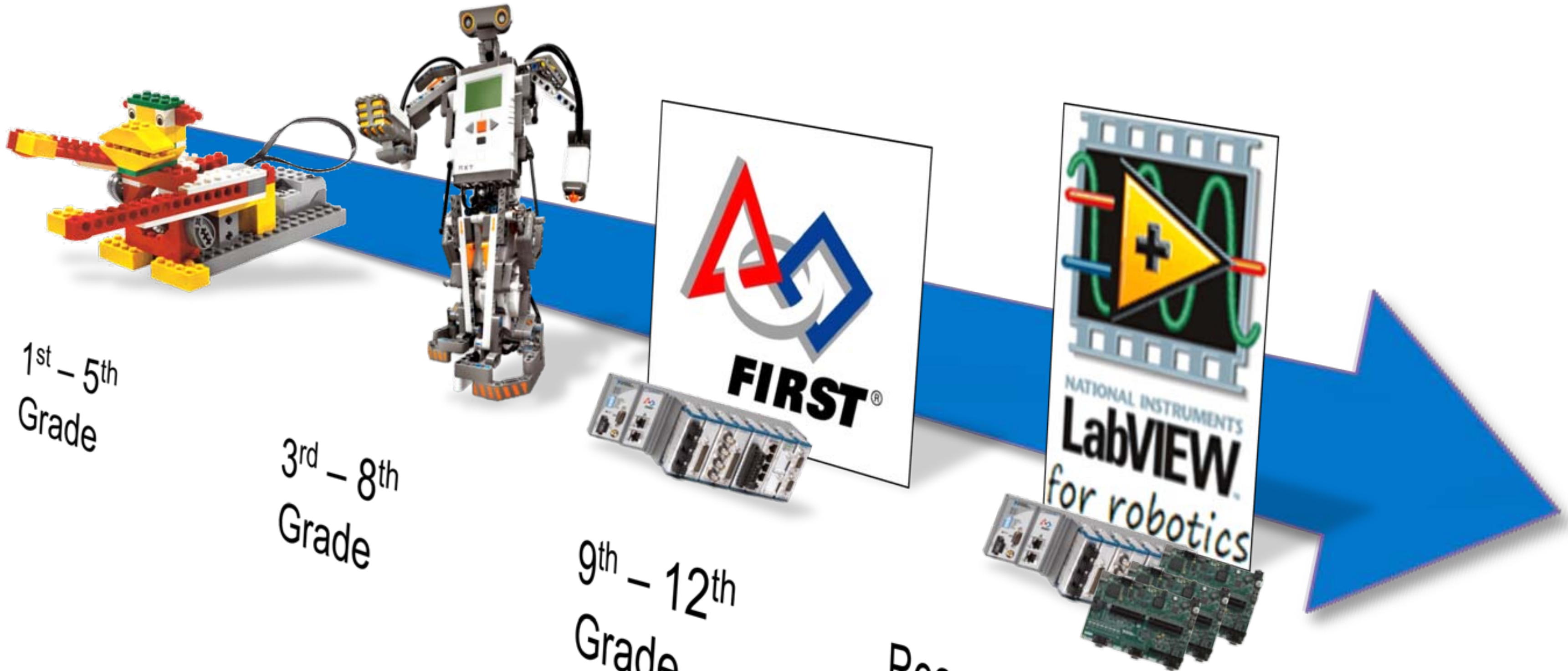
Do-it-yourself

MIT (C with a 40 core Linux cluster)



- NI dramatically reduces the cost of robotics system design, deployment, and testing
- Key strengths:
  - Rapid development software, Extensive, integrated I/O support, Tightly integrated system design platforms, World class support

Extending Graphical System Design for Robotics



1st – 5th Grade

3rd – 8th Grade

9th – 12th Grade

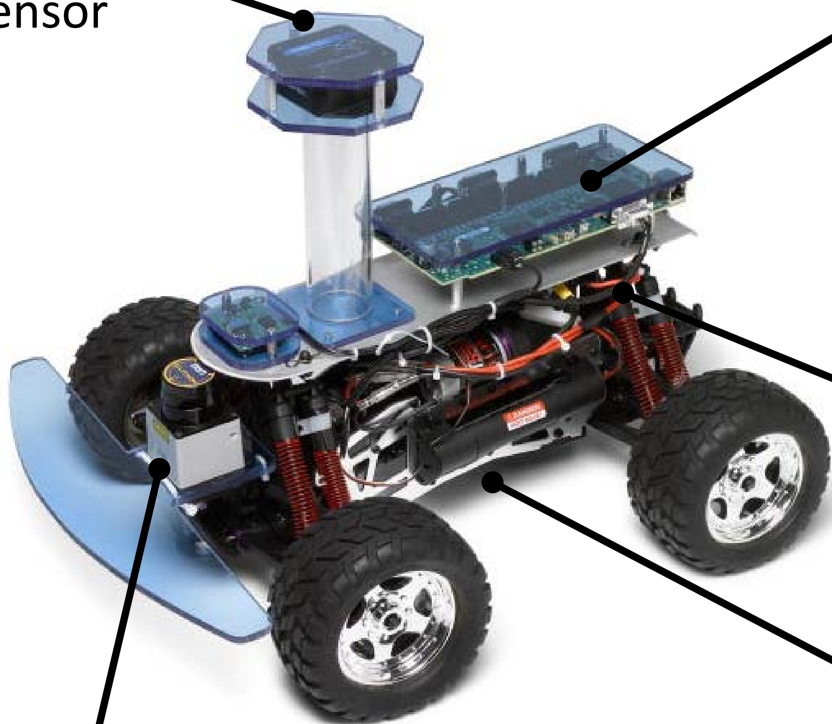
Research and Industry

Autonomous Ground Vehicle example

Microstrain®
Inertial Sensor
(inactive)

NI Single-Board RIO

- RT Power PC Processor
- FPGA
- Serial connectivity to sensors
- Ethernet communication to development laptop

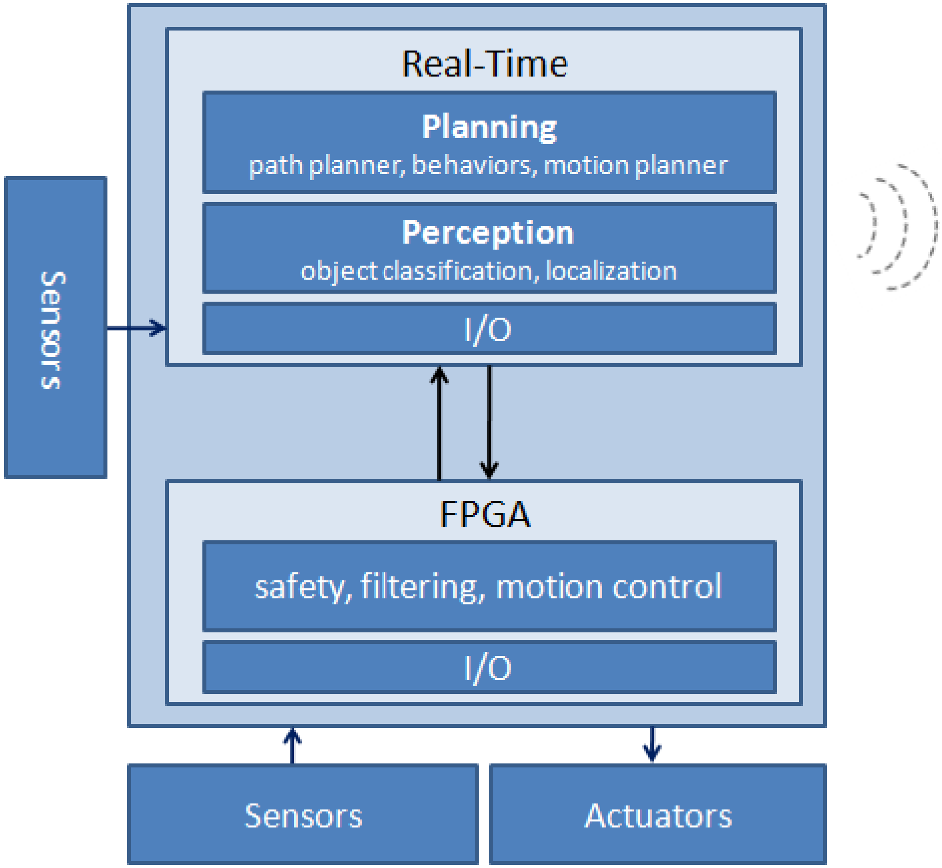


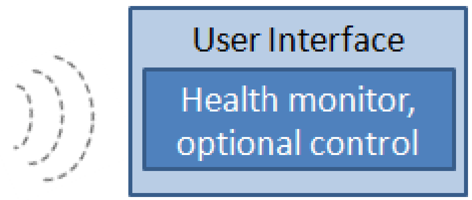
IFI Robotics®Victor 884
Speed Controller

HPI Racing® E-Savage
Sport Hobbyist RC Car

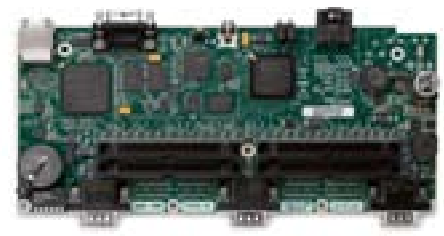
Hokuyo® LIDAR Sensor

LabVIEW Robotics on NI RIO Hardware



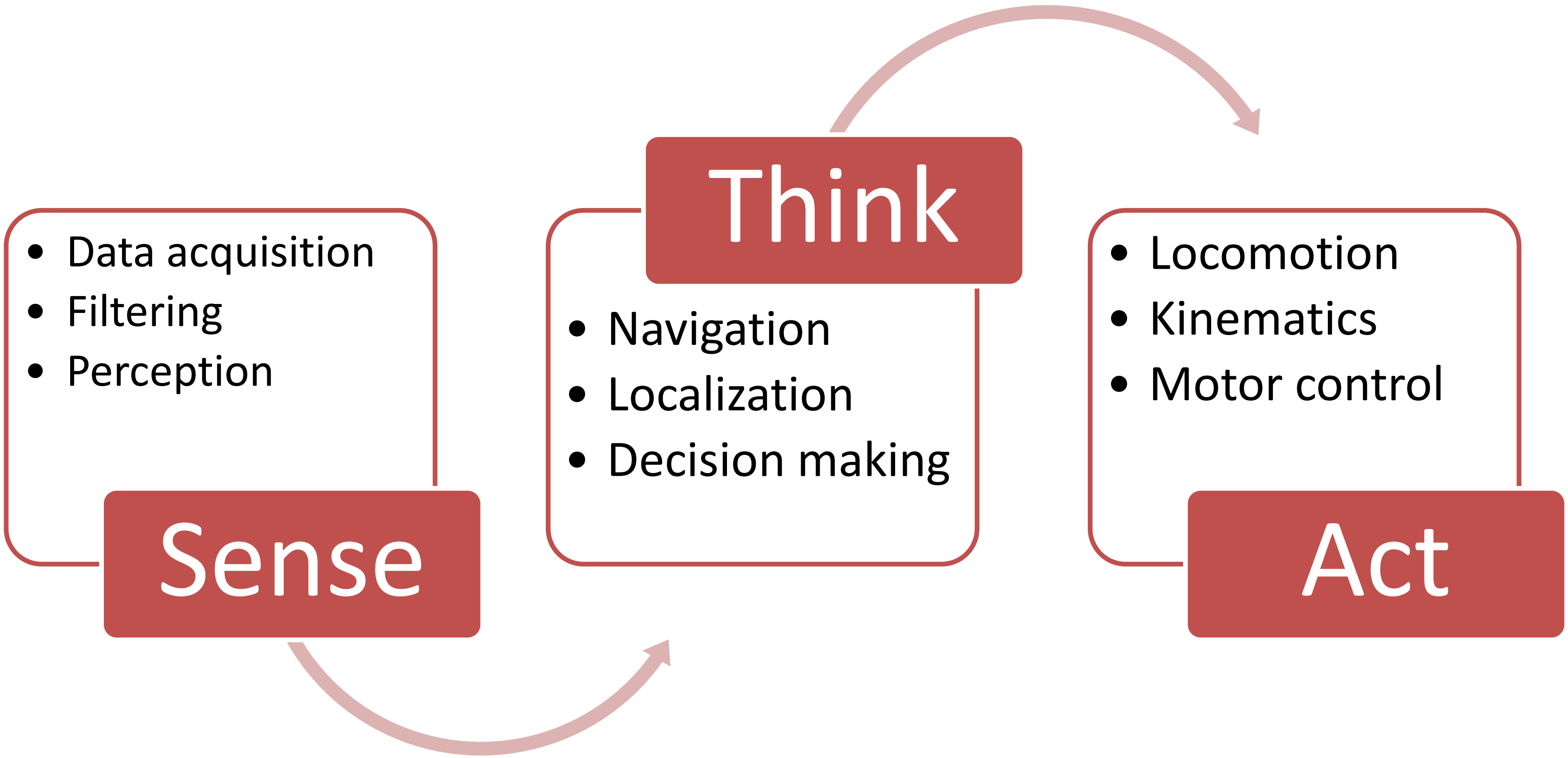


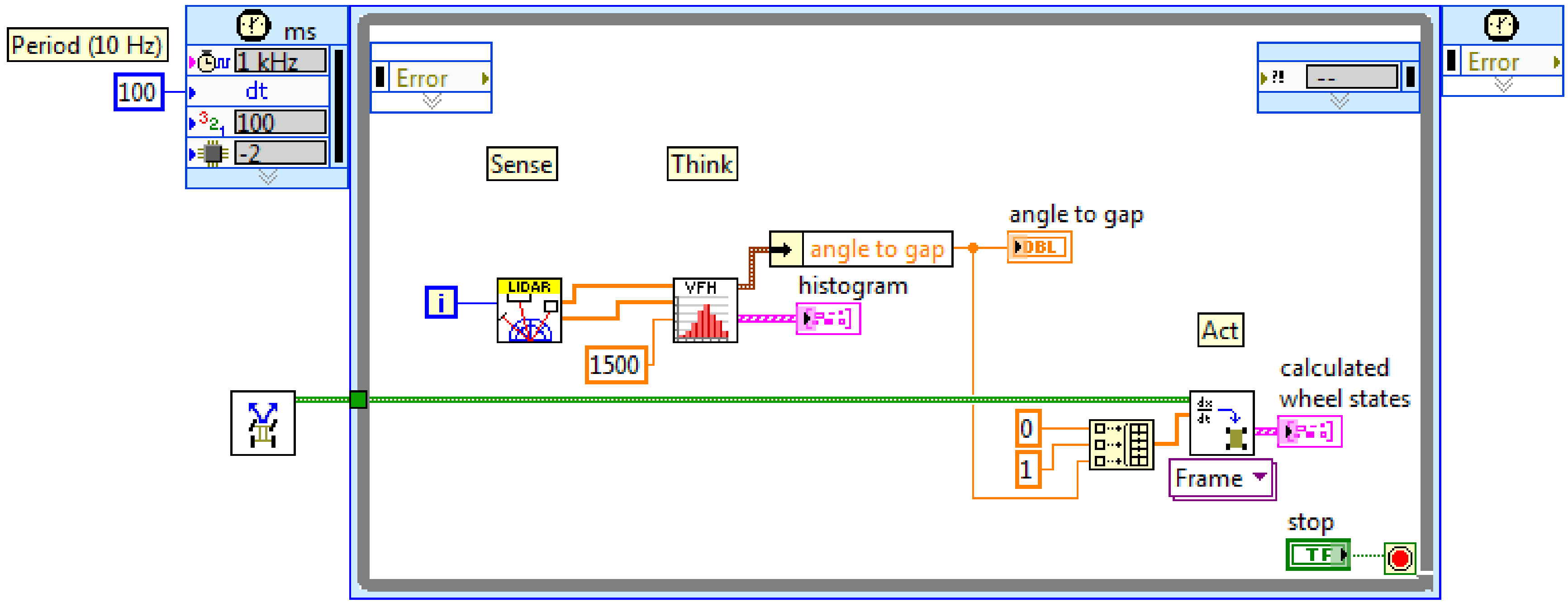
NI Single-Board RIO



NI CompactRIO

Overview of a Simple Mobile Robot

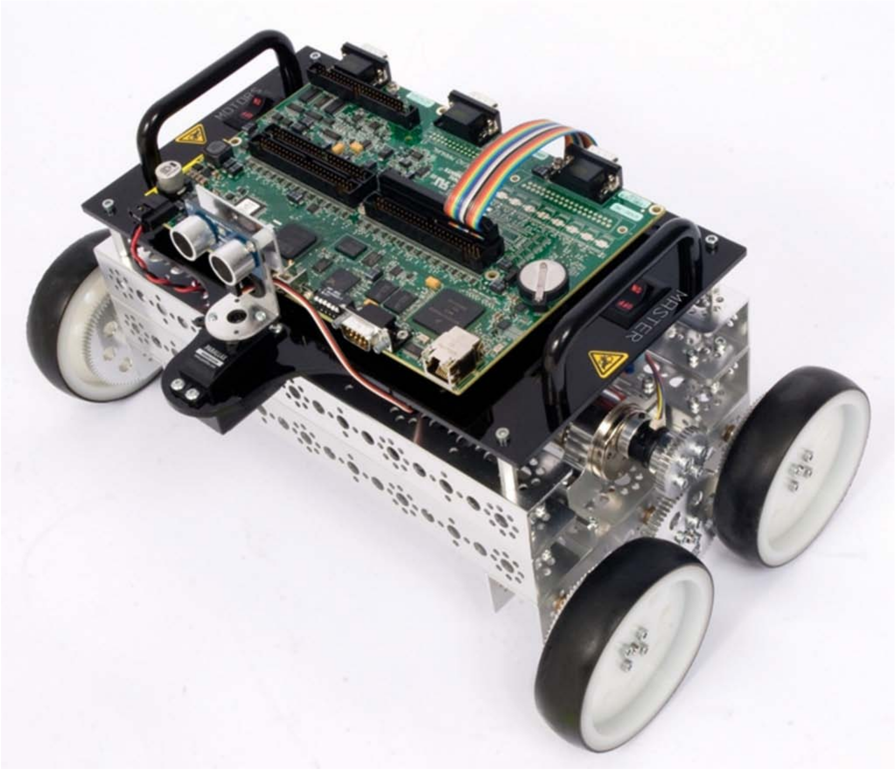




-> Scan area with LIDAR
-> calculate trajectory around objects
-> control motors

NI LabVIEW Robotics Starter Kit for Teaching and Research

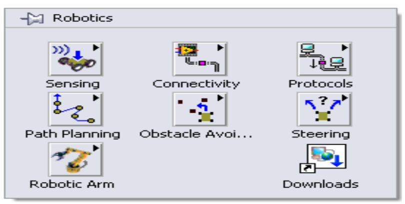
- Complete, out-of-the-box mobile robot platform
- For teaching robotics and prototyping
- Includes NI Single-Board RIO, motors, motor encoders, rotating ultrasonic sensor
- Can be expanded with additional sensors, actuators, and manipulators



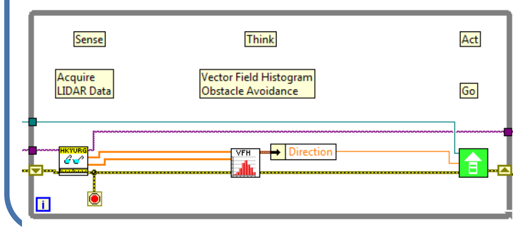
LabVIEW Robotics 2009

ni.com/robotics/education

IP for navigation, steering, kinematics and



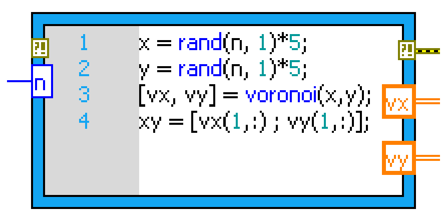
High-level **graphical programming**



Deployment to Real-Time and FPGA hardware

Connectivity to sensors and actuators from top vendors

Tools for integrating **text-based algorithms**



Examples of real-world applications